Investigations into the dynamics of the ICT ecosystem in Luxembourg

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Declaration

I declare that the work contained in this DBA thesis has not been submitted for any other award and that it is all my own work. I also confirm that this work fully acknowledges opinions, ideas and contributions from the work of others.

Any ethical clearance for the research presented in this thesis has been approved. Approval has been sought and granted by the Faculty Ethics on the 16.4.2014.

I declare that the Word Count of this commentary paper is 20707.

Name: Nico Binsfeld

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Date:

Abstract

Information and Communication Technologies (ICTs) are increasingly acknowledged as a General-Purpose Technology touching all sectors of the economy and offering the potential of technological improvements, increases in productivity and innovation as well as economic growth. Nevertheless, there is an on-going, fervent debate amongst scholars, practitioners and policy makers about the relevance of ICT as a sector of the economy in its own right. Consequently, researchers have shown great interest in examining the importance and the development of ICT ecosystems in different countries and regions of the world. Up until now, however, smaller countries have often been overlooked, perhaps guided by an assumption that findings from larger economies could simply be transposed to such settings.

This thesis set outs to address this research gap by investigating the ICT industry in Luxembourg, focusing on key developments since the telecommunications market was liberalised in the late 1990s as a means of identifying the main forces shaping developments within the sector in the period between 2000 and 2017.

This research aim has been broken down into four specific research objectives, which were: to examine the size and the structure of the ICT ecosystem in Luxembourg; to understand the role of the state as policy maker, regulator and as actor within the ecosystem; to analyse the current strengths and weaknesses of the ICT ecosystem and, to identify the needs for specific changes and improvements.

Overall, a critical realist approach has been adopted for the research, applying a quantitative analysis on existing data and complementing this with a qualitative approach building on new empirical data. Working for over 30 years as a manager and executive within media, telecommunication and ICT in Luxembourg, the author was able to interact with many senior professionals within the ICT industry in Luxembourg. Thus over 70 interviews have been conducted with a sample of executives from ICT organisations and institutions such as regulators, policy makers or promotion agencies. The outcomes of these interviews were complemented and triangulated with the help a 4-year long press review and an analysis of publicly available secondary sources.

One of the primary research outcomes has been a detailed identification and discussion of the strengths and weaknesses of Luxembourg's ICT ecosystem. Luxembourg has done well to focus on developing its ICT infrastructures and triggering the use of these infrastructures. Luxembourg has also performed well in liberalising its telecommunication sector and encouraging competition. In doing so, Luxembourg has been able to improve its position in terms of its ranking in international ICT related indices. However, Luxembourg's weaknesses have been identified in terms of marketing and communication in the context of international competition, limited risk taking and the lack of creativity and entrepreneurship.

An unexpected finding arose as it appeared that Luxembourg had neglected to develop or sustain a labour force with the necessary underlying e-skills and ICT competences. This problem has been acknowledged since and some initial remedial actions have been taken.

A major contribution to knowledge is a new conceptual and methodological framework to analyse the strengths and weaknesses of ICT ecosystems. This framework can be seen as a development and extension of the ICT ecosystem model developed by Martin Fransman. It may also potentially be applied to similar environments in order to make sense of their ICT ecosystem, or indeed to other network related ecosystems. Finally, the author has determined some implications for policy makers and suggested avenues for further research.

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Luxembourg

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Summary

Information and Communication Technologies (ICT) are increasingly acknowledged as a General-Purpose Technology (GPT) touching all sectors of the economy and offering the potential of technological improvements, increases in productivity and innovation as well as economic growth. In addition, there is an on-going debate amongst scholars, practitioners and policy makers about the relevance of ICT as a sector of the economy in its own right. Consequently, academics and practitioners have shown great interest in examining the importance and the development of ICT ecosystems in different countries and regions of the world. In doing so, smaller countries, such as Luxembourg, have often been overlooked. To some extent it was taken for granted that findings from larger economies could simply be transposed to such settings.

The author of this DBA thesis has worked as a manager and executive for over 30 years within media, telecommunication and ICT in Luxembourg and has developed a scientific interest in better understanding the ICT sector in Luxembourg. While working for the incumbent telecommunications operator, his professional role allowed him to interact with many senior professionals within the ICT industry in Luxembourg. This situation, combined with the relative scarcity of research into the ICT context of smaller countries, triggered this specific DBA thesis.

The author's overarching research aim has been to develop an understanding of the ICT industry in Luxembourg, focusing on the main developments since the telecommunications market was liberalised in the late 1990s and identifying the main forces shaping developments within the sector in the period between 2000 and 2017.

This research aim has been broken down into four specific research objectives, which were:

- to examine the size and the structure of the ICT ecosystem in Luxembourg;
- to understand the role of the state as policy maker, regulator and as actor in the evolution that has occurred over the period between 2000 and 2017;
- to analyse the current strengths and weaknesses of the ICT ecosystem in Luxembourg in order to provide policy makers with some guidance for further initiatives; and,
- to identify the needs for specific changes and improvements focusing on ICT and e-skills more generally.

The author has produced a set of research contributions towards these 4 research objectives and put together a portfolio of three published research articles and four conference papers. Within his professional environment, the author has also published two major studies in a local, that is, a Luxembourgish, technical review and contributed as co-author to a commissioned study about the e-skills situation in the country.

Overall, a critical realist approach has been adopted for the research, applying a quantitative analysis on existing data but complementing this with a qualitative approach building on new empirical data. In doing so, the author was able to take advantage of the small size of the country as well as the author's position within the ICT sector. This allowed for direct and in-depth interactions with some of the major ecosystem stakeholders. The author conducted over 70 interviews with a sample of executives from ICT organisations and institutions such as regulators, policy makers or promotion agencies. The outcomes of these interviews were complemented and triangulated with the help a 4-year long press review and an analysis of publicly available secondary sources.

One of the primary research outcomes has been a detailed identification and discussion of the strengths and weaknesses of Luxembourg's ICT ecosystem. Luxembourg has done well to focus on developing its ICT infrastructures and triggering the use of these infrastructures. Luxembourg has also performed well in liberalising its telecommunication sector and encouraging competition. In doing so, Luxembourg has been able to improve its position in terms of its ranking in international ICT related indices. However, Luxembourg's weaknesses have been identified in terms of marketing and communication in the context of international competition, limited risk taking and the lack of creativity and entrepreneurship.

An unexpected finding arose as it appeared that Luxembourg had neglected to develop or sustain a labour force with the necessary underlying e-skills and ICT competences. This problem has been acknowledged since and some initial remedial actions have been taken. In the later part of the thesis, the author has identified the most relevant digital skills and the most relevant ICT related job profiles. The author has also identified the underlying competences needed in the context of Luxembourg's economy with the objective of helping to improve the situation.

In addition, the author produced a new conceptual and methodological framework to analyse the strengths and weaknesses of ICT ecosystems. This framework can be seen as a development and extension of the ICT ecosystem model developed by Martin Fransman (2010a), which focuses on the identification of different layers of actors, but allows only very limited insights into the dynamics of their interactions.

This new framework may potentially be applied to similar environments in order to make sense of their ICT ecosystem, or indeed to other network related ecosystems. Finally, the author has determined some implications for policy makers and suggests avenues for further research.

1. Introduction

"Information technology and business are becoming inextricably interwoven. I don't think anybody can talk meaningfully about one without the talking about the other." (Bill Gates, Microsoft)

"The First Industrial Revolution used water and steam power to mechanize production. The Second used electric power to create mass production. The Third used electronics and information technology to automate production." (Klaus Schwab, World Economic Forum)

Information and Communication Technologies[1] (ICT) are increasingly acknowledged as a General Purpose Technology (GPT) (Basu & Fernald (2008)) touching all sectors of the economy and offering the potential of meaningful technological improvements and innovation within firms and countries (Hagemann (2008)). The diffusion of ICT as a GPT is of a high overall economic importance since it may contribute to a substantial rise in productivity in various industries and thereby increase the growth potential of the economy as a whole (Bashir et al. (2014); Bashir & Sadowski (2014)). There is also an on-going debate amongst scholars, practitioners and policy makers about the relevance of ICT as a sector of the economy in its own right, its potential importance for the sustainable development of Europe and its role in terms of competition with the US or Asia (Bughin et al. (2016)).

Consequently, there is a wide range of academic studies about the ICT sector available in the literature. Elixmann et al. (2003) discuss the development of the ICT sector in Germany since its liberalisation, Hulsink (1999) focuses on the telecommunications sectors in the UK, the Netherlands and France, Steen (2011) examines South Korea and China, Whalley (2006) concentrates on Nepal and Whalley & Curwen (2008) study the local loop access in the UK. Some of these studies and assessments use the ecological metaphor of an ecosystem which was first described by Moore (1993) to develop their analyses. In particular, they describe the dynamic nature and the rapid changes occurring at an increasing pace within the ICT sector.

Academic studies are often complemented by policy documents, many of which are provided or commissioned by the European Commission or similar institutional bodies, and by economic studies provided by specialized consultants (Barrios et al. (2008); European Commission (1998); European Commission (2005); Probst et al. (2017)). Furthermore, there is an ever-increasing range of measures and indices available which try to assess the position of different countries in terms of their ICT environment and development (Baller, Dutta, & Lanvin (2016); Bilboa-Osoria et al. (2014); EIU (2010); European Commission (2014); ITU (2013)).

1.1. The context

Common to many, if not most, of the studies discussed above is that they tend to overlook the situation of small countries. The author could only identify very few studies about the development of the ICT sectors in small countries (Evens et al. (2010); Symeou (2009); Vu (2013)). No previous work could be found in the academic or professional literature about the ICT ecosystem in Luxembourg. Being a "very small" or even "extremely small" country (Edquist & Hommen (2008). Luxembourg is often overlooked in academic research despite its open and service-based economy, its central location in Europe, its political influence in the EU as one of its founding member states and its leading position in many international league tables.

[1] Throughout this document, we use the OECD definition of ICT see for example OECD (2011).

This research gap, and the fact that the author has worked in media, telecommunications and ICT in Luxembourg and several other European countries[2] for over 30 years, were the two incentives to present this Doctor of Business Administration thesis.

With this thesis, the author intends to contribute to the academic knowledge about ICT ecosystems in small countries, building on the case study of Luxembourg. Moreover, the author fills some of the research gaps in relation to the Luxembourgish ICT ecosystem and contributes to his professional practice by transposing academic findings into his professional environment. This was achieved by taking advantage of his extensive network of relationships with industry actors and local policy makers[3]. Luxembourg is a full member of the EU and as such, it is influenced and governed by all EU rules and regulations, and participates in the common market. Looking at Luxembourg as a case study should therefore provide insights into the forces, which govern its ICT ecosystem, insights which can then be transposed to other larger EU member states but also to other small and open economies with similar features such as Singapore.

Most of the existing studies about ICT ecosystems mentioned above are based on quantitative evaluations using large samples of publicly available data such as the ones provided by the national or transnational statistical offices, regulators or market observatory institutions (European Commission (2015b, 2015a)). Building on his specific professional situation, the author has deliberately chosen a different, qualitative approach, which was facilitated by the "smallness" of Luxembourg. This smallness allowed for easy and direct access both to ICT actors and policy makers. This approach was also enabled by the author's own long-standing professional career as actor within the ecosystem. The author was able to collect a huge amount of new primary data through semi-directive interviews with over 70 actors within the ICT ecosystem.

1.2. Purpose and scope

This DBA thesis[4] has two equally important purposes:

1. To make an original contribution to the knowledge of ICT ecosystems in small countries, building on Luxembourg as a case study and illustration.
2. To make an original contribution to the author's professional practice within this Luxembourgish ICT ecosystem.

These two purposes have been broken down into a set of four research objectives of which the first three research objectives mainly address the author's contribution to knowledge whereas the final one focuses more on the author's professional situation[5], thus providing a contribution to practice as well. These research objectives are:

1. To examine the size and the structure of the ICT ecosystem in Luxembourg.
2. To understand the role of the state in the changes that occurred in the period between 2000 and 2017.
3. To analyse the current strengths and weaknesses of the ICT ecosystem in Luxembourg.
4. To identify the needs for changes and improvements focusing on ICT jobs and e-skills[6].

[2] See appendix for detailed CV.
[3] For example, as a member of different local ICT working groups and associations.
[4] Part-time studies while continuing full-time employment.
[5] Since September 2015, the author acted as CEO of a vocational education and training provider.
[6] This RO emerged during the process as e-skills were identified as one of the major issues experienced by actors within the ecosystem and because of the author's new job.

For each research objective, several research and professional contributions have been produced. The author published two articles in a local Luxembourgish technical review and three scientific peer-reviewed journal articles. The author also contributed to professional studies, conference papers and presentations. Finally, the author attended four DBA seminars and presented four peer-reviewed papers at academic conferences.

This document intends to establish the context in which these publications are to be understood and outlines their key points. In addition, it explains the research process that the author went through and shows the links between the different, independent publications, as well as the overall highlighting theoretical and empirical outcomes of the work.

1.3. The portfolio and how to read it

The author's research portfolio consists of the following elements:

1.3.1. Peer-reviewed journal articles

1. Binsfeld, N., Whalley, J., & Pugalis, L. (2016a). Competing against yourself: State duopoly in the Luxembourg telecommunications industry. *Telecommunications Policy*, *40*(8), 791–803.
2. Binsfeld, N., Whalley, J., & Pugalis, L. (2017b). Looking beyond official success measures : tales from the field of the complex forces shaping Luxembourg's ICT ecosystem. *Journal of Innovation Management*, *5*(2), 15–25. Retrieved from http://www.open-jim.org/article/view/254.
3. Binsfeld, N., Whalley, J., & Pugalis, L. (2017c). Playing the game: Explaining how Luxembourg has responded to the Networked Readiness Index. *Digital Policy, Regulation and Governance*, *19*(4), DPRG-02-2017-0008.

1.3.2. Reviewed conference presentations and papers[7]

4. Binsfeld, N., Whalley, J., & Pugalis, L. (2014). Luxembourg: A bastion of state ownership. In *25th European Regional Conference of the International Telecommunications Society (ITS), Brussels, 22-25 June 2014*. Brussels: Econstor.
5. Binsfeld, N., Pugalis, L., & Whalley, J. (2015). ICT ecosystems in small countries: An analysis of Luxembourg. In *26th European Regional Conference of the International Telecommunications Society (ITS), Madrid, 24-26 June 2015*. Madrid: www.econstor.eu. Retrieved from http://www.econstor.eu/dspace/handle/10419/127127.
6. Binsfeld, N., Whalley, J., & Pugalis, L. (2016b). Competing through e-skills: Luxembourg and its second level digital divide. In *27th European Regional International Telecommunications Society Conference – Cambridge 2016*. Cambridge: Econstor.
7. Binsfeld, N., Whalley, J., & Pugalis, L. (2017a). An analysis of the structure, actors and interrelationships producing Luxembourg's ICT ecosystem. In *28th European Regional International Telecommunications Society Conference - Passau 2017* (pp. 1–32). Passau.

1.3.3. Publications in Luxembourgish technical journals

8. Binsfeld, N. (2013). The Luxembourgish Telecommunications Market. *Cahiers Scientifiques Revue Technique Luxembourgeoise*, *2013*(1), 24–37.
9. Binsfeld, N., & Whalley, J. (2016). Measuring Luxembourg's State of ICT Development. *Cahiers Scientifiques Revue Technique Luxembourgeoise*, *2016*(1), 30–47.

[7] These were also presented and discussed during DBA workshops.

1.3.4. Commissioned Study

In addition, the author contributed to a major study about e-skills in Luxembourg. This study was commissioned by "ICT Luxembourg", the local ICT industry association[8].

10. Ant, M., Goetzinger, P., & Binsfeld, N. (2016). *E-Skills Study - Strategies for the creation of a virtual e-skills training centre in Luxembourg*. Luxembourg.

1.3.5. How to read the portfolio

The different contributions represent a volume of over 370 pages of text. Since the different contributions have been produced independently, for specific purposes (peer-reviewed journal papers, peer-reviewed conference contributions, etc.) and over a time period of five years, they contain some overlapping material.

For example, most contributions contain a brief overview of Luxembourg and a short introduction to its ICT ecosystem. Many also contain similar representations or discussions of the Fransman model. In the commissioned study, there is also an extensive history of ICT development, which may be less relevant within the current context.

Consequently, for an overall appreciation of the author's DBA thesis, it will not be necessary to read all of these contributions in detail. Generally, the different peer-reviewed conference papers focus on a specific aspect of the research, whilst the three journal papers summarise the main findings and outcomes of the research and show its value for the academic community.

Notwithstanding, the first three contributions (peer-reviewed journal articles) should be read in-depth as they constitute the core of the author's academic work.

Contribution 4 contains a lot of information which is also presented in contribution 1 and is only included for completeness.

Contribution 5 can be considered as an early version of the contribution 2 and can therefore be skim-read. The same holds true for contribution 9, which provides details about the different kind of indices and has been used to develop contribution 3.

Contribution 6, however, is relevant as a stand-alone paper, as it contains most of the author's work on RO4.

The same holds true for contribution 7, which provides a general overview and introduction to the ecosytem, in addition to offering a detailed identification and analysis of the different stakeholders.

Contributions 8 and 9 are more practice-orientated, but they also provide a detailed overview of recent developments, the actors of Luxembourg's ICT ecosystem and its position in international rankings. These two documents have been the most useful for the author's profession and therefore should be considered as part of his contribution to practice. They can be skim-read.

Finally, the commissioned study has been a direct result both of the initial outcomes of the author's empirical work and of the author's professional development over the course of the DBA study. It contains some suggestions about how to address the e-skills gap and this part should be read in-depth.

[8] See www.ictluxembourg.lu accessed 28.4.2018

1.4. Overview of the research process

This section presents the author's overall research approach, an overview of the research methodology, details about the research process, the methods applied and some of the tools that have been used. The author's objective was to take advantage of his professional situation in order to collect the views of the different actors within the ICT ecosystem. The focus is on recent developments (2010-2017) and the dynamic and nature of the major changes, which occurred over this period. The research philosophy, methods and tools presented below have been chosen with this objective in mind.

1.4.1. Research Philosophy

Within the area of the author's proposed research, 'normal science' (Kuhn (2012)) is largely about defining "measurement" indices, for example on the state of development of the ICT ecosystem and the underlying causes. Similarly, such indices are used to understand a country's or an organisation's competitiveness and performance. A lot of research (Binsfeld, Whalley, & Pugalis (2017b)) has been done to understand and predict the evolution of these indicators. The underlying approach is predominantly a positivist one. Evidently, the author has considered this prevailing paradigm, in particular for RO1 and RO2. However, some research objectives (RO3 and RO4) could not be fully addressed by following this paradigm alone, as the intention was to "look beyond the numbers".

Firstly, the study is a DBA research project and therefore focuses on the author's professional and business environment. Its main interests are the relationships between the different stakeholders, their views of the issues at stake, understanding why certain decisions were made, why certain policies were pursued and how the different stakeholders interacted with each other. Such topics cannot be understood completely by looking at numbers and statistics alone, nor by using purely quantitative methods. Human behaviour is very complex and cannot be predicted based simply on previous actions. Therefore, rich explorations of the different stakeholders' subjective and sometimes conflicting views are needed and a more critical approach has been followed.

Secondly, the author himself is an observer of, as well as an actor in, the situation at hand. The interpretations of results, identification of stakeholders, sources of information and selection of previous research have been influenced by his personal preferences, previous education and work experiences. Consequently, it has been difficult to take a completely objective and rational view on the issues involved.

Thirdly and most importantly, the author is most interested in changes to and the dynamic nature of the ICT ecosystem over time and has identified several cornerstones to consider. Amongst these are the following: the liberalisation of telecommunications in 1997, the introduction of mobile networks, the diffusion of the internet and more recent innovations, such as the invention of tablets, the development of the "cloud" and "fintech" services to mention just a few. Mentioned above, the positivist approach is useful for predictions based on existing theories but does not allow for predictions of radical changes in the "paradigm" of the ICT ecosystem. However, this ecosystem is often driven by such radical changes and positivist researchers may fail to predict these.

Therefore, the author proposes to take a 'critical realist' (Easterby-Smith et al. (2012); Fleetwood (2012)) approach to his research, trying to be critical of the status quo, while recognising and differentiating between the different levels of phenomena. This has led to more eclectic approach to research methods, especially in terms of structure processes, and the collecting and analysis of the data.

1.4.2. Research methods

Considering this critical realist mind-set, a pragmatic approach, using different research methods during different stages of the research process and for addressing the different research objectives, has been chosen. The following table identifies the methods that have been used for the contributions to the four research objectives identified above. It also provides some comments on the advantages of using a given method and its potential limitations or difficulties. Finally, it provides some key points that the author learnt as part of the research process.

Table 1 - Research objectives and methods

Research Objective	**Methods**	**Pros**	**Cons**	**Comments & learnings**
RO1: To understand the role of the state in the changes that occurred over the period at stake.	Systematic Literature review (Cronin et al.(2008))	Provides a good overview into the subject, forces an initial sense of rigour	Time consuming, limited creativity, outcome depends on quality of "key words" searches	Outcomes were discussed with supervisors and stakeholders and presented at conference, which helped to develop a critical approach
RO2: To understand the size and the structure of the ICT ecosystems in Luxembourg.	Document surveys (Denscombe (2010)) based on "indices" for example from WEF, ITU, OECD, EU	Building on a wide range of freely available data	Available documents might be biased, limited access to commercial data sources, problem of comparing "apples with pears"?	Developed necessary statistical skills e.g. SPSS. Developed a critical approach. Became aware of the initial purpose of the underlying data sets.
RO3: To understand the current strengths and weaknesses of the ICT Ecosystem.	Literature reviews and semi-structured interviews (Schultze & Avital (2011))	Provides a wealth of information derived from new primary data	Difficulties in analysing the data, biased view of researcher and stakeholders	Allowed to develop interviewing skills. Learn how to work with NVIVO software.
RO4: To understand needs for changes and improvements focussing on ICT jobs and e-skills.	Interviews and discussions with stakeholders	Detailed understanding of the specific subject of e-skills	Access to stakeholders not always given, political messages sometimes difficult to understand	Further critical application of qualitative research methods.

1.4.3. The collection of empirical data

For the collection and analysis of the empirical data, a two-stage approach was adopted. The process started with a focus group consisting of major industry and institutional players in order to establish a summary SWOT analysis and an initial template of codes (King (1998)). This template then helped to design open questions to start the interviews and to assist with the coding process of the interviews later on (Silverman (2013); Symon & Cassel (2012)).

In a first phase, a total of 52 interviews were conducted over a period of nine months in 2014 and early 2015, roughly one or two per week all lasting between one (for the shortest) and two hours (for the longest). The interviews usually started with open questions, such as:

- According to you (or your company), in the last few years what has worked for Luxembourg's ICT ecosystem? What has worked less well?
- How did it affect you? Your company?
- Is Luxembourg well positioned to face international competition?
- What are the major regulations and their changes that affect Luxembourg or your organisation?
- What would you want to change?

All interviews took place in a location chosen by the interviewee (usually their offices) and were audio-recorded. To guarantee confidentiality, a "non-disclosure agreement" was signed by each interviewee.[9]

No clear definition of the ICT ecosystem was provided but participants were asked to give their own definition. This was an interesting experience in its own right, as it turned out that participants had different views of its boundaries.

Initially, the interviews were completely unstructured. However, after a first round of interviews followed by an initial analysis and in order to avoid too much duplication of topics, subsequent interviews were semi-structured in order to identify the widest possible range of different views.

The recordings of the interviews were then imported into NVIVO, a computer aided qualitative data analysis software, to be processed and analysed, following the approach proposed by, for example, Beekhuyzen (2010), Di Gregorio (2000), Welsh (2002), or Wong et al. (2008).

For a detailed discussion of the functionalities and the advantages of NVIVO for qualitative research projects see:

- In their book, Bazeley & Jackson (2007) provide a full tutorial on how to make the best use of NVIVO in different research settings. They explain how NVIVO enables the researcher to save time by managing their data for them, giving the researcher time to concentrate on extracting meaningfull information from the qualitative data. In addition, they show how NVIVO can be used to produce conceptual frameworks.
- Bringer et al. (2004) show how NVIVO, in particular, can be used in psychological research to gradually build up a grounded theory framework.
- Crowley et al. (2002) discuss the possible downsides of using a software such as NVIVO and show how to avoid or overcome these.
- Hutchison et al. (2010) also provide a worked example of how to build up a grounded theory with NVIVO.
- Johnston (2006) provides a detailed empirical account on how he? used NVIVO in doctoral research and teaching.

[9] Ethical approval granted.

- Neill (2013) provides a detailed and pratical toolkit (supported by the editor of the software) on how to use the software.
- Richards (1999) discusses the underlying ideas on which NVIVO has been build, more generally.

These authors provide a strong argument for working with this tool and the author has made extensive use of the many functionalities provided. For example, NVIVO allows to code data directly in either text, pdf, audio or video files. It was therefore decided to code directly on the audio content, transcribing and translating however the main ideas and topics into text as well. In addition, the use of NVIVO provides many other facilities. For example, it allows immediate display all the codes for each interviewee. It allows basic statistical analysis of, for instance, the frequency of codes, the time spent on specific messages and how often a certain code or even expression has been used. It allows for a graphical representation of interviews, the topics covered as well as the relationships between codes.

A particularity of Luxembourg is its multilingual workforce. Interviews were conducted in four languages - Luxembourgish, French, German and English, and were then partially translated into English for inclusion in the different research contributions. A major advantage of the NVIVO software is that it allows almost instantaneous access to any of the underlying data so that everything that has been said can be traced back directly from coded outcomes and therefore all raw data is always available (Anderson (2010)).

Coding started with the initial template (Waring & Wainwright (2008)) based on the aforementioned focus group analysis but evolved over time whenever new topics were mentioned by interviewees. Additional interviews were conducted until no further new codes or topics arose. Translation, partial transcription and coding took about three to four hours per interview.

Arranging, conducting and analysing interviews can be very time consuming. Thus, the number of interviews had to be limited to people that the author had already some professional relationship with. Although this covered a wide range of actors, not all subsectors of the ICT ecosystem are represented. Therefore, it was decided to also include in the analysis, publicly available information for example, press cuttings, speeches, and observations at events or meetings that the author attended. The author has gathered information published by the local, regional and international press to identify the wider forces that influence the evolution of the ICT sector in Luxembourg. Thus, between 2012 and 2017 over 750 press articles were reviewed, referenced and added to the NVIVO database when appropriate.

In parallel to these activities, a literature review of the major relevant academic journals was carried out on a continuous basis. As research in ICT and telecommunications is developing at a quick pace, this was necessary to keep in touch with the technological, regulatory, political and economic forces that affect the ecosystem. The outcome of the literature review was also used to adapt and refine the questions addressed during the interviews. This process went on for the entire duration of the project.

Over the period of these interviews, the author was employed as the CEO of one of the subsidiaries of POST[10], the incumbent telecommunications operator, which is, with over 4300 employees, by far the largest, most important and influential actor within the ICT ecosystem of Luxembourg. Consequently, as a member of different management committees, the author had direct access and permanent interactions with the senior management staff of this organisation. These interactions enabled the gathering of empirical data through personal observations as well (Easterby-Smith et al. (2012);

[10] For more information see www.post.lu accessed 28.4.2018

Greener (2008)). However, as the author often was personally involved in the decision-making process as a member of the management team, it was decided not to rely on these observations as they would not necessarily be completely objective. Instead, the author conducted a few interviews with different members of lower-level management staff that were involved in the promotion of POST's activities on an international scale. In addition, information collected during some of the public speeches of POST's senior management representatives and of the representatives of the ministry of economy (in charge of POST) has been included in the process, when it related to the questions at hand. This allowed for the views of this key stakeholder to be included in the analysis.

In September 2015, the author changed jobs to become CEO of a vocational training provider[11] (Couset (2016); Thelen (2016)). This had an influence on both the timing of the research activities planned for late 2015 and on the overall orientation of the project. In fact, the author's main professional interest turned towards the underlying skills required in and by the ICT ecosystem. RO4 emerged largely due to this change to the author's professional situation. Consequently, the author initiated a second round of 20 interviews, specifically focusing on human resources representatives and some purposefully selected additional actors in the ICT ecosystem.

In the same context the author also contributed, as co-author and interviewer, in a strategic study about e-skills in Luxembourg with the objective of recommending the creation of a specific organisation to take care of digital training (Ant, Goetzinger & Binsfeld (2016). This study was officially presented in December 2015 (Zabatta (2015)). It was commissioned by the Luxembourgish government as part of their Digital Lëtzebuerg policy initiative (Land (2014)) and by an ICT industry federation[12].

1.4.4. The selection of interviewees

As the author's objective was to collect new primary data and determine the viewpoints and experiences of active stakeholders within the ICT ecosystem, it was necessary to identify these stakeholders and to ensure access to them. It was also important to ensure that they really were representative of the ecosystem overall. Therefore, as part of the DBA project, the author worked on an inventory of the ICT ecosystem and its actors, building on Martin Fransman's work on ICT ecosystems (Fransman (2001, 2002a, 2006, 2007, 2010a, 2011, 2014); Quatraro (2009)). This was achieved with the assistance of a Master student from University of Luxembourg. This student carried out the desk research work, which the author checked and co-supervised over a period of six months from March to June 2015 (Binsfeld, Whalley, & Pugalis (2017a); Krylova (2015)).

According to Luxembourg's statistical office (STATEC (2013, 2016b)), in 2014[13], there were over 2000 companies active within the ICT ecosystem and this number has grown substantially since 2008 (Binsfeld, Whalley, & Pugalis (2017a). Some care has to be taken when looking at these numbers, as the STATEC statistical classification framework (STATEC, 2008) does not correspond exactly to the OECD definition (OECD, 2011b) of the ICT sector. Moreover, institutional actors or external influencers, for example regulators, are not considered in the list produced annually by the statistical office.

[11] For more information see www.houseoftraining.lu accessed 28.4.2018
[12] This led to the creation of an ICT centre of competence see www.lidit.eu accessed 28.4.2018
[13] Latest information available, see www.statistiques.public.lu accessed 28.4.2018

Table 2 - Organisations and stakeholders interviewed

Actors	Interviewed Organisations, Institutions and their representatives	Individuals
Network element providers	CEO Alcatel-Lucent[14] Luxembourg, Area Manager Cisco Luxembourg, Country Manager HP Luxembourg, Country Manager Unify Luxembourg	4
Converged communication and content distribution providers	COO Broadcasting Center Europe, Area Management British Telecom Luxembourg, Head of Sales and CEO Cegecom/Artelis, CEO and Head of Sales Eltrona, President Fédération des Opérateurs Alternatifs Luxembourg, CEO HotCity, Head of MVNO Join Wireless, International Sales Manager Post, CEO SES Techcom, CEO Telecom Luxembourg	13
Platforms, content and applications	President Association des professionels du secteur financier, President Association des professionels du secteur de l'information, CEO CTTL, CEO Data4, CEO Datacentre Luxembourg, CEO Ebrc, CEO Itrust, CEO, CFO and Head of Sales Luxconnect, CEO Luxcloud, CTO Netcore, CEO Systemat, CEO and CTO Telindus	15
Consumers	CEO Appolo Strategies, CTO Association des Banques et Banquiers, CEO and CTO Exxus, Area Manager Gartner Luxembourg, CIO Ikano, CEO Fédération des Artisants, Secretary General Luxembourg Business Federation, CEO ProNewTech, Partner Digital Business PwC Luxembourg	10
Outside influencers – finance, regulation, standardisation	Director and Vice Director Interdisciplinary Centre for Security Networking and Trust, Director Institut Luxembourgeois de Regulation, Manager ICT Cluster Luxinnovation, CEO Luxembourg Institute of Technology, Director Ministère de l'Economie, CEO Moskito, Director Service des Médias et des Communications	8

In terms of the numbers of actors situated on the different layers of the Fransman model (Binsfeld, Whalley, & Pugalis (2017a)), it is layer III (platform, content and applications) which dominates the ICT ecosystem with about 1670 companies in 2014. There were about 240 companies active in layer I (network element and infrastructure providers). Most of these are distributors of international or global hardware manufacturers, as only five local ICT manufacturing companies were/are? registered in Luxembourg.

Consumer electronics, magnetic and optical media are not produced in the country. This clearly confirms the importance of services for Luxembourg's economy (see below, section 2). In terms of the number of actors, layer II (network providers) is the smallest of the Luxembourgish ICT ecosystem consisting of only 88 companies. However, it is also layer II that provides the largest contribution Luxembourg's economy in terms of GVA. For further details see Binsfeld et al. (2017).

As the author has been an actor in the ICT ecosystem for more than 20 years[15], potential interviewees were identified based on the author's professional network and contacts – about 60 people have been identified, all known personally (see table 2). The table also presents the different companies involved and identifies the job roles of the different interviewees. Only senior executives, generally CEOs or CTOs, were interviewed, all with many years of experience in ICT and the Luxembourgish market.

[14] Now Nokia Services and Networks
[15] See full CV in appendix

They are of different nationalities, some being local natives but many coming from abroad as part of their job assignments. This mixture and diversity allowed the different questions to be approached from different angles and different cultural lenses. Care was taken to select a purposeful sample of actors from the different Fransman layers. They are from different areas of activities, and different sizes of companies, as well as from institutions and other outside influencers. Whenever a new topic was identified, additional interviewees were added to validate this new topic with additional examples. Several industry associations or representation bodies were also included as they represent a sub-sector of the ecosystem. Requests for interviews were made via email or telephone calls. The response rate was generally positive, with over 80% of people agreeing to participate and additional people contacting the author to volunteer as interviewees. It was not clear at the start of the process how many interviews would be necessary and no specific limitation was set.

In early 2016, a second round of interviews was conducted, this time focusing on about ten questions around e-skills and job roles to address research objective 4 following the author's professional career change mentioned above. A different set of people was approached, all of them in charge of recruitment or within Human Resources departments (see table 3).

Table 3 - Companies interviewed in the second round

Company	**Main Activity**	**Number of Employees**
Amazon	E-commerce	1500
Luxembourg Institute for Science and Technology*	Research and Development	200
Econnect	Web and Online Marketing	30
e-kenz	SAP integrator	30
IMRIM	Cybersecurity	5
Instants Presentations	Web design	5
I-trust	Cybersecurity	5
L-Pod	Digital Marketing	5
Lutin Technologies	Software Development	5
MIT	IT maintenance services	15
Pixelir	IT infrastructure and cloud services	15
POST*	Telecom incumbent operator	4300
Proconsult	IT Consulting	50
RTL*	International media company	500
SES – Astra*	Satellite operator	500
Smart IT	IT Project Management	30
Sogeti	Software Development	350
Tekno Solutions	IT Consulting	30
Telindus*	ICT Integrator	450
Unify	VoIP equipment provider	20

*Also present in the first round of interviews

The author did not know these interviewees personally, so it took more time to arrange meetings. Some of the companies approached in the first round were also present in the second. Care was taken to talk to the largest employers in the ecosystem but also to some of the smaller companies. As the focus of this second part of the work was on ICT professionals and their e-skills, at this stage no interviews were made with ‘consumers’ from Fransman’s layer four, nor with institutional actors or outside influencers.

The approach presented above, and in particular, the two rounds of interviews allowed for direct collection of data from actors within the ecosystem and thus a detailed insight into the forces present in it. The process was facilitated by Luxembourg’s small size, the author’s long-standing involvement with the ICT sector and his extensive professional network.

Having said this, the chosen approach also carries a few risks and limitations. In fact, the choice and number of interviewees, although purposeful, may not have been completely representative of the ecosystem as the interviewees were partially chosen according to “ease of access” and the likelihood of a positive response to the author’s request for a meeting. The same can be said about the set of questions posed, as these were chosen by the author based on his prior knowledge of the interviewees’ situations. It could be questioned whether those questions were really the right ones and whether the author’s interpretation was truly objective. These risks have been mitigated by the relatively large number of interviewees. Whenever an issue appeared problematic, the topic was checked during the next interviews or “triangulated” by making use of the publicly available information and the collected newspaper extracts. During the process, it appeared that many of the interviewees were focusing on the same issues and it is to be expected that these truly are the ones that the ecosystem is most concerned about.

In terms of the responses given, one may ask whether these responses were in fact personal ones or were imposed or expected by the interviewees’ employers. This dilemma was raised during the interviews too. As most of the interviewees were senior managers, they choose to present their respective organisation’s views rather than their own ones.

As mentioned above, to reduce any potential biases in that respect, the author has not just relied on the interviewees themselves but collected publicly available information from press releases, press cuttings or public speeches made at events that he attended. Again, the intention was to “triangulate” the information provided and to confirm or otherwise any statements collected.

Finally, there are also some methodological elements to consider. Because of the specific language situation in Luxembourg, in some cases the author had to translate the answers provided by the interviewees. Evidently, some information could have been lost in this process. The same could be said about the transcription process. Similarly, some of the answers could be attributed to one single code and a judgement had to be made when attributing parts of answers to the different relevant codes. To take these limitations into account and to minimise the risk of errors or distortions, the author asked for some independent verification of both the translation, the transcription and the coding by some family members and study colleagues and a few corrections were made accordingly.

1.5. Overview of outcomes

Tables 4 to 6 present an initial high-level overview of these different contributions. They indicate where and when the documents were published, present their main outcomes and indicate the main learning points and/or contribution(s) to knowledge or practice. The following contributions have been made towards achieving research objective 1: to examine the size and the structure of the ICT ecosystem in Luxembourg.

Table 4 - Contributions to research objective 1

Document	**The Luxembourgish Telecommunications Market (8)**	**An analysis of the structure, actors and interrelationships producing Luxembourg's ICT ecosystem (7)**	**Measuring Luxembourg's State of ICT Development (9)**	**Playing the game: Explaining how Luxembourg has responded to the Networked Readiness Index (3)**
Published	Locally in Luxembourg in the "Revue technique Luxembourgeoise".	International Telecommunications Society Regional Conference 2017 in Passau published in the conference proceedings.	Luxembourg in "Cahier Scientifique 1/2016" of "Revue technique Luxembourgeoise".	"Digital Governance, Regulation and Policy" in July 2017.
Outcome	To provide an overview of the size and structure of the ICT ecosystem in Luxembourg.	To apply the ecosystem model developed by Martin Fransman to a small country.	To present and discuss Luxembourg's position regarding international ICT related league tables.	To present Luxembourg's position in an international league table and to understand the main strengths and weaknesses of the ICT ecosystem according to the NRI.
Contribution to knowledge	Case study about the ICT ecosystem in small countries-	Case study application of the Fransman model to an ICT ecosystem of a small country. The model is well-known but there are not many examples of its practical application in existing literature.	Overview and discussion of the strengths and weaknesses of some different international indices on ICT development.	Discussion of different indices and their limitations.
Contribution to practice	First time a complete inventory of the ICT ecosystem, its size, its actors and its stakeholders was undertaken.	The study proposes to complement and extend the application of the Fransman model with a stakeholder analysis.	Inventory of Luxembourg's position and evolution in different indices, useful for policy makers.	Longitudinal analysis of Luxembourg's position within the NRI, lessons for improvements.

The following contributions have been produced to achieve research objective 2: to understand the role of the state in the changes which occurred between 2000 and 2017.

Table 5 - Contributions to research objective 2

Document	**The Luxembourgish Telecommunications Market (8)**	**Luxembourg, a bastion of state ownership (4)**	**Competing against yourself: State duopoly in the Luxembourg telecommunications industry (1)**
Published	Locally in Luxembourg in the "Revue technique Luxembourgeoise", published in 2014.	Paper and Presentation at ITS Regional conference in Brussels 2014 and subsequent DBA seminar. Published as part of conference proceedings, certificate of successful completion of DBA seminar awarded.	Published in "Telecommunications Policy" 40 (2016).
Outcome	To illustrate the historical developments of the Luxembourgish telecommunications market since its liberalisation.	To explain the involvement of the state within the telecommunications market in 2014.	To present and understand the role of the state as policy-maker, regulator and owner of telecommunication operators.
Contribution to knowledge	Case study about the ICT ecosystem in small countries.	Case study about the ICT ecosystem in small countries.	Presented the special liberalisation approach taken by Luxembourg, i.e. the state competing with itself, to the academic community.
Contribution to practice	The first historical overview of the liberalisation process in Luxembourg. Useful reference document for local actors of the ecosystem.	Introduces Luxembourg and its ICT ecosystem to the academic community.	First document highlighting the involvement of the state in the ICT sector.

The following contributions have been made to achieve research objective 3: analysing the current strengths and weaknesses of the ICT ecosystem in Luxembourg.

Table 6 - Contributions to research objective 3

Document	**ICT Ecosystems in small countries: the case of Luxembourg (5)**	**Looking beyond official success measures: tales from the field of the complex forces shaping Luxembourg's ICT environment (2)**
Published	Paper and Presentation at ITS Regional conference in Madrid 2015 and subsequent DBA seminar. Positive feedback received from seminar participants. Paper published as part of the conference proceedings. Credits from Chalmers University awarded for successful attendance of DBA Seminar.	Journal article for "Journal of Innovation Management", published in August 2017.
Outcome	To present outcome of interviews with stakeholders within the ICT ecosystem in terms of its strengths and weaknesses.	To present the main strengths and weaknesses following from an in-depth analysis of the outcome of the interviews with stakeholders and identify areas for improvements.
Contribution to knowledge	Main contribution of the DBA project – qualitative analysis of the perceived strengths and weaknesses of the Luxembourgish ICT ecosystem.	Inform the academic community and actors of the local ecosystem about the underlying forces of the ICT ecosystem of a small country.
Contribution to practice	Useful to professional organisations, ICT stakeholder groups and policy makers.	Useful to professional organisations, ICT stakeholder groups and policy makers.

The outcome of the different activities has allowed major weaknesses of the ICT ecosystem in Luxembourg to be identified. In the later part of the research process, the author focused on these weaknesses and investigated possibilities for initiatives to address some of these.

The ICT industry is a very dynamic and quick-changing one. Thus, several major disruptions on a technological, economic and political level occurred during the period of the DBA project. Similarly, major changes occurred within the author's professional setting. To take these changes into account, the overall goal as well as the individual aims and objectives of the research had to be adapted over time. Adaptations were made iteratively and were based on feedback from the different stakeholders within the industry collected during the empirical part of the project.

In particular, RO4 was added because it was seen as a major weakness of the ecosystem by many of the stakeholders interviewed. It also followed on from the author's professional career change[16]. Taking into account these developments, in September 2015 it was decided that the focus should be on the situation around "e-skills" which was identified as one of the most notable weaknesses.

[16] See full CV in appendix 1.

The following contributions have been produced towards achieving RO4 - to identify the needs for specific changes and improvements focusing on ICT jobs and e-skills.

Table 7 - Contributions to research objective 4

Document	**Competing through e-skills: Luxembourg and its second level digital divide (6)**	**Strategies for the creation of a virtual e-Skills training centre in Luxembourg (10)**
Published	Presentation and paper for ITS Regional Conference and DBA seminar in Cambridge in September 2016.	Study commissioned by the author's professional organisation (ICT Luxembourg) published in spring 2016.
Outcome	To highlight the importance of e-skills for the development of the ICT ecosystem.	To contribute to a specific initiative to improve the situation in terms of missing e-skills.
Contribution to knowledge	Discussion of different frameworks for e-skills and competencies assessment and applying these to Luxembourg.	Identification and comparison of different models for e-skills and e-competences.
Contribution to practice	Contribution allowing stakeholders to adapt their training and education offer to develop the competences needed in the near future.	Set-up of a competence centre for ICT of which the author is a board member[17].

Based on the different outcomes above, the author has come up with comments and suggestions for both specific policy actions for Luxembourg and some guidance for further research.

[17] See www.lidit.eu accessed 28.4.2018

2. Luxembourg

This section provides some basic facts about Luxembourg and provides a short overview of its economy. It also presents some of the opportunities and challenges which Luxembourg experiences within the broader environment of the European Union.

2.1. Overview

Luxembourg is a land-locked country situated between Belgium, Germany and France. It is rather small and has a land area of only 2,586 km^2 and a population of 572,000 in 2016 (STATEC, 2016a).

Figure 1 - Luxembourg's map and position in Europe (source: Encyclopaedia Britanica)

The Grand-Duchy of Luxembourg, hereafter Luxembourg, became fully independent in 1867 and today it is a constitutional monarchy with a Prime Minister ((Service Information et Presse (2006)).

Luxembourg's government has a strong reputation for efficiency due to a long tradition of cooperation between the two biggest political parties in the interest of social peace and the creation of a business-friendly environment (Haag (2015)). The official languages are Luxembourgish, French and German but most? inhabitants also speak English. Luxembourg is a full member of all major international institutions and a founding member of the European Union.

2.2. An open and service-driven economy dependent on financial services

Luxembourg is one of the wealthiest countries in the world with a GDP per capita of about €91,600 (STATEC (2016a)) in 2015. This figure has to be treated with care because of the high percentage of cross-border workers (Schuller (2013)). Nevertheless Luxembourg is still in the top league if only the Gross National Product is considered (OECD (2015b)).

Luxembourg's industrialization began in the nineteenth century, driven by the steel industry, which is still important today – Arcelor Mittal, the world's largest integrated steel and mining company, is headquartered in Luxembourg (Zahlen (2008)). The attractive economic environment, coupled with a small and flexible state has attracted a range of international companies which have invested in Luxembourg, such as Delphi, DuPont de Nemours, Elcoteq SE, Electrolux, Ferrero, Goodyear, Guardian Industries, IEE, RTL Group and SES. In addition, due to its geographic location, Luxembourg is also seen as a logistic service provider for, for example Cargolux, DHL, Kühne & Nagel and Panalpina which all invest in the country (Zahlen (2008)).

Overall, about 13.4% of the GDP are generated by industrial activities whereas services contribute approximately 87% (OECD (2012a)). The services sector is largely dominated by financial services with 28% of GDP, followed by real estate, leasing and consulting services (22.5%) (Gargano (2012)). The banking industry took advantage of Luxembourg's highly experienced and skilled work force, its substantial international clientele and the favourable regulatory environment to dramatically expand the range of services and products that it offered. In 2017, 141 banking institutions offering the entire spectrum of corporate and private banking services, were active in Luxembourg (KPMG & Luxemburger Wort (2017)). It is worth noting that investment funds play a significant role within the financial sector, managing funds totalling €3.6 trillion in August 2016[18]. Successive EU directives that liberalized the marketing of investment funds contributed to the growth, as did an attractive fiscal framework implemented by Luxembourg.

The insurance sector also benefits from the country's large number of private banking clients. Insurance companies sell various products that are used by institutional clients as asset management tools for their mainly foreign clients. Approximately 244 reinsurance companies are licensed to operate in Luxembourg. These companies manage about €50 billion in investments (KPMG (2012a)). Around 15% of the reinsurance companies are part of an insurance group, with the remaining 85% being part of industrial, financial or trading groups (KPMG (2012b)). Luxembourg is also emerging as a leading EU location for the cross-border life insurance industry, with companies taking advantage of niches associated with cross-border transactions in recent years. One factor that has facilitated the development of this business is the local financial regulator's constructive approach to new products, such as multi-currency life insurance contracts, unit linked life insurance contracts and, again, an attractive fiscal environment (KPMG (2012b)).

The Luxembourg Stock Exchange opened in 1929. Today, the Luxembourg Stock Exchange is ranked first for? international bonds in Europe - as of early 2012, more than 29,000 debt securities were listed. This success is mainly due to a solid legal and regulatory framework, the large financial community in Luxembourg and the presence of multiple legal vehicles in Luxembourg that benefit from attractive tax regimes. The Luxembourg Stock Exchange has operated two markets since 2005: an EU-regulated market (Bourse de Luxembourg) and an exchange-regulated market (KPMG (2012b)).

[18] See www.alfi.lu accessed 28.4.2018.

Being well aware of the country's current dependency on the financial sector (Bourgain, Pieretti, & Høj (2009)), the government is increasing efforts to diversify the industry (Schneider (2012)). It has started several initiatives to attract companies that are active in the health and biotechnological industry (Gouvernement du Luxembourg (2013); Lounge et al. (2014); Merker (2013)). It is also trying to stimulate competition in telecommunications and ICT more generally (Bettel (2014); Cencetti (2014a); De Fooz (2014b)). The government is currently also putting in place some initiatives to develop the "fintech" activities in Luxembourg (Cencetti (2015a); Deloitte SnT Bourse (2015); Ducat (2015); KPMG (2014); Labro (2015); Luxembourg for Finance (2015); Thibaut (2015a, 2015b)) but further diversification of the economy is still necessary (Paperjam (2014)). In that respect, the government has successfully attracted investments in logistics and e-commerce over the last decade (PWC (2011)). Moreover, new legislation was enacted in 2009 which provides additional incentives relating to research and development (R&D). However, currently the country spends just 1.6% of its GDP on Research and Development (Cencetti (2014b); Ducat (2014); FNR (2014); Gouvernment du Luxembourg (2014a)). Additionally, private R&D remains relatively low and cooperation between the private and public sector is limited (OECD (2015c)). It is apparent that the dominant financial sector does not really invest in R&D but focuses instead on launching new or improved services.

Luxembourg's society is multicultural, with people from all parts of Europe and indeed the world, living in the country. As of 2016, almost 47% of the total population is of foreign origin (STATEC (2016a)). Consequently, Luxembourg is the EU country with the highest number of foreign nationals as residents and the proportion of foreigners in the resident population is steadily growing. In addition, out of a total labour force of around 368,400, more than 143,400 are foreign cross-border workers, commuting every day primarily from France, Belgium, and Germany (Schmitz et al. (2012); Statec (2012)).

A very multicultural society also relies on the local school systems to be multilingual. While this represents a strength of Luxembourg, it also constitutes a barrier for pupils who do not have knowledge of the three official national languages (Luxembourgish, French and German) at least. Therefore, Luxembourg often scores poorly in international student assessment tests (Chrillesen (2013)). Whilst its tertiary education attainment rate is relatively high, mainly due to the relative importance of a highly educated immigrant population, it scores very low on skills related to science, technology, education and mathematics (European Commission (2016)).

2.3. A founding member of the European Union

Luxembourg is one of the founding members of the EU and joined the euro zone in 1999. Luxembourg has been a long-term promoter of the EU spirit and its citizens are generally happy to be part of the EU (Allegrezza (2016)). Several major European institutions, including the European Investment Bank, the European Court of Justice and the European Court of Auditors, the Secretariat of the European Parliament, the European Financial Stability Facility have their headquarters in Luxembourg. Three former Luxembourgish prime ministers have acted as Presidents of the European Commission and Luxembourg has representatives in all the EU institutions.

Albeit being a net contributor to the EU budget, Luxembourg benefits from its EU membership in many ways; most importantly through its access to the single market and the local presence of EU institutions which create a substantial amount of local employment opportunities. Also, EU funds contribute significantly to projects related to economic capacity building, supporting agriculture, research and regional development.

However, Luxembourg also faces some challenges arising from its EU membership. As such, it was and is still affected by the global financial crisis, the sovereign debt crisis, imbalances within the euro zone and the recent political developments in some member countries. Most importantly, it has also been influenced by the fact that some of the EU's single market initiatives do not really consider the specificities of small countries, for instance the recent debate about the abolishment of roaming charges (Cencetti (2015b); Luxemburger Wort (2015); Sutherland (2010)). Additionally, Luxembourg's economy is likely going to be affected by the overall stagnation of the economy at EU level which may be explained by the huge asymmetries between the northern EU countries (to which Luxembourg belongs) as creditors and the southern EU member states as debtors, including the tough austerity measures imposed by the former.

3. Luxembourg and its ICT ecosystem

3.1. From Value Chains to Ecosystems

This summary document, like the different research contributions in this DBA, builds on the definition of the ICT sector and the underlying classification suggested by OECD (OECD (2011b)). This definition of the ICT sector includes IT goods and services, information content as well as telecommunications goods and services, including manufacturing and production of equipment.

There is a wide range of models available to make sense of the structure of and the competitive forces within of the ICT industry. Many of these apply or develop the Porter's value chain (Bouron (2008); Dedrick et al. (2011); Maitland et al. (2002)) to the ICT sector or parts of it (Maitland et al. (2002)), or have extended this model to a so-called value net (Li & Whalley (2002); Peppard & Rylander (2006); Rafique et al. (2012)). This idea has also been taken up and developed further by, for example, Hallikas et al. (2008) or Oestreicher et al. (2012), introducing ideas and models such as relationships, networks and alliances.

Similarly, Porter's model about competitive forces (Porter (1979)) has been adapted to the ICT environment (Dobbs (2014); Karagiannopoulos et al. (2005)). Along the same lines, Briglauer (2004) has developed a generic reference model in order to asses competition within different communications markets, focusing on the regulatory environment.

Additional work has been done to characterize the ICT sector as a network (Garcia & Vicente (2012)), and has also looked into how such networks are built and maintained (Partanen & Möller (2011)). These models are essentially static ones. However, today's business environment is complex and dynamic and includes multiple relationships in which companies interact to deliver their products and services. Consequently, the ICT sector, just as many other industry sectors, is increasingly characterized as a socio-technological (eco)system, facing asymmetric and delayed feedback structures. These can lead to turbulent changes, such as instability or existence of multiple equilibria, high levels of uncertainty (Moore (1993, 2006)). As a result, the general concept of a 'business ecosystem' has emerged (Anggraeni et al. (2007); Battistella et al.(2013); Sardegna, Ict, & Nachira (2006)).

According to Kim et al. (2010), an ecosystem can be defined as an economic community involving many companies working together to gain a competitive advantage as a result of their symbiotic relationships and collaborations. The authors also argued that ecosystems permit companies to create new values that no company could achieve alone. Likewise, they identified symbiotic relationships that can provide some benefits for related parties such as consumers and partners. More specifically, Koslowski et al. (2012) see the ICT sector as 'an ecosystem with many heterogeneous organizations that are woven into a web of links and respond interactively to forces in the environments'. The dynamics of one domain cannot be understood in isolation from the other and proper appreciation demands a systemic and evolutionary view.

Hence it is important to examine ICT ecosystems, in order to understand the co-evolution between technological and economic, as well as regulatory forces and developments, and to provide a comprehensive basis for policy makers. A recent discussion about using the ecosystems model to analyse the ICT sector is provided in Basole et al. (2015).

Here it is suggested to use the layer model described by Martin Fransman (Fransman (2001, 2002a, 2002b, 2004, 2006, 2014)) for the purpose of understanding the structure of the ICT ecosystem in Luxembourg. This model identifies the different categories of actors within the system as well as the 'interfaces' and relationships between those actors. Therefore, it provides a simple yet effective way to gain a good understanding of the different types of actors, their respective roles and importance to the sector as well some of the relations between them.

Fransman deliberately used the term ecosystem to stress the importance of the links between the various ICT actors. When looking at the supply side of the ICT ecosystem, four types of actors have been identified by Fransman:

- Layer I: Network element providers (e.g. Cisco, Samsung, Alcatel-Lucent, Ericsson, Nokia Networks)
- Layer II: Network operators (fixed and mobile) (e.g. BT, Deutsche Telekom, Vodafone)
- Layer III: Content & application providers (e.g. Google, Apple, YouTube)
- Layer IV: Final consumers

The Fransman model is not often used by researchers as it does not go into depth in terms of describing and analysing the actual activities and behaviours of actors within the different layers. However, it is relatively simple and straightforward to apply as it builds on an ISO standardized layer model[19]. Fransman suggests that this model builds on the experiences made by telecommunications and ICT engineers over time when they use layered models for organising their work and knowledge interdependencies. The model gives a clear definition of the industry or ecosystem boundaries and subsectors, a modularisation and hierarchy of the different categories of actors within the system as well as the 'interfaces' and relationships between actors. It also describes the industrial organisation of the ICT ecosystem, the identification of the location of R&D. Furthermore, it further enables the identification of entry and exit barriers, and most importantly, the role of the customers or consumers. Thus, it provides a simple yet effective way to gain a good understanding of the different types of actors, their respective roles and importance to the sector as well their interrelations.

Nevertheless, it is essentially a static model hiding to a certain extent the dynamics of change. As a result, it is not well suited to identifying modes of cooperation and coordination between the different actors nor does it cope well with diversity within the different layers. Finally, it does not take into account externalities, such as interacting institutions or organisations such as regulators or financial institutions.

In the 'new ICT ecosystem', defined by Fransman as post-internet (Fransman (2010b)), users gain presence on the supply side of the system by co-creating with suppliers. In contrast to the so-called

[19] https://www.iso.org/standard/16011.html accessed 28.4.2018.

‘old ICT ecosystem’ (pre-internet), which can be described as a closed innovation system with the most important links existing between network operators and network suppliers (Layers I and II), the new ICT ecosystem is more open, dynamic and complex. In recent years, the focus has shifted to the interactions between platform, content and application providers (Layer III). The ecosystem has also become more dynamic because of the relationships between the different actors and the environment has become more elaborated.

Acknowledging these developments, in more recent works (Fransman (2007, 2010, 2011)), Fransman has focused on the role of the dynamic, or as he calls them, ‘symbiotic’ relationships between the different layers and their role for innovation (Fransman (2014)). These relationships can be described as multi-dimensional as they represent financial and material flows, as well as information and input flows, into the innovation processes of the ecosystem.

An example of how this model can be used to understand the interactions between different actors is provided by Arlandis & Ciriani (2010), for example. This example also includes a detailed database of players in the different layers and it provides a high-level view by looking at different economic clusters such as the EU, the US and Asia. Another application of the Fransman model can be found in Veugelers (2012). Here the model is used to understand why Europe’s ICT companies are lagging behind the US. In particular, this is the case with regard to the ‘leading platform providers who are capturing most of the value in the ICT ecosystem’. It is argued that a very fragmented EU market, a lack of entrepreneurial spirit, as well as a lack of risk capital are the main barriers to the development of a EU ecosystem.

For further details about the model has been applied to the situation in Luxembourg see (Binsfeld, Whalley, & Pugalis (2017a). It has become apparent that even in this revised model, Fransman does not take into account externalities which are however a very important element of the ICT ecosystem as the current research has been able to show. Consequently, the author has proposed some extensions to this model (see sections 4 and 5).

3.2. Luxembourg’s ICT ecosystem

The following section briefly introduces the ICT ecosystem in Luxembourg and presents some recent government initiatives aimed at supporting its development[20]. It also sets the context for both RO1 and RO2.

3.2.1. Communication infrastructures

In terms of ICT infrastructure and connectivity, Luxembourg has made considerable efforts to efficiently build and operate state-of-the-art high capacity fibre networks, which ensure national and international connectivity. These connect Luxembourg to the major internet hubs in Europe and position the country as player in the middle of the so-called Golden Ring, which connects London, Amsterdam, Frankfurt and Paris (Luxembourg for Business (2013b)). In terms of communication access paths, Luxembourg holds one of the strongest positions of any OECD country, as 230 access paths were calculated per 100 inhabitants in 2009 (OECD (2011a)).

By 2009, 100% of Luxembourg’s population was covered with 3G or third generation mobile networks, while in 2012 4G networks covered 64% of the population. Similar considerations apply to fixed broadband connectivity. This will be developed further, very high-speed networks are part of the national strategy (Antzorn (2014); Bettel (2014); Cencetti (2014a); Gouvernment du Luxembourg

[20] More details can be found in the different research contributions

(2014b); Land (2014)). The government intends to increase the speed of existing networks and provide, in the medium term, the entire country with access to optical fibre. It is the government's intention to transform Luxembourg into one of the first fully fibre-connected countries in the European Union.

In Europe, Luxembourg has become a key location for data centre facilities and more than 19 data centres are operational, generally with the highest securities standards (Cencetti & Le quotidien (2014)). This has attracted substantial investment by major international actors such as Amazon, Ebay and Apple (Binsfeld (2013); Binsfeld, Whalley, & Pugalis (2014)).

Over the past few years, Luxembourg has been striving to become a major European hub for ICT technologies and services (PWC (2011)), especially for e-commerce, e-security and financial technology. However, this success has to be largely attributed to Luxembourg's heavy investments in ICT infrastructure and to the exploitation of specific EU rules and regulations.

In comparison to other European countries, the Digital Economy and Society Index 2016 (European Commission (2016)) indicates that Luxembourg is sixth among EU countries in terms of connectivity. Broadband coverage is available for 100% of households and a fast broadband connection (at least 30 Mbit/s) is available to 94% of households[21].

3.2.2. ICT is widely used by companies and households

Based on figures for 2012 provided Luxembourg's statistical office[22], companies in Luxembourg make wide use of ICT equipment. Practically all organisations (98%) with ten or more employees have Internet access, virtually all (95%) through a broadband connection and many (54%) also through a mobile connection. It can be assumed that these numbers have improved even more since then.

In a study about the use of ICT in households and among individuals, STATEC (Bodson & Frising (2015)) highlights the recent expansion of social networks and cloud activities, especially among young people.

In terms of the propensity of individuals to use Internet services, Luxembourg ranks fifth among EU countries and internet use continues to grow. Following the above-mentioned study, Internet users in Luxemburg are have digital skills and do not hesitate to engage in a broad range of online activities. They read news online (85%), listen to music, watch films and play online games (59%), use the Internet to communicate via video calls (42%) or social networks (64%), and obtain video content using their broadband connections (28% of households with a TV use Video on Demand). For most of these activities, engagement among users in Luxembourg is in line with or higher than the EU average. Similarly, in terms of online commerce, in 2014 74% of residents bought goods and services on the Internet. This percentage almost doubled in 10 years (39% in 2005). Among the most common purchases are those related to holidays (hotels (45%) and airplane tickets, 39%). Purchases of books and magazines are also common (44%). On a European level, Luxembourg is in fourth position in terms of online purchases.

Finally, the estimate of the average household annual expenditure on ICT (which primarily includes equipment and services related to telephony, audio-visual services and IT) amounted to €1.837 million, or 3.2% of the annual Luxembourgish household spending, over the period 2011-2013.

[21] Further details about Luxembourg's ICT infrastructure can be found in (Binsfeld, 2013).
[22] See http://www.statistiques.public.lu/fr/index.html accessed 28.1.2018.

In comparison to previous studies, STATEC also denotes that in 2014, 96% of the local households had access to the Internet, an increase of 6 percent compared to 2010 and 26 percent compared to 2006. Luxembourg now rates highest of all European countries.

3.2.3. A high demand for skilled workers

Luxembourg for Business (2013b) reports that the country not only has a high proportion of highly skilled workers, but also one of the highest concentrations of ICT-using occupations among OECD countries. In 2011, 56% of all jobs could be considered as being part of a knowledge-intensive economy. Put together by the Swiss Federal Institute of Technology, the KOF Index of Globalisation, which focuses on the economic, social and political dimensions of globalisation (IT One (2014)), indicates that Luxembourg is in second place in terms of economic globalisation, second only to Singapore.

In terms of computer skills, Luxembourg, together with some of the Nordic countries, has the highest shares of highly skilled computer users in Europe (European Commission (2016)).

With a Human Capital score of 0,65, Luxembourg is in sixth place in the EU. 93% of the population are internet users and the rate of people having basic digital skills (82%) is the highest in Europe.

However, the application of technology to new ideas and products hinges on the availability of highly skilled workers. Despite widespread basic digital skills, there is a shortage of qualified ICT experts in Luxembourg. In 2015, over 58% of companies which recruited or tried to recruit staff for jobs requiring specialist ICT skills reported problems in filling these positions, up from 52.8% in 2012. This is the second-highest percentage in the European Union. This problem is related to Luxembourg's low number of science, technology and mathematics graduates. In the EU, it has the lowest number of graduates in these areas with a mere 3.6 graduates per 1000 individuals, compared to an EU average of 17 graduates per 1000 individuals.

Among the five Digital Economy and Society Index (DESI) dimensions, Luxembourg has the second worst score (0.33) in terms of businesses using digital technology and ranks only 16th among EU countries (European Commission (2016)). Luxembourg has to make efforts to create a truly digital economy in which businesses take full advantage of the possibilities and benefits offered by digital technologies to improve their efficiency and productivity, and to reach out to customers to sell goods and services.

3.2.4. A government which supports ICT development

In the national economy, the information and communication sector encompasses a large variety of activities as well as an array of local and multinational companies, large and small, that contribute 6.6% to the total gross value added (GVA) generated in Luxembourg in 2012. This rate is noticeably above the EU-27 average (4.6% of the total GVA) and is the highest among the 27 EU member states.

The Luxembourgish ICT stakeholders have recognized the important role that information and communication technologies play in the national economic development. In recent years, Luxembourg has experienced major progress in this area, with the increasing appearance and development of companies that use innovative technology, whether in the media sector, in e-commerce, for digital content, cloud computing, Big Data, electronic payments, or to solve security issues,.

In recent years, Luxembourg has also seen some improvements in use of e-government and the supply of e-government services. Luxembourg's scores place it among medium-performance countries.

Moreover, a considerable amount of money has been spent to transform Luxembourg into a highly connected country, while providing the necessary support structures, such as communications infrastructure (connectivity, data centres, security-related services, etc.), research and innovation institutions (university, research centres, support to innovative companies, etc.), and adapting the legislative framework to a dematerialized digital society. Consequently, it was possible to create an attractive setting for companies wishing to develop their activities in Luxembourg. New employment opportunities for highly specialised workers are also provided as a result of that and the nation's overall competitiveness has increased too.

Thus, the ICT sector has slowly become an economic player in its own right and is not merely limited to its function as a service provider to other economic sectors, especially the financial sector, any longer. As an economic sector by itself *and* as a vector of competitiveness for all other socio-economic sectors, the ICT sector will play an ever-increasing part in the modernisation, performance, competitiveness and efficiency of the country and can therefore be considered as "General Purpose Technology"[23].

In order to strengthen and consolidate the country's position in t ICT and to transform its ICT sector into a high-tech centre of excellence, the Luxembourgish government, in conjunction with industry stakeholders, has adopted a comprehensive digital strategy (Land (2014)). This strategy encompasses subjects as diverse as the computerization of government services, e-skills, the adaptation of financial support instruments, the development of new, more niche, markets such as big data, health technologies, fintech (services offered to the financial sector), virtual currencies or creative industries (Bettel (2014)). It has triggered further growth and development of the ecosystem since its adoption (Somnard (2018))[24].

[23] More information can be found in the author's contribution to the 28th ITS regional conference in Passau (Binsfeld, Whalley, & Pugalis (2017a)

[24] See as well https://digital-luxembourg.public.lu/ accessed 18.3.2018.

4. Research outcomes

This section will present the main outcomes of the different research contributions and identify connections and links between these using the conceptual framework developed by the International Telecommunication Union for its ICT development index (International Telecommunication Union (2016) and in particular its three pillars: ICT Readiness, ICT Use and ICT Skills.

4.1. ICT Readiness

A total of four different contributions have been made, which have focused on developing an understanding for Luxembourg's ICT readiness. They are linked specifically to research objective 1. Two of these contributions have shown how Luxembourg's telecommunications market developed over time and how the ICT ecosystem has presented itself in recent years (Binsfeld (2013); (Binsfeld, Whalley, & Pugalis (2017a)). Another contribution has shown where Luxembourg positions itself on different international indices and how its ranking has evolved over time (Binsfeld & Whalley (2016)). Finally, the author extracted lessons about the ICT ecosystem in Luxembourg by looking more specifically at its position on the Networked Readiness Index (NRI) (Binsfeld, Whalley, & Pugalis (2017c)).

4.1.1 The development of the telecommunications market focusing on infrastructures

In a comprehensive study about the development of the Luxembourgish Telecommunications Market since its liberalisation in 2008 (Binsfeld (2013)), the author presents some statistics on the development of the ICT sector in Luxembourg and shows that even in 2013, the vast majority of homes had access to high-speed internet, just as most companies made use of ICT[25].

Different government agencies have started initiatives to develop the sector, focusing on the 'ultra-high broadband' strategy launched in 2010. The author also presents the relative importance of different broadband access technologies and introduces some of the main alternative telecommunication providers both for the fixed and the mobile market. This leads to an analysis of the intensity of competition of these two markets and an identification of the poor development of alternative access technologies such cable TV networks.

In 2013 (and in some sectors still in 2017) the fixed telecommunications market was largely dominated by the country's incumbent operator. While the mobile telecommunications market saw competition between three mobile operators, the incumbent operator[26] still owned a market share of around 50% (Institut Luxembourgeois de Régulation (2015)). Luxembourg was not an 'early adopter' of the liberalisation process, which can be explained by both the small size of the country and the economic and political importance of Post which is, with more than 4300 employees, the largest employer in the country (Binsfeld, Whalley, & Pugalis (2014)).

The government has tried to intervene in the market and created a second, fully state-owned operator[27] with the goal of increasing the offer of both national and international broad-band connectivity and data centre capacity (Binsfeld, Whalley, & Pugalis (2016a)). This was successful as it reduced the barriers experienced by companies wanting to establish themselves in Luxembourg and it has attracted several international operators from neighbouring countries to Luxembourg. However, this state intervention was purely limited to infrastructures, which has led to an overcapacity in fibre optic connections and of the data centres. Today it is still not entirely clear how to best use these capacities

[25] This was the first study of this kind about Luxembourg.
[26] See www.post.lu accessed 17.4.2018.
[27] See www.luxconnect.lu accessed 22.4.2018.

(Thompson & Kettels (2013)). There is also a lack of 'value-creating' services and applications. Due to changes in EU regulations, Luxembourg has lost its attractiveness as a low-VAT country which traditionally has been the main reason for international actors to use data centre capacity in Luxembourg. As a result, this article calls for further research on these topics, which the author has embarked on since (Binsfeld et al. (2016a, 2017b)).

4.1.2. The size of the ICT ecosystem, actors within the ICT ecosystem

Applying Fransman's model to Luxembourg's ICT ecosystem allowed the researcher to identify a huge number (almost 2000) of actors, many of which are very small (one-person) organisations which focus on software development activities to a large extent. It also found that most of the Gross Value Added (GVA) is generated in the network layer 2 by telecommunications network operators in which the Luxembourgish government holds a substantial stake. Also, there is nearly no local production activity of ICT goods and equipment (layer 1).

Indeed, Layer 1 (network element providers) consists mainly of distributors, local sales branches or subsidiaries of international or global ICT equipment providers like Cisco, Ericsson, Huawei, Nokia Services and Networks, HP, IBM, Dell, Oracle and EMC.

Layer 2 (network operators) consists of 88 companies, of which 11% are companies with more than 50 employees. Companies acting in layer 2 provide high speed internet, cable TV, fixed line telephony, satellite and mobile connections.

Layer 3 (content & application providers) is the 'largest' layer in terms of the number of actors. It consists of 1670 companies, which for the most part (97%) are companies with less than 50 employees. The larger companies in this layer are mainly active in e-commerce, software, ICT-consulting and ICT-integration, as well as being data centre operators. More recently, cybersecurity and fintech companies have started to establish themselves. Additionally, the regulator of the financial sector created an accreditation for 'professionals of the financial sector'[28] which attracted some international ICT integrator firms to Luxembourg (Deloitte (2013)).

The study was made more difficult because of the limited amount of publicly available information. Although detailed information about companies such as financial figures, core business, year of foundation and investment in R&D is collected by Statec and Eurostat, it is not openly available due to data protection issues. The data which is available from the Statec and Eurostat databases, not divided into NACE nomenclature (STATEC (2008) subsections, is limited and not always up-to-date.

Therefore, some key elements of this study, such as GVA, turnover and number of employees, could not be accessed nor analysed for the entire period covered by the study. Getting access to information about the companies' profitability, returns and R&D expenditure would have allowed the researcher to do a far more detailed analysis on a firm level and would have enabled him to look in more depth into the 'symbiotic relationships' such as networks, cooperation and/or competition relationships between the different actors in the ecosystem. Notwithstanding these limitations, to the best of our knowledge, this is the first time that an in-depth analysis of Luxembourg's ICT ecosystem was undertaken and the first time that the Fransman model has been applied to a small country.

4.1.3. A focus on improving within international indices and league tables

Luxembourg's authorities have always been eager to compare themselves with other countries and are trying to improve Luxembourg's position in international rankings. Therefore, the author was

[28] For more information see http://www.luxembourgforfinance.com/en/products-services/psf accessed 24.8.2018

interested in understanding how Luxembourg positions itself in a European and international environment. This was achieved by looking at several indices related to the development of the ICT sector in different countries (Binsfeld & Whalley (2016))[29]. Firstly, the authors introduced an extensive inventory of relevant secondary data sources both on a national and international level to extract such indices. The authors discussed some of these indices in detail, focusing on Luxembourg's ranking or position. Then, they did an in-depth examination of the information provided by the national telecommunications regulator as well as by Eurostat. These statistics provide further insights into the size of Luxembourg's ICT sector and its position in the European Union. The authors also positioned Luxembourg in term of OECD's Communications and Internet Economy Outlook (OECD (2012b, 2013)), the World Bank's Knowledge Economy Index (The World Bank (2012)) as well as on some commercial indices such as the Booz & Co Digitization Index (Booz&Co (2013)) or Cisco's Broadband Quality Score (Cisco & Saïd Busines School (2010)). The study positions Luxembourg, using 'real-life' measurements taken directly from the internet (Akamai (2013)). Again, this was the first time that such a study, looking at the specific situation in Luxembourg, was produced.

The authors completed their analysis with a brief assessment of the performance of the national regulatory authority according to the Polynomics Telecommunications Regulation Index (Zenhäusern et al. (2012)) and the Telecommunications Regulatory Governance Index (Waverman & Koutroumpis (2011)). Both indices show that the regulator has not been intervening much in the development of the market and that the "overall political transparency" of the regulation process is rather limited in Luxembourg. This topic has been further explored in Binsfeld et al. (2016a).

Despite the many limitations and methodological problems of measuring 'information society', it was possible, using a wide range of different indicators and indices, to conduct an assessment of the state of development of Luxembourg's ICT landscape and to confirm that:

- In terms of ICT, Luxembourg positions itself amongst the top performers in the EU and worldwide. Its ICT sector is well developed and an important part of its economy.
- Over the last decade or so, Luxembourg has been able to improve this position and in particular was able to extend the underlying technical infrastructures and to develop the use of ICT. As a result it has increased its e-readiness overall. As has become apparent by looking at one specific index (see below) in more detail, Luxembourg has not been successful, however, in increasing its population's the skills which needed for ICT and has not managed to improve the educational aspects related to ICT.

Furthermore, the different indices have raised additional questions, some of which have subsequently been explored in interviews with the relevant actors in the ecosystem (Binsfeld et al. (2017b)).

4.1.4. Lessons learned from the Networked readiness index

A specific index, the Networked Readiness Index (NRI) which is produced on an annual basis by the World Economic Forum, has attracted a lot of attention by Luxembourg's policy makers (De Fooz (2014c); Henry (2013)). Therefore, the author decided to take a more detailed look at its development and he published a peer-reviewed article in *Digital Policy, Regulation and Governance* (Binsfeld et al. (2017c)). A longitudinal case study-based approach, drawing on secondary data and the annual publication of the NRI between 2003 and 2016, was performed.

The analysis shows that Luxembourg has successfully improved its position on the NRI over the course of the past 13 years. In both 2015 and 2016, the World Economic Forum ranked Luxembourg

[29] Of which the IDI mentioned above is a well-known and widely reported one.

among the top ten network ready countries globally, up from rank 27 in 2003. This was achieved by a series of governmental initiatives that have contributed to the development of the underlying ICT infrastructure, in terms of international connectivity, broadband and ultrahigh-speed broadband as well as datacentres. Several segments of the ICT ecosystem have become much more competitive, which has led to more appropriate overall prices and a good level of take-up of these services. This can largely be attributed to the creation of Luxconnect[30], a second state-owned operator. This has led to a situation in which the state competes with itself, rather than relying on market forces (Binsfeld et al. (2016a)).

However, Luxembourg has not developed substantial local electricity production capabilities and relies instead on imports from surrounding countries. Currently, this can be seen as an advantage as the local energy prices are amongst the lowest in the EU (Enovos Luxembourg (2014)). However, in the long run, this may not be sustainable as the country is completely dependent on foreign electricity providers. The first lesson we can draw from the analysis is the importance of infrastructure-based competition for improving a country's NRI position. Importantly, this infrastructure includes more than just ICT.

Luxembourg has not tried to establish the necessary educational programmes and institutions that would allow it to develop its local population's much needed IT skills. Instead, Luxembourg has relied on the importing of knowledge from neighbouring countries, whilst focusing on its language skills, encouraging legal, financial and humanities education. Increasingly, this is seen as a significant obstacle to continuing the further development of the ICT sector and further improvement of Luxembourg's position on the NRI. In a recent publication of the Digital Economy and Society Index (European Commission (2016)), Luxembourg came last amongst EU member states, in terms of the percentage of students embarking on technical, scientific or mathematical studies, which are often considered at the base of ICT skills. Currently, different initiatives are under discussion (Binsfeld, Whalley, & Pugalis (2016b)) both on the supply side (new training programmes, private schools, continuous professional development and vocational training) (Ant (2015); Ant et al. (2016)) and on the demand side (promotion of Luxembourg as an attractive place to live and work, stimulation of e-skills amongst young children). However, these initiatives will take time before they can yield real benefits and help with the provision of the necessary skills. Thus, a second lesson that can be drawn from this analysis, is that skills are equally as important as infrastructure.

Concerning changes in the legal and regulatory environment that would facilitate the start-up of new businesses, the situation is similar to that around e-skills, as a major change is required. Commercial law would have to be redesigned. Currently, if an entrepreneur goes bankrupt, he or she is forbidden by law from starting a second (new) venture. A change to this law would have to be accepted by all relevant stakeholders and political parties. Once again, tt would take time to get these stakeholders on board and make the necessary changes to the legal framework. This gives rise to a third lesson, namely, the need to engage with all relevant stakeholders, which, even for a small country like Luxembourg, can sometimes prove very difficult.

Luxembourg's position on the NRI illustrates that to be in the ICT "premier league" a holistic policy approach is necessary. It is not enough to rely on the development of basic ICT infrastructures and the fostering of competition. The development of complementary infrastructures such as electricity generation is also necessary and, perhaps most importantly, efforts are required on a social level in

[30] See www.luxconnect.lu accessed 27.4.2018.

terms of adapting the education system and its priorities, promoting ICT usage and developing digital skills.

Concluding the analysis of Luxembourg's ICT readiness, the different contributions discussed above have helped to understand the size and structure of Luxembourg's ICT ecosystem, to identify some of its historical developments, to position Luxembourg on international rankings and present some of its major strengths and weaknesses, as highlighted by the NRI. They have also contributed to identify a certain number of questions and/or critiques which have subsequently been explored further.

4.2. ICT Use

Four different contributions have been made which help to understand Luxembourg's ICT use and relate more specifically to RO2 and RO3. Two of these contributions have shown the importance of and different roles played by the state as policy maker, regulator and owner of two telecommunications operators (Binsfeld et al. (2014, 2016a)). Another contribution has looked at how the telecommunications market has been liberalised and whether this process has been successful (Binsfeld, Pugalis, & Whalley,2(015). A final contribution has looked at the different forces which have shaped the ICT ecosystem in recent years (Binsfeld et al. (2017b)). From this final contribution a detailed analysis of the strengths and weaknesses of Luxembourg's ICT ecosystem has been derived, which will be further explored in section 4.5 below.

4.2.1. The role of the state as policy maker, regulator and operator

The author presented the specificities of the Luxembourgish telecommunications market to the ITS community (Binsfeld et al. (2014)). The author showed that whilst Luxembourg's telecommunication landscape has witnessed a limited degree of liberalisation, the incumbent and 100% state-owned operator is still the dominant player of much of the market; a market which has grown substantially over the period discussed here. The government has intervened in a major way on the supply side and has made significant investments, which have resulted in a network duopoly where the state competes with itself. Given this situation, it was shown that, in fact, Luxembourg is a bastion of state ownership, as the government has not followed other European countries in reducing its ownership and intervention in the telecommunications sector.

As indicated previously, Luxembourg has a good ICT infrastructure and international connectivity as well as substantial datacentre capacity. Local customers are presented with attractive triple and quadruple play offers, nationwide xDSL and 3G availability. Luxembourg is well positioned on many of the international ICT indices and enjoys a good international ICT competitiveness. In that sense, the Luxembourgish situation seems to confirm previous findings from countries like Cyprus (Symeou (2009) in that liberalisation is not necessarily the right answer for small economies.

However, Luxembourg has not been able to attract much in the way of foreign investment and when investment has occurred it can be argued that it was mainly for tax reasons. This has raised a significant question, namely, what will happen once these fiscal incentives are much reduced, given the change in law in 2015[31]? Will the government seek to compensate for their removal by extending its commitment to the sector through, for instance, continued investment? Or will the investment in infrastructure that has occurred so far, begin to attract (foreign) investment into value added services and thus generate economic activity? It has become clear since that foreign investors have started to turn away from Luxembourg and the government has increased its efforts to attract investors in some

[31] Due to changed EU regulations mainly about VAT on Ecommerce activities.

new areas, for example in Space Mining[32], and more recently by trying to encourage Google to build a data center[33] in Luxembourg.

As the work developed further, the author published a paper in *Telecommunications Policy* (Binsfeld et al. (2016a)) on the subject of "state-duopoly", which appears to be a unique policy approach to liberalisation that, to the best of our knowledge, only Luxembourg has adopted so far. The approach has led to the creation of a second state-owned telecommunications operator. Luxconnect, the second 100% state-owned operator was created purposefully by the government to foster competition (Gaudron (2013a, 2015); Poujol (2014); Zahlen (2016)). Therefore, the state is now in a unique situation and has to act in different, sometimes contradictory, roles as a policy maker, regulator and telecommunications operator. As a result, Luxembourg's telecommunications sector is rather unique. The Luxembourgish state is not at the forefront of neoliberal trends but rather has taken the "wait-and-see" approach that could be qualified as an "informed follower" approach. The government not only decided that the incumbent operator would continue to be 100% state-owned but also created a second operator, in order to create competition at least in terms of national and international broadband connectivity and data centre capacity. This has reduced entry barriers for several national and international alternative operators and service providers, and has contributed (as shown above and in Binsfeld et al. (2017b)) to a dramatic improvement of Luxembourg's position as ICT-enabled country in international rankings.

Overall the two contributions have allowed for a better understanding of the involvement and role of the state in the development of the ICT ecosystem in Luxembourg. A rather unique and unconventional approach was taken, which has triggered questions relating to the independence of the different roles of the state as regulator and policy makes. Arguably, the overall analysis shows that Luxembourg has benefited from this decision. Perhaps this approach could be adopted in other similar contexts as an alternative model for the development of the telecommunications market or indeed in other utilities or infrastructure markets?

4.2.2. An analysis of the forces affecting the ecosystem

Above, the author has shown how it was possible to use secondary and publicly available data to describe, analyse and evaluate the ICT ecosystem and its position in an international context. To gain a deeper understanding and to confirm these findings, it was decided to conduct an additional study. This qualitative research centred around a series of interviews with ecosystem actors with the aim of identifying the major strengths and weaknesses of the ICT ecosystem during the period at hand (2012-2016), as experienced by actors within the ecosystem.

A set of initial outcomes to this part of the research, which constitutes a major part of the author's work, was presented at an academic conference in Madrid in 2015 (Binsfeld et al. (2015)). This study presented an extensive list of factors and forces that affect the ecosystem either positively or negatively. Some of these could be qualified as exogenous such as competition from Luxembourg's neighbouring countries France, Belgium and Germany as well as from the Netherlands and Ireland, or regulatory issues such as roaming charges or VAT regulations imposed by the European Commission. Other factors were more endogenous and these included issues such as financing, innovative and entrepreneurial thinking, policies or infrastructures. At this stage, the author presented a first attempt

[32] See http://www.spaceresources.public.lu/en.html accessed 22.12.2017.
[33] See more details http://www.datacenterdynamics.com/content-tracks/design-build/report-luxembourg-has-found-new-land-for-googles-1bn-data-center/98642.fullarticle accessed 22.12.2017.

to classify these factors according to their relative importance. A second and extended version of the work was presented in the peer-reviewed *Journal of Innovation Management* (Binsfeld et al. (2017b)).

The underlying data used for the analysis was extracted from two sources (see section 1.4). The authors collected publicly available information like press cuttings, company presentations and public speeches. In addition, they conducted over 50 individual interviews with key players (CEO level) from a representative set of actors (chosen according the four Fransman layers). These interviews were based on a set of questions which was derived from an earlier focus group discussion. The data was analyzed with the help of NVIVO software, as described in section 1.4.

Firstly, this process allowed the researchers to produce a map of the ICT ecosystem in Luxembourg according to Fransman's four layers. Fransman's model is not widely used by scholars and there are only a few similar studies mentioned in the literature (Fransman (2011); Rey-Moreno et al. (2016); Veugelers (2012)). Despite this being a rather high level and generic approach, no such mapping existed for Luxembourg before.

Secondly, it identified the different exogenous forces shaping the ecosystem. The first category of exogenous factors concerns the regulatory environment. Many actors mentioned that European regulations do not encourage the emergence of ecosystems in small countries, and that the law favors large companies. It was also mentioned that VAT discrepancies are an obstacle to market fluidity, in particular blocking cross-border e-commerce activities.

Interviewees also identified competitive pressures. The main competitor countries mentioned were, the Netherlands, Germany, Ireland, Belgium and France. The fact that Luxembourg is much smaller and sometimes has a negative reputation (prejudice of it being a tax haven) led some interviewees to consider Luxembourg as particularly vulnerable in that respect.

The study went on to identify endogenous factors affecting the ecosystem. The first endogenous factor mentioned was government policies. Efforts made by public authorities in Luxembourg and their ability to adapt regulations were praised. However, the absence of a comprehensive strategic plan was noted. Conversely, ICT Luxembourg (Cencetti (2014b); Gaudron (2014b); ICT Luxembourg (2015); Le Quotidien (2015)), an initiative by representative bodies of the industry and the government's Digital Lëtzebuerg programme (Gouvernment du Luxembourg (2014b)) were found to be helpful. The second endogenous factor concerns regulatory aspects, with an emphasis on security, data protection and the legal framework for intellectual property. The third endogenous factor refers to the training and labour market aspects, such as the difficulty of finding employees with the necessary skills, a lack of locally appropriate training and the weakness of science education in Luxembourg. Trilingual education and the existence of six universities in the greater region were considered assets. The fourth endogenous factor concerns attitudes. Luxembourg is considered as not having enough international ambition. It shows a lack of appetite for the creation of start-ups, limited entrepreneurial spirit and a reluctance to take risks.

The fifth endogenous factor concerns infrastructure, which was found by most interviewees as being well, if not overdeveloped. The survey respondents praised the government's efforts to develop infrastructure and highlighted the good complementarity between public and private investments, while noting the need to invest in energy, transport and logistics. In fact, these complementary infrastructures were considered to be necessary to support the development Luxembourg's economy and ICT ecosystem.

Building on the outcome of the interviews, the author has developed a generic conceptual framework that supports the identification of the strengths and weaknesses of Luxembourg's ICT ecosystem. This generic framework (see figure 3), as well as a SWOT analysis, are presented in detail in section 4.5. Together, the four contributions presented in this section have led to a better understanding of the role of the state within the ICT ecosystem (RO2) and to identify the forces, which affected the ICT ecosystem during the period studied (RO3).

4.3. ICT Skills

Based on the outcome of the studies above, several major weaknesses were identified. Due to limited space, the author chose one of these weaknesses and identified potential ways of addressing it. Following the changes in the author's professional situation[34] in September 2015, it was decided to focus on the lack of e-skills. This led to drafting of RO4. The fourth research objective is both academic and pragmatic and in his professional environment, the author has actually been able to contribute to some initiatives, which were put into place by industry representatives to address some of the issues identified.

The author presented a study of the most sought-after profiles and skills of ICT professionals to the ITS community at a regional conference in Cambridge (Binsfeld et al. (2016b)) and acted as co-author to a study commissioned by ICTLuxembourg[35] and Digital Luxembourg[36] (Ant et al. (2016)). The aim of the later study was to identify ways of addressing the ICT skill shortage by setting up a specific ICT competence centre. In addition, the author contributed to an bi-annual survey about jobs in ICT, published by the Luxembourg business association FEDIL (Fedil, ABBL, & CLC (2016)).

In Binsfeld et al. (2016b), the author first identifies and then discusses different models and frameworks to define the e-skills or digital competences of ICT professionals. One of these frameworks, developed by the European Committee for Standardization (European Committee for Standardization (CEN) (2014)), defines different jobs categories and different job roles for ICT professionals. This framework was used to discuss, with 20 human resources managers from a representative set of ICT actors (see section 1.4.), what their current and future priorities are, in terms of job profiles and ICT competences. In the process, major technological trends perceived to influence these competences were also identified. These are mobility and mobile application technologies, the growing importance of social media for both private and business purposes, cloud computing, big data analytics, the Internet of things (IoT) and IT security.

This process allowed for the identification of six categories of e-jobs, which were considered as being the most relevant for the Luxembourgish ICT sector. These are jobs related to marketing, communication and business intelligence, IT management, quality, testing and security, technical oriented profiles, infrastructure and network management, IT governance and IT project management, user assistance, support and design, and development and maintenance of software and applications. The participants then chose the job profiles they felt to be the most important ones in the near future. They defined profiles as being more or less business critical and more or less difficult to train for (see table 8).

The interviews also enabled feedback to be collected from the participants about the questions themselves. Questions included, what countries are they currently recruiting their ICT professionals from? How important do they feel are previous working experience and vocational training? Which

[34] See detailed CV in appendix 1.
[35] See www.ictluxembourg.lu accessed 28.4.2018
[36] See http://www.digital-luxembourg.public.lu/fr/index.html accessed 8.8.2017.

profiles have been the most difficult to find so far? In exploratory workshop and brainstorming sessions, the most sought-after skills and perceived main reasons for a lack of competences were discussed.

Table 8 - ICT job profiles and training needs

Less critical jobs profiles – low recruitment needs – low training needs	**Business dependent job profiles – high recruitment needs**
Project Manager, E-journalist, Graphical Expert, Telecommunications Engineer, IT Manager, CIO, Data Security Engineer, Online Marketer, Web Designer	Social Media Administrator, Social Media Consultant, Social Media Operator, 3D Designer, Programmer (C, C++), Maintenance Engineer, Maintenance Technician, Software Developer, Helpdesk Technician, IT Technician, IT Administrator, Network Administrator
Technological jobs profiles – high training needs	**Critical job profiles – high recruitment needs – high training needs**
Bioinformatics, Security researcher, ERP consultant, IT trainer/consultant, SaaS consultant, Strategic coordinator, Change and Innovation manager, E-services managers, IT Engineer, Network Engineer, Systems Engineer, Penetration Tester, Internet of Things Specialist, Transition Manager, Video Specialist	Cloud Architect, Cloud Engineer, Cloud Orchestrator, Cloud Technical Product Manager, Cloud Consultant, Cloud Administrator, Security Engineer, Security Consultant, Business Intelligence Analyst, Data Analyst, Data scientist, Legal Experts, Systems Architects, Technical Sales People, Virtualisation Consultants, Application Designer, Application Developer

The study concluded by identifying potential avenues which might lead to an appropriate management of the situation. Initiatives need to involve a wide range of actors and stakeholders from public and private sectors and the creation of a national coalition for jobs and skills, as suggested by the EU commission, was considered helpful[37].

Building on this work, the author became professionally involved in the setting up of the national coalition for digital skills and jobs[38] but was also asked to contribute, as co-author, to a more in-depth study in order to propose strategies for setting up a specific ICT related "centre of competence" (Ant et al. (2016)). In this study, the authors presented an overview of the global ICT environment and introduced the ICT sector in Luxembourg, largely building on the research discussed above. They conducted additional empirical research within the ecosystem to collect further evidence on the ICT skills gap. They looked at a wide range e-skills reference frameworks and suggested the establishment of a virtual ICT competence centre based on the European Qualification Framework (European Committee for Standardization (CEN) (2014)). It was suggested that several, existing vocational training providers could create this new platform, in order to coordinate their training programmes and offers. This centre could be able to develop e-skills on the different level of the qualification framework. This competence centre was formally founded in November 2015 (Zabatta (2015)) and the author became its vice-president[39]. In that respect, the two contributions mentioned in this section

[37] see http://www.digital-luxembourg.public.lu/en/actualites/e-skills/2017/20170519_nationalcoalition/index.html accessed 9.8.2017.
[38] See www.lidit.eu accessed 28.4.2018
[39] For more information see www.lidit.eu accessed 28.4.2018

have not only addressed the academic question but have also had a practical outcome in the author's professional environment.

4.4. Summary

In terms of ICT Readiness, Luxembourg has been focusing mainly on constructing underlying infrastructures both in terms of national and international connectivity and data centres. While doing so, it has been able to considerably improve its overall ranking on several international ICT-related indices, as shown by the example of the NRI. The overall size of the ICT ecosystem has also grown substantially and in 2017 more than 2000 companies were active. However, many of these companies are very small and they are not creating a lot of value added. The sector is still dominated by a few larger players, amongst which the former incumbent operator is the most important one.

In terms of ICT Use, Luxembourg has been able to create a more competitive telecommunications sector by liberalising the market using a very special approach, as it created a second state-owned operator to compete with the existing one. So far, Luxembourg has not been able to attract a lot of foreign investment, probably because of the small size of its domestic market. The development of the ICT ecosystem has been supported mainly by favourable tax laws, a supportive government and a stable political environment. However, the analysis highlighted that Luxembourg lacks the necessary technical and ICT skills and entrepreneurial mind-set. It is also negatively affected by some international regulations, as well growing competition from neighbouring countries.

Finally, in terms of ICT Skills, interviewees showed the most interest and had the most problems to find suitable candidates in six categories of jobs. The extent to which Luxembourg is lacking ICT skills became very apparent. For years, the government relied on importing labour from neighbouring countries, a strategy that clearly has its limitations. The research showed an urgent need to launch new and local initiatives, involving the different stakeholders, to address the situation. One of these initiatives, leading to the creation of the Centre of Competence for Digital Training has been presented in detail.

4.5. An analysis of the strengths and weaknesses of the ecosystem

An important outcome of the research process (RO3) has been a conceptual framework to identify the different forces that affect the ecosystem in Luxembourg positively or negatively. These include, on one hand, endogenous factors such as policies, infrastructures, competition within the ecosystem, innovation, finance, entrepreneurial spirit and education. On the other hand, they include exogenous factors such as international competition and regulations (Binsfeld et al., (2017b)).

This model can serve as a basis to understand the forces affecting ICT ecosystems, not just in Luxembourg but in other countries, and, more specifically, in countries of similar sizes or at similar economic development stages. It can also be replicated or extended to other, similar, network economic sectors. As a result, the model is one of the author's DBA thesis's main contributions to knowledge. The figure below shows the application of the framework to Luxembourg. The colour code indicates whether a force is supporting the development of the ecosystem (green) or hindering it (red). Forces, which are both strengthening and weakening the development of the ecosystem are shown in amber. These colours represent the consolidated position of the different interviewees.

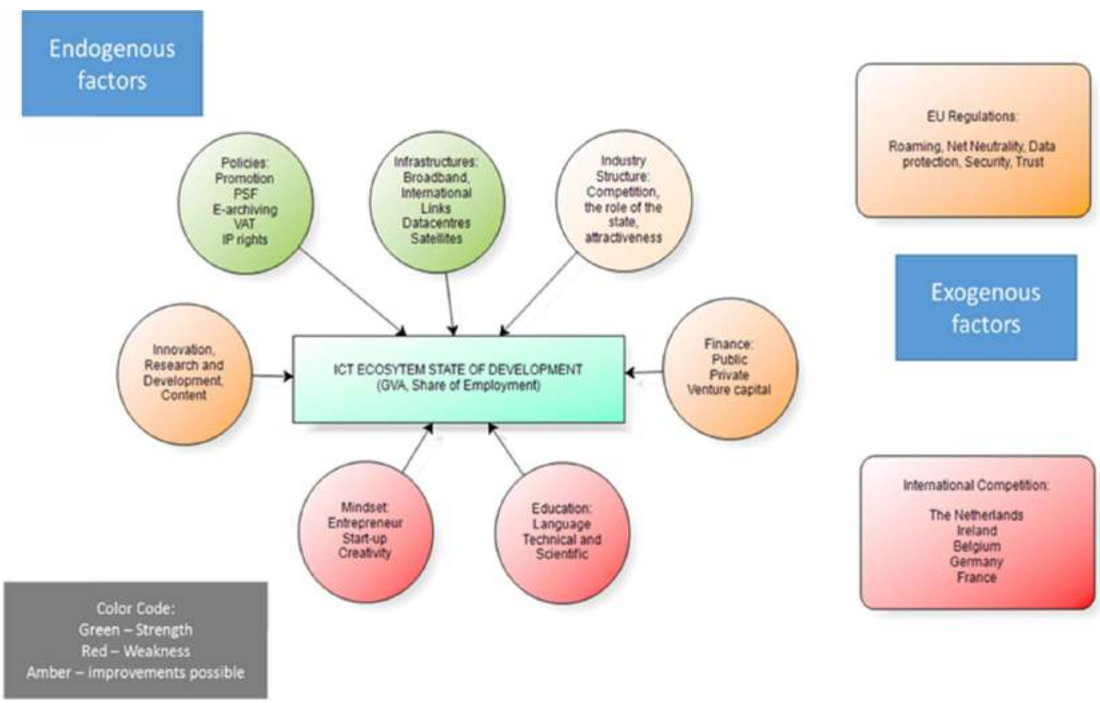

Figure 2 - Strengths and weaknesses of the ICT ecosystem

The research process also enabled the author to conduct a comprehensive SWOT analysis of Luxembourg's ICT ecosystem, collecting and combining the views of the different interviewees. This SWOT analysis has subsequently been referred to in several publications produced by others (Ant et al. (2016); Cottong (2016); The TIR Consulting Group (2016)).

According to table 9, the ecosystem's strengths are related mainly to national and international infrastructures both in terms of connectivity and data centres. Political support, pragmatic regulations and policies, a multi-cultural workforce and a well developing economy (buildt to a large extent on the financial sector) are other positive forces that were identified. The ecosystem's weaknesses are the country's small size, its missing ICT skills, an underdeveloped entrepreneurial mind-set, as well as a lack of creativity and innovation.

Table 9 - High level SWOT analysis

Strengths	**Weaknesses**
International infrastructures Data centres Nationwide fibre network Fiscal policy Competitive price for electricity PSF Status PSDC Status Law on cloud computing Financial sector as main driver Simple access to authorities and political decisions makers High GDP Multilingual workforce	Small country – no critical mass Underdeveloped ICT skills Underdeveloped entrepreneurial mind-set Limited creativity
Opportunities	**Threats**
Development of specialist functional skills to service large ICT suppliers Development of advanced networking solutions and intelligent networks, Provision of high data storage capabilities, large data processing, data mining and knowledge extraction capacities Attraction of multinational investment Position of Luxembourg as secure, trusted hub Redundant electricity grid Cyber security Pro-active government Small country can act as innovation lab	Failure to continuously invest in infrastructure Competing in a local market where international brands are most trusted Competing on a world-wide scale Innovating and producing in fragmented markets Intensive competition from neighbouring countries New VAT and tax regimes EU and G20 pressures Political pressure on international companies Dependent on electricity grids of neighbouring countries Missing ICT workforce and skills

In terms of opportunities, interviewees felt that more ICT skills could be developed mainly related to cyber-security and trust. The existing data centre capacity to could be used more and more efficiently. The government could try to attract more foreign investment and the small size of the country could be turned into advantage if it acts as an innovation lab to test new products and services.

Threats were mostly related to developments and changes in the global economy, more stringent regulations, reduced local autonomy on tax regimes but also to the ever-growing lack of relevant e-skills and growing international competition.

4.6. An extension of the Fransman Model

The different limitations of the Fransman model mentioned in section 3.1 became very apparent in this study. The model allows for the identification of different actors but is not conducive to understanding the behaviours of these actors, nor their links and dynamic relationships such as the creation of innovations.

The model is designed as static and forces a classification? of actors into four layers. What about actors active in more than one of these layers? What about actors which use ICT extensively but for whom it is not their core activity, for example banks? What about the distinction between different sizes of actors or in fact professional versus private ICT users? What about the differences such as size, history, strategy and focus of different actors within a given layer? These and many more questions remain unaddressed by the model as it stands.

In addition, the model only partially identifies the relationships and interactions between different actors. Although Fransman defines the interactions between layers (Fransman, 2010a), calling them ‘symbiotic relationships’, he does not provide any practical advice about how to identify these in a practical case. Furthermore, the model does not enable an examination of individual actors’ specific decisions. The motivations driving their behaviours remains unclear and is even obscured by the strict classification of actors into different layers (Fransman (2002a)).

In addition, the model does not cope well with the dynamics of the closely-linked and wider external environment or the influence of ‘semi-external actors’. To address this weakness, the author proposes to extend the model, to take into account external (or semi-external) stakeholders which are not part of the different layers but nevertheless affect the ecosystem (Binsfeld et al. (2017a)).

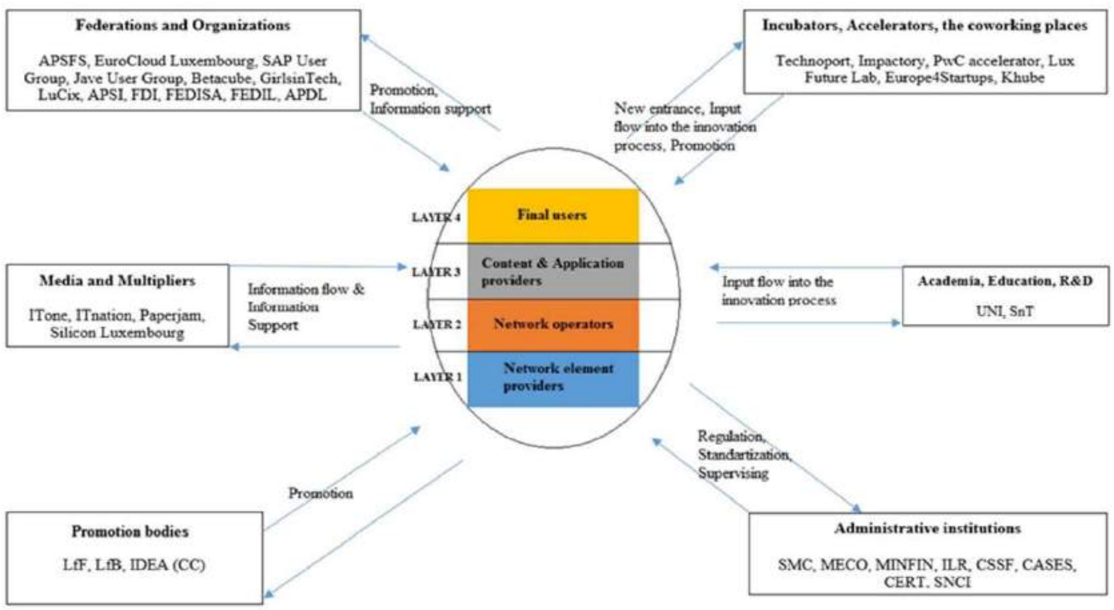

Figure 3 - An extended Fransman model including major external stakeholder groups

In fact, the different interviews have led the researcher to complement the Fransman four-layered model with a stakeholder analysis looking at six external groups of stakeholders as shown in figure 3. These groups were considered by many of the interviewees as being more or less relevant for and having an influence on their business activities. The external stakeholders affecting the ICT ecosystem can be divided into the following groups:

- Government and administrative bodies
- Media and multipliers
- Representation bodies (associations, organizations and users’ platforms)
- Education, R&D and academia
- Business incubators, accelerators
- Promotion agencies

The author identified the different actors within each category and provided a brief description of their activities (Binsfeld et al. (2017a)). In addition, actors have been classified into three groups, based on whether they are active on a purely national, a regional or an international level (Binsfeld et al. (2017a)). Figure 3 depicts the outcome of the analysis, lists the main actors and shows the interrelations between these, as well as the different layers of the ICT ecosystem.

As a result, it is suggested to use the above-mentioned framework to extend the model provided by Fransman, as it gives a more complete picture of the different categories of actors affecting the ICT ecosystem. This model is a generic one, that can also be used to get a better understanding of the forces at stake in different ICT ecosystems, ecosystems more generally as well as different network-based industries or contexts.

5. Conclusions

By building on the discussions of the different research papers above, it is possible to summarise the author's main research contributions. Considering the author's professional situation and the deliberate choice to do a 'professional doctorate of business administration' (Neumann & Goldstein (1969); Sarros, Willis, Fisher, & Storen (2005); Scaringella & Vidal (2011)), contributions have been made both to theory/knowledge and to the author's professional practice.

5.1. Contributions to knowledge

First and foremost, the DBA project has put Luxembourg and its ICT ecosystem on the academic research map. To the best of the author's knowledge, there have been no previous academic studies on the ICT environment in Luxembourg. More generally, there have only been a few studies focusing on the ICT sector of small countries (Schlichter & Danylchenko (2014); Symeou (2009)) or on innovation more generally in small countries (Doyle & O'Connor (2013); Edquist & Hommen (2008); Roolaht (2012); Thorhallsson (2015)). There has been some research done on smaller countries in Asia such as Singapore or Hong Kong (Goh & Pang (2016); Lee & Win (2004); Lin (2013); Vu (2013); Wu & Leung (2009); Yang (2005)). Generally, studies in Europe or on the European Union focus on larger economies such as Germany (Elixmann et al. (2003)), France (Hulsink (1999)) or the UK (Cooper, Jacquet, & Soppera (2011)). During the course of the DBA project, one relevant book about small countries was published which looks specifically at the smaller EU member states (Briguglio (2016)). It also contains a section on Luxembourg's economy (Allegrezza (2016)). Although this is an important contribution, the author's own research, focusing specifically on the ICT ecosystem (Binsfeld et al. (2015)), was not addressed by Allegrezza (2016).

The author has looked into the historical evolution of Luxembourg's telecommunication sector since its liberalisation as part of the EU single market initiative (European Commission (1987); Ungerer (2013)). He provided both a historical case analysis (Binsfeld (2013); Binsfeld et al. (2014)) as well as a discussion about the role of the government in this liberalisation process (Binsfeld et al. (2016a)). In that respect, the Luxembourgish government has chosen a very specific approach, which so far, has been undocumented in academic publications.

Luxembourg is included in many ICT-related international statistics and international league tables, produced for example by the OECD (2015), the European Commission (2015b, 2016), the World Economic Forum ((Baller et al. (2016)), or the International Telecommunications Union (2016). However, very often the underlying statistical data is difficult to interpret due to Luxembourg's small size and the specifics of its economy (Schuller (2013)). To the best of the author's knowledge, up until now no research had focused on Luxembourg's situation or tried to understand how these ratios can be used to better understand the strengths and weaknesses of Luxembourg's ICT ecosystem. Consequently, that has been the focus of the author's research (Binsfeld & Whalley (2016)).

More specifically, the author looked at Luxembourg's position on the Networked Readiness Index (Binsfeld et al. (2017c)) and drew four major lessons (section 4.1.4) from this analysis. The first key point is the importance of infrastructure-based competition for improving a country's NRI position. Significantly, this infrastructure is wider than pure ICT infrastructure and needs to be include roads, railways, airports and the electricity grid. The second point is that ICT skills are at least equally as important as infrastructures. This gives rise to a third lesson, namely, the need to engage with all relevant stakeholders. The final lesson highlights that it is not enough to rely on the development of basic ICT infrastructure and the fostering of competition. The development of complementary infrastructure needed for example to produce sufficient electricity production is also necessary. Perhaps most importantly, efforts are required on a social level in terms of establishing a future-orientated education system and aligning its priorities, which promotes ICT usage and develops the population's e-skills.

Additionally, the analysis has also shown how publicly available secondary information might be used to understand and assess underlying policy decisions and how this information can help to set the scene for further, more in-depth investigations. In fact, the author has provided an illustration of how a widely available index, such as the NRI, can be used to come to potentially valuable conclusions for policy makers and politicians.

Focusing on the forces that govern the ICT ecosystem, the author has provided a practical application of Fransman's ICT ecosystem model (Binsfeld et al. (2015, 2017a, 2017b)) and as a result, he was able to design a conceptual framework which maps the different forces (see figure 2). This model could serve as a generic tool to analyse the ICT ecosystems of other countries or economic regions.

Whilst Fransman's model is well known and he has received a lot of credit for it, it is not often applied as it has some major limitations. These limitations were identified and discussed in relation to Luxembourg's situation (Binsfeld et al., 2017a). An extension to the model was suggested (see figure 3), which includes six different 'semi-external' stakeholder groups. This model can serve as an illustration of how the Fransman model can be extended to allow for a better understanding of the forces at stake. It could also be reproduced for other network ecosystems.

Using this extended model, the author has also come up with a more complete list of stakeholders, which did not previously exist for Luxembourg's ICT ecosystem. He also has provided a detailed list of their different activities.

While working on this model (figure 3), the author also produced a high-level SWOT analysis of the ICT ecosystem in Luxembourg. This analysis, shown in table 9, has since been referred to and reproduced in different studies on Luxembourg's digital economy (Ant et al. (2016); Cottong (2016); The TIR Consulting Group (2016)).

In the latter part of the project, the author focused on the level of professional e-skills in Luxembourg. He identified the existence of a second level digital divide (Binsfeld et al. (2016b)) in that respect. Again, no previous academic work on this topic could be identified in the context of Luxembourg.

During the research process, the author conducted over 70 in-depth interviews with relevant stakeholders from within the ICT ecosystem. All this material was translated (if necessary) and transcribed. The transcriptions can be made available (including the audio recordings) electronically for further exploitation and additional research using Luxembourg as a case study.

5.2. Contributions to practice

As part of the above-mentioned analysis of international indices and league tables, the author was asked to contribute as co-author to a summary document 'Luxembourg and ICT – a snapshot'. Published in 2013 the survey presented for the first time a general overview of the different statistical data available from different sources (Luxembourg for Business (2013a)).

Similarly, the author was asked to contribute to a comprehensive study about the professional e-skills situation in Luxembourg (Ant et al. (2016)) and the setting-up of a specific ICT centre of competence[40] of which the author became the initial Vice-Chairman. In his professional role as CEO of the House of Training, the author also contributed to the development of a portfolio of over 70 e-skills related vocational training courses[41].

In 2015, 2016 and 2017, the author attended several professional conferences as both speaker and panellist. Furthermore, the author was invited to participate in different e-skills and training related working groups in the context of the two governmental programmes mentioned in section 3[42].

The research and writing process change the author's mind-set and understanding of the world around him. Working on the DBA project allowed him to re-orientate his professional career and his understanding of the ICT ecosystem changed from a purely technical one to wider one, which takes into account social, economic, regulator and important political aspects. It also led to several additional jobs such as lecturer at different universities at Luxembourg[43] and France[44]. It eventually led to the author being in charge, as project coordinator, of an initiative by the Ministry of Labour and the Ministry of Economy which helps companies in Luxembourg to better prepare for the challenges and opportunities of the digital transformation[45].

5.3. Recommendations for the future development of the ICT ecosystem

Building on the main research outcomes above and more particularly the SWOT analysis, the author has identified a set of recommendations that might help contribute to the future development of the ICT ecosystem in Luxembourg. These recommendations are presented briefly in this section in no specific order.

A stable and constantly up-to-date, innovative and secure ICT infrastructure is needed, as the ICT ecosystem is built on that foundation. The past high level of investment in ICT infrastructure to boost the so-called Internet highways, needs to be continued and even expanded, by both public and private partners. In order to make the most of these investments, it is essential to increase the number of initiatives that aim at delivering products or services, that create economic added value and that do not simply focus on infrastructural elements. The support measures already in place for the industrial players in the ICT sector need to be developed further through additional public initiatives with increased activity scope and to develop new solutions, products and applications to maintain their market position.

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[40] See www.lidit.eu accessed 28.4.2018
[41] See https://www.houseoftraining.lu/search?search_term=ICT accessed 4th January 2017.
[42] See http://www.digital-luxembourg.public.lu/fr/index.html accessed 4th January 2017 and http://portal.education.lu/digital4education/ accessed 4th January 2017.
[43] See www.isec.lu accessed 18.3.2018.
[44] See http://www.assas.org/enseignants accessed 18.3.2018.
[45] See www.skillsbridge.lu accessed 28.7.2018

It will also be necessary to continue developing a highly efficient, innovative and creative ICT-related ecosystem (education, research, financing, support systems, regulations, …), that encompasses a large series of measures, programmes and projects. These are needed to finance and implement all relevant strategies in a coordinated, systematic and professional way. While the government's ICT policy[46] is slowly showing results (Antzorn (2014); Bettel (2014); Gaudron (2014)), it will be necessary to invest more into a precise, coordinated and coherent long-term vision to develop the ICT sector, on both a national and regional level. To achieve new goals and to change the country into a fully-digital society, Luxembourg with its government, its ICT industry and its other industry sectors and in conjunction with all the stakeholders, needs to establish and implement a coherently elaborated and well thought-through ICT strategy. This is a challenge should be a priority of public and private ICT actors and should guide their daily business behaviours.

In Luxembourg, as in Europe in general, the quantity and quality of ICT specialists is insufficient. The demand for ICT professionals continues to vastly exceed the supply (European Schoolnet (2015)). Luxembourg's school system cannot currently be considered a dynamic driver in terms of ICT. Not only is the number of students in ICT-related branches too low by far, but the Luxembourgish school system is also not able to integrate a digital agenda and to expand its curricula to the realm of ICT. Even though first attempts to introduce ICT into school curricula go back as far as 1986, ICT is not yet used as a pedagogical instrument generally, but only as a means for information presentation and exchange. As the author's research has illustrated, it is not enough to create highly specialised research centres to promote ICT learning and teaching more widely (De Fooz, 2014a). In order to close the ICT professionals gap, primary, secondary and tertiary education and even quaternary training or lifelong learning need to take on prominent roles in talent development. The objective should be to develop high levels of digital literacy in all companies and for everyone in Luxembourg.

Fortunately, this issue has been acknowledged by the different stakeholders involved (policy makers, schools, VET providers, ICT companies. However, the different stakeholders within the ICT ecosystem are not yet able to define common goals, policies, initiatives or activities that enhance the development of the country as an ICT hub. Many uncoordinated initiatives have been mentioned in the different interviews and often actors not involved in them were unaware of them. For a small country, which is competing not only on a European, but on an international level, it is essential that all actors collaborate and are able and willing to define common strategies, instead of letting personal interests and individual preferences prevail. In short, the interviews showed that there are too many institutions and too many different interests– but not enough common ground. In addition, many of the recent initiatives, in particular by the public education system, still focus on infrastructure or equipment rather than on competences and skills (Gouvernement du Luxembourg (2015)).

Over the past years, Luxembourg has replaced its dependency on the steel sector, with a dependency on the financial sector. Thus, the country risks finding itself in a similar situation in relation to ICT, becoming high dependent on it economically. In any case, all economic development in one sector needs to be counter-balanced by increased economic diversification into promising areas. The country needs further development in terms of industries, products, services and professions that are highly effective, innovative and that are having wider benefits. This dynamic change is needed in order to remain competitive, strengthen resilience and reduce vulnerabilities.

Like other small or very small countries (Edquist & Hommen, 2008), Luxembourg , because of its inherent vulnerabilities, must keep very alert to international developments in order to seize new

[46] See continuous updates on http://www.digital-luxembourg.public.lu/en/ accessed 23.12.2017

opportunities and to maintain the diversity, competences and creativity of its multinational workforce. However, while doing so, Luxembourg also needs to take care to foster social cohesion, through the construction of a shared national 'identity' (Fondation Idea (2014)). A feeling of 'we-ness' (Hostert (2014)) is crucial to maintain the country's high quality of life.

5.4. Avenues for future research

The ICT ecosystem is evolving extremely quickly and since this DBA project started in 2012, major technological changes have occurred. Many of these have only been partially addressed in the work described above. Topics such as cloud and high-performance computing, smart home, smart cities, industry 4.0, cybersecurity and 'fintech' (Baller et al. (2016)) have all gained in importance and Luxembourg has started several new initiatives to address these developments recently. In addition, major political and economic changes have occurred for example Brexit. These changes call for further research and warrant academic attention. As a result, it would be appropriate and necessary to update the current work on a regular basis (every two to three years).

Inter-platform competition between fixed and mobile networks, between 3G, 4G, 5G and WIFI, between fibre optical and CATV technologies, or satellite communications are areas for potential further research as well.

In terms of the conceptual frameworks that were developed, it would be interesting to explore their validity in different settings, economical or geographical contexts further. Fransman's model, given the limitations mentioned, needs to be examined in more detail, to develop a better understanding of the 'symbiotic' relationships and their dynamic nature. It woud also be interesting to compare and contrast this model with Porter's five forces model (Karagiannopoulos et al. (2005)) for example.

With the help of a prominent consultant, Luxembourg has recently embarked on a study about the so-called 'third industrial revolution' (Moyse (2016); The TIR Consulting Group (2016)). In this context, ICT was mentioned as a major enabler and further work is needed to better understand how the ICT ecosystem can help (or otherwise) to turn into reality some of the many ideas put forward in this study.

Finally, further work can be undertaken not just on the content and scope of ICT training but also on the way these trainings are delivered. Teaching methods need to take full advantage of the opportunities offered by digital learning in all its different shapes and sizes.

The main objective of this study has been to put Luxembourg on the research map. It is hoped that it raises the interest of other researchers who will embark on examining the above mentioned, non-exhaustive list of potential research areas. This study has looked at the ICT and telecommunications markets. However, it might also be useful to conduct a similar analysis of other sectors in which the Luxembourgish state plays a major role, such as satellite communications, electricity, gas and water distribution and transportation (road, air, water).

6. References

Akamai. (2013). *The State of the Internet 2013* (Vol. 6).

Allegrezza, S. (2016). The economy of Luxembourg. In L. Briguglio (Ed.), *Small States and the European Union* (1st ed., pp. 134–152). Routledge.

Anderson, C. (2010). Presenting and evaluating qualitative research. *American Journal of Pharmaceutical Education*, *74*(8), 141. Retrieved from http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=2987281&tool=pmcentrez&rendertype=abstract

Anggraeni, E., Hartigh, E. Den, & Zegveld, M. (2007). Business ecosystem as a perspective for studying the relations between firms and their business networks. *Eccon 2007*, (January 2016), 1–28. Retrieved from http://www.academia.edu/download/31071215/bes.pdf.

Ant, M. (2015). *A competence Centre for ICT in Luxembourg*. Hochschule Bonn-Rhein-Sieg.

Ant, M., Goetzinger, P., & Binsfeld, N. (2016). *E-Skills Study - Strategies for the creation of a virtual e-skills training centre in Luxembourg*. Luxembourg.

Antzorn, F. (2014, June 4). Feu vert pour la stratégie ICT et Digital Lëtzebuerg. *Paperjam*. Luxembourg.

Arlandis, A., & Ciriani, S. (2010). How Firms Interact and Perform in the ICT Ecosystem? *Communications & Strategies*, *79*(3), 121–141.

Baller, S., Dutta, S., & Lanvin, B. (2016). *The Global Information Technology Report 2016 - Innovating in the Digital Economy*. Geneva. Retrieved from http://www3.weforum.org/docs/GITR2016/WEF_GITR_Full_Report.pdf.

Barrios, S., Mas, M., Navajas, E., Quesada, J., Navjas, E., & Quesada, J. (2008). *Mapping the ICT in EU regions: Location, Employement, Factors of Attractiveness and Economic Impact*. Luxembourg.

Bashir, S., Matzat, U., & Sadowski, B. M. (2014). The Adoption of Information and Communication Technologies in the Design Sector and their impact on Firm Performance : Evidence from the Dutch Design Sector Eindhoven Centre for Innovation Studies (ECIS), School of Innovation Sciences , Eindhoven Univer. In *International Telecommunications Society Regional Conference* (pp. 1–34). Brussels.

Bashir, S., & Sadowski, B. M. (2014). General Purpose Technologies: A survey, a critique and future research directions. In *International Telecommunications Society Regional Conference* (pp. 1–38). Brussels.

Basole, R. C., Park, H., & Barnett, B. C. (2015). Coopetition and convergence in the ICT ecosystem. *Telecommunications Policy*, *39*(7), 537–552.

Basu, S., & Fernald, J. G. (2008). Information and communications technology as a general purpose technology: evidence from U.S. industry data. *Economic Review*, *8*(2), 1–15.

Battistella, C., Colucci, K., De Toni, A. F., & Nonino, F. (2013). Methodology of business ecosystems network analysis: A case study in Telecom Italia Future Centre. *Technological Forecasting and Social Change*, *80*(6), 1194–1210.

Bazeley, P., & Jackson, K. (2007). *Qualitative Data Analysis with NVivo*. *Sage Publications* (Vol. 2nd). Retrieved from http://www.loc.gov/catdir/enhancements/fy0728/2006936346-d.html.

Beekhuyzen, J. (2010). The Nvivo Looking Glass: Seeing the Data Through the Analysis. *Qualitative*

Research, 1–12.

Bettel, X. (2014, October 20). Xavier Bettel présente l ' initiative " Digital Lëtzebuerg ". *Gouvernement Du Luxembourg*. Luxembourg.

Bilboa-Osoria, B., Dutta, S., & Lanvin, B. (2014). *The Global Information Technology Report 2014 Rewards and Risks of Big Data*. Geneva.

Binsfeld, N. (2013). The Luxembourgish Telecommunications Market. *Cahier Scientifque Revue Technique Luxembourgeoise*, *1*, 24–37. Retrieved from www.revue-technique.lu.

Binsfeld, N., Pugalis, L., & Whalley, J. (2015). ICT ecosystems in small countries: An analysis of Luxembourg. In *26th European Regional Conference of the International Telecommunicatons Society (ITS), Madrid, 24-26 June 2015*. Madrid: www.econstor.eu. Retrieved from http://www.econstor.eu/dspace/handle/10419/127127.

Binsfeld, N., & Whalley, J. (2016). Measuring Luxembourg's State of ICT Development. *Cahier Scientifque Revue Technique Luxembourgeoise*, *2016*(1), 30–47.

Binsfeld, N., Whalley, J., & Pugalis, L. (2014). Luxembourg a bastion of state ownership. In *25th European Regional Conference of the International Telecommunicatons Society (ITS), Brussels, 22-25 June 2014*. Brussels: Econstor.

Binsfeld, N., Whalley, J., & Pugalis, L. (2016a). Competing against yourself: State duopoly in the Luxembourg telecommunications industry. *Telecommunications Policy*, *40*(8), 791–803.

Binsfeld, N., Whalley, J., & Pugalis, L. (2016b). Competing through e-skills: Luxembourg and its second level digital divide. In *27th European Regional International Telecommunications Society Conference - Cambridge*. Cambridge: Econstor.

Binsfeld, N., Whalley, J., & Pugalis, L. (2017a). An analysis of the structure, actors and interrelationships producing Luxembourg's ICT ecosystem. In *28th European Regional International Telecommunications Society Conference - Passau* (pp. 1–32). Passau.

Binsfeld, N., Whalley, J., & Pugalis, L. (2017b). Looking beyond official success measures : Tales from the field of the complex forces shaping Luxembourg's ICT ecosystem. *Journal of Innovation Management*, *5*(2), 15–25. Retrieved from http://www.open-jim.org/article/view/254.

Binsfeld, N., Whalley, J., & Pugalis, L. (2017c). Playing the game: Explaining how Luxembourg has responded to the Networked Readiness Index. *Digital Policy, Regulation and Governance*, *19*(4), DPRG-02-2017-0008.

Bodson, L., & Frising, A. (2015). *Les TIC dans les ménages et chez les particuliers en 2014*. Luxembourg.

Booz&Co. (2013). *2013 Telecommunications Industry Perspective*. Retrieved from http://www.booz.com/media/uploads/BoozCo_2013-Telecommunications-Industry-Perspective.pdf.

Bourgain, A., Pieretti, P., & Høj, J. (2009). *Can the Financial Sector continue to be the Main Growth Engine in Luxembourg ?* (No. 660). Paris. Retrieved from www.oecd.org.

Bouron, T. (2008). Methodological analysis of ICT value in service industry. *Journal of Harbin Institute of Technology New Series*, *15*, 274–279.

Briglauer, W. (2004). Generic reference model for the analysis of relevant communications markets: Fundamental competition concepts. *Info*, *6*(2), 93–104.

Briguglio, L. (2016). *Small States and the European Union: Economic Perspectives*. *Snall States and the European Union: Economic Perspectives*. London: Routledge.

Bringer, J. D., Johnston, L. H., & Brackenridge, C. H. (2004). Maximizing Transparency in a Doctoral Thesis: The Complexities of Writing About the Use of QSR*NVIVO Within a Grounded Theory Study. *Qualitative Research*, *4*(2), 247–265.

Bughin, J., Hazan, E., Labaye, E., Manyika, J., Dahlström, P., Ramaswamy, S., & Conchin de Billy, C. (2016). *Digital Europe : Pushing the Frontier , Capturing the Benefits*.

Cencetti, J. (2014a, June 5). Nei Digital Lëtzebuerg. *IT Nation*. Luxembourg.

Cencetti, J. (2014b, September 24). Pour une meilleure coopération FNR et Luxinnovation. *IT Nation*. Luxembourg.

Cencetti, J. (2015a, February 17). APSI day n°1 « FinTech: Financial institutions, Technologies & Start-ups. *IT Nation*. Luxembourg.

Cencetti, J. (2015b, March 11). La fin du roaming repoussée à 2018. *IT Nation*. Luxembourg.

Cencetti, J., & Le quotidien. (2014, July 3). Datacenter Luxembourg fait peau neuve. *Le Quotidien*, p. 6. Luxembourg.

Chrillesen, N. (2013, December 3). Pisa : le Luxembourg reste sous la moyenne. *Paperjam*.

Cisco & Saïd Busines School. (2010). *Broadband quality score 2010*.

Commission, E. (1998). *Fourth Report on the Implementation of the Telecommunications Package*. Brussels.

Cooper, A., Jacquet, A., & Soppera, A. (2011). Bandwidth Usage and Management : A UK Case Study. In *Telecommunications Policy Research Conference Washington, D.C.* (pp. 1–22).

Cottong, S. (2016). *Digital Transformation of Business and Society*. Luxembourg. Retrieved from http://www.cc.lu/uploads/tx_userccpublications/Digital_Transformation_in_Business_and_Society_final_26102016.pdf.

Couset, I. (2016, January). House of Training La maison de la formation continue du patronat. *Entreprises Magazine*. Luxembourg.

Cronin, P., Ryan, F., & Coughlan, M. (2008). Undertaking a literature review: a step-by-step approach. *British Journal of Nursing (Mark Allen Publishing)*, *17*(1), 38–43. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/18399395.

Crowley, C., Harré, R., & Tagg, C. (2002). Qualitative research and computing: methodological issues and practices in using QSR NVivo and NUD*IST. *International Journal of Social Research Methodology*, *5*(3), 193–197.

De Fooz, A. (2014a, September 8). le SnT accueille le Prof. Paulo Verissimo. *Soluxions*. Luxembourg.

De Fooz, A. (2014b, October 21). Digital Lëtzbuerg, en avant! *Soluxions*. Luxembourg.

De Fooz, A. (2014c, November 19). Xavier Bettel veut faire de Luxembourg une “smart nation.” *Soluxions*. Luxembourg.

Dedrick, J., Kraemer, K. L., & Linden, G. (2011). The distribution of value in the mobile phone supply chain. *Telecommunications Policy*, *35*(6), 505–521.

Deloitte. (2013). *Professionals of the financial sector (PSF) in Luxembourg Overview and outlook of a resilient sector*. Luxembourg. Retrieved from http://www.deloitte.com/view/en_LU/lu/library/publications-whitepapers/industries/psf/index.htm#.UpWtruKeHJO.

Deloitte SnT Bourse. (2015). *FinTech Industry Talent&Research*. Luxembourg.

Denscombe, M. (2010). *The Good Reseach Guide*. (O. U. Press, Ed.) (4th ed.). Maidenhead: MacGraw Gill Education.

Di Gregorio, S. (2000). Using NVIVO for your literature review. *Analysis*, (September), 1–12. Retrieved from http://www.sdgassociates.com/training.html#literature

Dobbs, M. E. (2014). Guidelines for applying Porter's five forces framework: A set of industry analysis templates. *Competitiveness Review*, *24*, 32–45.

Doyle, E., & O'Connor, F. (2013). Innovation capacities in advanced economies: Relative performance of small open economies. *Research in International Business and Finance*, *27*(1), 106–123.

Ducat, A. (2014, July 3). Stratégie et gouvernance pour la recherche. *Paperjam*. Luxembourg.

Ducat, A. (2015, July 30). Fintech : le « handicap sérieux » des compétences. *Paperjam*. Luxembourg.

Easterby-Smith, M., Thorpe, R., & Jackson, P. (2012). *Management Research* (4th ed.). London, UK: Sage Publications.

Edquist, C., & Hommen, L. (2008). *Small Country innovation Systems: Globalization, Change and Policy in Asia and Europe*. (C. Edquist & L. Hommen, Eds.) *Small Country Innovation Systems* (Edward Elg.). Cheltenham, UK.

EIU. (2010). *Digital economy rankings 2010 Beyond e-readiness*. Retrieved from http://www.eiu.com/site_info.asp?info_name=digitaleconomy_2010.

Elixmann, D., Schwab, R., & Stappen, C. (2003). Development of the telecommunications market in Germany since liberalisation. *Info*, *5*(1), 41–51.

Enovos Luxembourg. (2014, March 20). Gaz et électricité au plancher. *Paperjam*, p. 1.

European Commission. (1987). *Towards a dynamic European Economy Green Paper on the Development of the Common Market for Telecommunications Services and Equipment*. Brussels. Retrieved from http://ec.europa.eu/green-papers/pdf/green_paper_telecom_services__common_market_com_87_290.pdf.

European Commission. (2005). *Key Indicators of the competitiveness of the EU's ICT industry*.

European Commission. (2014). *Digital Agenda Scoreboard 2014 – Digital Performance of Luxembourg*. Brussels.

European Commission. (2015a). *Digital Agenda Scoreboard 2015: Luxembourg*. Brussels.

European Commission. (2015b). *Digital Economy and Society Index 2015 Country Profile Luxemburg*. Brussels.

European Commission. (2016). *Digital Economy and Society Index 2016 Country Profile Luxemburg*. Brussels.

European Committee for Standardization (CEN). (2014). *European e-Competence Framework 3.0: A common European framework for ICT Professionals in all industry sectors*. Brussels. Retrieved from http://ecompetences.eu/wp-content/uploads/2014/02/European-e-Competence-Framework-3.0_CEN_CWA_16234-1_2014.pdf.

European Schoolnet. (2015). *THE e-SKILLS Manifesto* (2015th ed.). Brussels: European Schoolnet.

Evens, T., Schuurman, D., De Marez, L., & Verleye, G. (2010). Forecasting broadband Internet adoption on trains in Belgium. *Telematics and Informatics*, *27*(1), 10–20.

Fedil, ABBL, & CLC. (2016). *Les TIC - ton job d'avenir - édition 2016*. Luxembourg. Retrieved from http://www.tic-tonjobdavenir.lu/brochure/.

Fleetwood, S. (2012). Organization Ontology in Organization and Management Studies : A Critical Realist Perspective. *Organization*, *12*(2), 197–222.

FNR. (2014, September 19). The National Research Fund and Luxinnovation strengthen their cooperation for the development of research and innovation. *Fonds National de La Recherche*. Luxembourg.

Fondation Idea. (2014, July 2). "Nation Branding" - nouveau positionnement du Luxembourg. *Idée Du Mois 3*, pp. 1–16. Luxembourg.

Fransman, M. (2001). Evolution of the Telecommunications Industry into the Internet Age. *Communications & Strategies*, (43), 57–113.

Fransman, M. (2002a). Mapping the evolving telecoms industry: the uses and shortcomings of the layer model. *Telecommunications Policy*, *26*(9–10), 473–483.

Fransman, M. (2002b). *Telecoms and the internet age - from Boom to Bust to...* (1st ed.). Oxford: Oxford University Press.

Fransman, M. (2004). The telecoms boom and bust 1996-2003 and the role of financial markets. *Journal of Evolutionary Economics*, *14*(4), 369–406.

Fransman, M. (2006). *Global Broadband Battles*. (M. Fransman, Ed.) (1st ed.). Stanford: Stanford University Press.

Fransman, M. (2007). Innovation in the New ICT Ecosystem. *International Journal of Digital Economics*, (68).

Fransman, M. (2010a). The New ICT Ecosystem. *The New ICT Ecosystem: Implications for Policy and Relation*, (68).

Fransman, M. (2010b). *The New ICT Ecosystem - Implications for Policy and Regulation* (New and re.). Cambridge: Cambridge University Press. Retrieved from www.cambridge.org/9780521171205.

Fransman, M. (2011). The evolving ICT industry in Asia and the implications for Europe. *JRC Technical Notes*, *63986*, 78. Retrieved from http://ipts.jrc.ec.europa.eu/.

Fransman, M. (2014). *Models of Innovation in Global ICT Firms : The Emerging Global Innovation Ecosystems* (No. EUR 26774 EN). (M. Bodganowicz, Ed.). Luxembourg: European Commission.

Garcia, A. S., & Vicente, M. R. (2012). *ICT Technologies in Europe : A Study of Technological Diffusion and Economic Growth under Network Theory* (No. WP-AD 2012.21).

Gargano, L. (2012). *L'essor du sector tertiaire au Luxembourg*. Luxembourg.

Gaudron, J.-M. (2013, October 9). Luxconnect grandit encore. *Paperjam*. Luxembourg. Retrieved from www.paperjam.lu

Gaudron, J.-M. (2014, October 20). Digital Lëtzbuerg avance ses pions. *Paperjam*. Luxembourg.

Gaudron, J.-M. (2015, February 8). Telecom Luxembourg s'offre un bout de Luxconnect. *Paperjam*. Luxembourg.

Goh, D., & Pang, N. (2016). Protesting the Singapore government: The role of collective action frames in social media mobilization. *Telematics and Informatics*, *33*(2), 525–533.

Gouvernement du Luxembourg. (2013, October 10). Inauguration de LuxFold, société de biotechnologie, première start-up financée par le fonds Advent Life Science. *Press Release*. Luxembourg.

Gouvernement du Luxembourg. (2015). Digital4Education. Luxemboug.

Gouvernment du Luxembourg. (2014a, April 27). Le FNR, un acteur central et reconnu dans le système de la recherche Luxembourgeoise. *Gouvernement Du Luxembourg*. Luxembourg.

Gouvernment du Luxembourg. (2014b, June 5). Lancement de la stratégie " Digital Lëtzebuerg " par le Conseil de gouvernement des 3 et 4 juin 2014. *Gouvernement Du Luxembourg*. Luxembourg.

Greener, S. (2008). *Business Research Methods*. Retrieved from BookBooN.com.

Haag, E. (2015). *The Rise of Luxembourg from Independence to Success* (Editions S.). Luxemboug.

Hagemann, H. (2008). Consequences of the new information and communication technologies for growth, productivity and employment. *Competitiveness Review: An International Business Journal Incorporating Journal of Global Competitiveness*, *18*(1/2), 57–69.

Hallikas, J., Varis, J., Sissonen, H., & Virolainen, V. M. (2008). The evolution of the network structure in the ICT sector. *International Journal of Production Economics*, *115*, 296–304.

Henry, R. (2013, October 8). Luxembourg dans le top mondial de UIT. *IT Nation*. Luxembourg. Retrieved from www.itnation.lu.

Hostert, M. (2014, April 30). RTL.lu - Carte-Blanchen - Nation Branding: Mir wëlle bleiwen, wat mir sinn. *RTL*, pp. 1–2. Luxembourg.

Hulsink, W. (1999). *Privatisation and Liberalisation in Europe Telecommunications: Comparing Britain, the Netherlands and France*. Oxford: Routledge.

Hutchison, A. J., Johnston, L. H., & Breckon, J. D. (2010). Using QSR-NVivo to facilitate the development of a grounded theory project: an account of a worked example. *International Journal of Social Research Methodology*, *13*(4), 283–302.

Institut Luxembourgeois de Régulation. (2015). *Rapport statistique des télécommunications du Luxembourg de l'année 2014*. Luxemboug. Retrieved from http://www.ilr.public.lu/communications_electroniques/statistiques/rapp_statistiques_ILR/rapport-statistique-telecom-2014.pdf.

International Telecommunication Union. (2016). *Measuring the Information Society Report 2016*. Geneva.

IT One. (2014, April 18). Le Luxembourg 15ème de l'indice KOF. *IT One*. Luxembourg.

ITU. (2013). *Measuring the Information Society 2007 - ICT Opportunity Index and average annual growth 2001-2005*.

Johnston, L. (2006). Software and Method: Reflections on Teaching and Using QSR NVivo in Doctoral Research. *International Journal of Social Research Methodology*, *9*(5), 379–391.

Karagiannopoulos, G. D., Georgopoulos, N., & Nikolopoulos, K. (2005). Fathoming Porter's five forces model in the internet era. *Info*, *7*(6), 66–76.

Kim, H., Lee, J.-N., & Han, J. (2010). The role of IT in business ecosystems. *Communications of the ACM*, *53*(5), 151.

King, N. (1998). Template analysis. In *Qualitative methods and analysis in organizational research A practical guide* (pp. 118–134).

Koslowski, T. G., Longstaff, P. H., Vidal, M., & Grob, T. (2012). Resilience Analysis of the ICT Ecosystem. In *23rd European Regional International Telecommunication Society conference; Vienna* (pp. 1–18).

KPMG. (2012a). *Luxembourg Business Compass October 2012*. Luxembourg. Retrieved from http://www.kpmg.com/LU/en/topics/LuxembourgBusinessCompass/Documents/Full-Allensbach-Report.pdf.

KPMG. (2012b). *Luxembourg Platform for Business*. Luxembourg.

KPMG. (2014). *The Fintech Landscape in Luxembourg*. Luxembourg.

KPMG & Luxemburger Wort. (2017). *Luxembourg Banking Insights 2017*. Luxembourg. Retrieved from https://home.kpmg.com/content/dam/kpmg/lu/pdf/lu-en-banking-insights-2017.pdf.

Krylova, S. (2015). *The ICT inventory in Luxembourg*. Université du Luxembourg.

Kuhn, T. S. (2012). *The structure of scientifc revolutions* (4th ed.). Chicaga: University of Chicago Press.

Labro, T. (2015, January 14). FinTech révolution très rapide. *Wort*, p. 14. Luxembourg.

Land. (2014, June 6). Digital Letzebuerg. *Land*, p. 9. Luxembourg.

Lee, J., & Win, H. N. (2004). Technology transfer between university research centers and industry in Singapore. *Technovation*, *24*(5), 433–442.

Li, F., & Whalley, J. (2002). Deconstruction Of The Telecommunications Industry : From Value Chains to Value Networks. *Telecommunications Policy*, *44*(9–10), 451–472.

Lin, T. T. C. (2013). Convergence and regulation of multi-screen television: The Singapore experience. *Telecommunications Policy*, *37*(8), 673–685.

Lounge, B. V., Technoport, L., Caratini, C., Partners, T., Schneider, D., Luchetta, P., & Biomedicine, S. (2014, May 1). Les start-up biotech se font valoir au Grand-Duché. *Paperjam*. Luxembourg.

Luxembourg for Business. (2013a). *Luxembourg & ICT: A snapshot*. Luxembourg.

Luxembourg for Business. (2013b). *LUXEMBOURG and ICT : a snapshot*. Luxembourg. Retrieved from http://ict.investinluxembourg.lu/ict/luxembourg-and-ict-a-snapshot.

Luxembourg for Finance. (2015). *FinTech in Luxembourg. Luxembourg for Finance Magazine*. Luxembourg.

Luxemburger Wort. (2015, January 31). EU Kommission Gebühren fur Roaming sollen fallen. *Wort*. Luxembourg.

Maitland, C. F., Bauer, J. M., & Westerveld, R. (2002). The European market for mobile data: evolving value chains and industry structures. *Telecommunications Policy*, *26*(9–10), 485–504.

Merker, J. (2013). A sectoral presentation of the Luxembourg economy The ICT , logistics and bio health sectors Where are we heading ? In *Exploring the social. political and business environment of Luxembourg*. Luxembourg: AMCHAM, Luxembourg School of Commerce.

Moore, J. F. (1993). Predators and Prey: A New Ecology of Competition. *Havard Business Review*, *May-June*, 75–86.

Moore, J. F. (2006). Business ecosystems and the view from the firm. *The Antirust Bulletin*, *51*(1).

Moyse, L. (2016, November 15). Le plan Rifkin est lancé. *Paperjam*. Luxembourg.

Neill, M. O. (2013). *The NVivo Toolkit*. Retrieved from http://explore.qsrinternational.com/nvivo-toolkit.

Neumann, R., & Goldstein, M. (1969). Issues in the Ongoing Development of Professional Doctorates : The DBA Example.

OECD. (2011a). *OECD Communications Outlook 2011*. Paris: OECD Publishing.

OECD. (2011b). *OECD Guide to Measuring the Information Society 2011*. OECD Publishing.

OECD. (2012a). *OECD Economic Surveys: Luxembourg 2012*. Paris, Paris: OECD Publishing.

OECD. (2012b). *OECD Internet Economy Outlook 2012*. OECD Publishing.

OECD. (2013). *Communications Outlook 2013*. OECD Publishing.

OECD. (2015a). *OECD Digital Economy Outlook 2015*. Paris: OECD Publishing.

OECD. (2015b). *OECD Economic Surveys: Luxembourg 2015*. OECD Publishing, Paris.

OECD. (2015c). *OECD Reviews of Innovation Policy Luxembourg 2015*. Paris.

Oestreicher, K., Walton, N., & Grove, H. (2012). *New Internet-Based Technology Ecosystems*. Worcester.

Paperjam. (2014, May 27). Diversification : le grand défi. *Paperjam*. Luxembourg.

Partanen, J., & Möller, K. (2011). How to build a strategic network: A practitioner-oriented process model for the ICT sector. *Industrial Marketing Management*, *In Press,* 1–14.

Peppard, J., & Rylander, A. (2006). From Value Chain to Value Network : Insights for Mobile Operators. *European Management Journal*, *24*(2).

Porter, M. (1979). How Competitive Forces Shape Strategy. *Harvard Business Review*, 137–145.

Poujol, V. (2014, November 28). Luxconnect soigne ses statuts. *Paperjam*. Luxembourg.

Probst, L., Pedersen, B., Lonkeu, O.-K., Martinez-Diaz, C., Araujo, L. N., Klitou, D., … Rasmussen, M. (2017). *Digital Transformation Scoreboard 2017: Evidence of positive outcomes and current opportunities for EU businesses*. Brussels.

PWC. (2011). *Luxembourg: an e-hub for Europe Opportunities and actions on the horizon 2015*. Luxembourg. Retrieved from http://www.pwc.lu/en/information-communication-technology/publications.jhtml.

Quatraro, F. (2009). Martin Fransman: the new ICT ecosystem. Implications for Europe. *Journal of Evolutionary Economics*, *20*(2), 321–328.

Rafique, K., Yuan, C., Tareen, A. W., Saeed, M., & Hafeez, A. (2012). Emerging ICT Ecosystem - from Value Chain to Value Ecosystem. In *8th International Conference on Computing Technology and Information Management (ICCM),* (pp. 95–100).

Rey-Moreno, C., Blignaut, R., May, J., & Tucker, W. D. (2016). An in-depth study of the ICT ecosystem in a South African rural community: unveiling expenditure and communication patterns. *Information Technology for Development*, *1102*(April 2017), 1–20.

Richards, L. (1999). Data Alive! The Thinking Behind Nvivo. *Qualitative Health Research*, *9*(3), 412–428.

Roolaht, T. (2012). Innovation Systems in Small Catching-Up Economies. In *Innovation Systems in Small Catching-up Economies: New Perspectives on Partice and Policy* (pp. 21–38). New York: Springer.

Sardegna, C., Ict, T., & Nachira, F. (2006). Digital Business Ecosystems Transition towards the knowledge-economy SMEs : a weakness or a potential for Europe ? SMEs in a Dynamic knowledge-based globally-networked economy • How to reach the critical mass of resources ?, 1–9.hei feelen saachen

Sarros, J. C., Willis, R. J., Fisher, R., & Storen, A. (2005). DBA Examination Procedures and Protocols. *Journal of Higher Education Policy and Management*, *27*(2), 151–172.

Scaringella, L., & Vidal, D. (2011). The Satisfaction of DBA Graduates : A Matter of Return on Investment and Promotion. *Business Leadership Review*, (September), 1–11.

Schlichter, B. R., & Danylchenko, L. (2014). Measuring ICT usage quality for information society building. *Government Information Quarterly*, *31*(1), 170–184.

Schneider, E. (2012). Top 10 : Luxembourg ICT assets. *Eurocloud Congress 2012*. Luxembourg: Eurocloud. Retrieved from http://www.itone.lu/index.php?option=com_content&task=view&id=7196&Itemid=80.

Schuller, G. (2013). *Paradoxes in Economic Analysis* (No. 69). Retrieved from http://www.statistiques.public.lu/catalogue-publications/economie-statistiques/2013/69-2013.pdf.

Schultze, U., & Avital, M. (2011). Designing interviews to generate rich data for information systems research. *Information and Organization*, *21*(1), 1–16.

Service Information et Presse. (2006). *About Political institutions in Luxembourg*. Luxembourg.

Silverman, D. (2013). *Doing qualitative research* (4th ed.). London: Sage Publications.

Somnard, A. (2018, March). Le Luxembourg doit miser sur la modernité. *Paperjam*, 52–64.

STATEC. (2008). *NACELUX Rév. 2*. Luxembourg. Retrieved from http://www.statistiques.public.lu/catalogue-publications/nace/PDF-NACE-2.pdf.

STATEC. (2013). *Les principaux employeurs au Luxembourg d'après l'effectif* (Vol. 2013). Luxembourg. Retrieved from http://www.statistiques.public.lu/fr/publications/thematique/entreprises/principal-employeurs/index.html.

STATEC. (2016a). *Luxembourg in figures 2016*. Luxembourg.

STATEC. (2016b). *Répertoire des entreprises luxembourgeoises 2016*. Luxembourg. Retrieved from http://www.statistiques.public.lu/catalogue-publications/repertoire/2016/fascicule-1.pdf.

Steen, H. U. (2011). Indicators of development or dependency in disguise? Assessing domestic inventive capacity in South Korean and Chinese infrastructural ICT standards. *Telecommunications Policy*, *35*(7), 663–680.

Sutherland, E. (2010). What lies beyond the second Roaming Regulation? *Info*, *12*(3), 16–29.

Symeou, P. C. (2009). Does smallness affect the liberalisation of telecommunications? The case of Cyprus. *Telecommunications Policy*, *33*(3–4), 215–229.

Symon, G., & Cassel, C. (Eds.). (2012). *Qualitative Organizational Research* (1st ed.). London: Sage Publications.

The TIR Consulting Group. (2016). *The Third Industrial Revolution Structuring Document for The Grand Duchy of Luxembourg: Presented on 2 January 2016*. Luxembourg.

The World Bank. (2012). *Knowledge Economy Index (KEI) 2012 Rankings*.

Thelen, C. (2016). Réussir à former et former pour réussir ! Retrieved July 30, 2016, from http://www.carlothelenblog.lu/2016/07/13/reussir-a-former-et-former-pour-reussir-2/

Thibaut, F. (2015a, March 23). Les Fintech ne sont pas une menance pour les banques. *Paperjam*. Luxembourg.

Thibaut, F. (2015b, March 26). Devenir le prochain hub Fintech. *Paperjam*. Luxembourg.

Thompson, G., & Kettels, T. (2013, June 6). Luxembourg to Have 20 % of World-Wide Tier IV Data Centre Capacity by Year-End. *Chronicle.Lu*. Luxembourg.

Thorhallsson, B. (2015). *How Do Little Frogs Fly ? Small States in the European Union* (No. 12). *Norwegian Instiute of International Affairs. Policy Broef* (Vol. 12). Oslo.

Ungerer, H. (2013). Back to the roots: the 1987 telecom green paper 25 years after – has European telecom liberalization fulfilled its promise for Europe in the internet age? *Info*, *15*(2), 14–24.

Veugelers, R. (2012). *New ICT sectors: Platforms for European Growth?publisher?*

Vu, K. M. (2013). Information and Communication Technology (ICT) and Singapore's economic growth. *Information Economics and Policy*, *25*(4), 284–300.

Waring, T., & Wainwright, D. (2008). Issues and Challenges in the Use of Template Analysis : Two Comparative Case Studies from the Field. *The Electronic Journal of Business Research Methods*, *6*(1), 85–94. Retrieved from www.ejbrm.com.

Waverman, L., & Koutroumpis, P. (2011). Benchmarking telecoms regulation – The Telecommunications Regulatory Governance Index (TRGI). *Telecommunications Policy*, *35*(5), 450–468.

Welsh, E. (2002). Dealing with Data: Using NVivo in the Qualitative Data Analysis Process. *Forum Qualitative Sozialforschung / Forum: Qualitative Social Research*, *3*. Retrieved from http://www.qualitative-research.net/index.php/fqs/article/view/865/1880.

Whalley, J. (2006). Recent developments in the telecommunications industry of Nepal. *Info*, *8*(1), 57–71.

Whalley, J., & Curwen, P. (2008). Equality of access and local loop unbundling in the UK broadband telecommunications market. *Telematics and Informatics*, *25*(4), 280–291.

Wong, L. P., Medicine, F., & Lumpur, K. (2008). Data Analysis in Qualitative Research: A Brief Guide to Using NVivo. *Malaysian Family Physician*, *3*, 14–20.

Wu, R. W. S., & Leung, G. L. K. (2009). Hong Kong and Singapore: Two models of telecommunications regulations? *Telematics and Informatics*, *26*(4), 322–332.

Yang, K. C. C. (2005). Exploring factors affecting the adoption of mobile commerce in Singapore. *Telematics and Informatics*, *22*(3), 257–277.

Zabatta, J. (2015, November 29). Lancement du nouveau Centre de Compétences Information and Communication Technologies. *Le Quotidien*. Luxembourg. Retrieved from http://www.lequotidien.lu/economie/un-centre-de-competences-pour-les-tic-en-2016/.

Zahlen, J. M. (2016). *Next Generation Access Networks in Luxembourg: Wholesale competition and the economic impact of public investment in NGA network infrastructure*. Montepellier.

Zahlen, P. (2008). *L'économie luxembourgeoise - une histoire mouvementée*. Luxembourg.

Zenhäusern, P., Schneider, Y., Berner, S., & Vaterlaus, S. (2012). *Polynomics Regulation Index 2012*. Olten (CH).

Appendix 1: Curriculum Vitae Nico Binsfeld

Born in Luxembourg 4.4.1961, Married, two daughters, Luxembourgish Nationality

Professional Career:

Septembre 2017	Conseiller, Formation, Chambre de Commerce du Luxembourg
2015 - 2017	Vice President – Luxembourg Institute for Digital Training (www.lidit.lu)
2015 – 2017	Chief Executive Officer House of Training
	Overall operational and strategic management responsibility for the largest vocational education and training provider in Luxembourg which is a foundation belonging to the Luxembourg Chamber of Commerce and the Bankers Association. 35 members of staff, 500 teachers, 800 different courses, 24.000 registrations in 2016
2014-2015	Chief Executive Officer Post Telecom PSF SA and board member of Post Telecom PSF SA
2010-2014	Chief Executive Officer Netcore PSF SA
2007 - 2010	Country Director Luxembourg and Customer Team Head Nokia Siemens Networks
2006	General Manager Siemens Networks
2005	Business Manager Carriers Siemens Luxembourg
2002-2005	Business Manager Alternative Carriers and CATV Siemens Luxembourg
2001-2003	Business Manager New Carriers with Siemens Luxembourg
1999-2001	Vice President Telecoms and Transmission Broadcasting Centre Europe
1987 – 1999	Different Engineering, Management and Business Development roles for RTL and CLT-UFA
1987	Research assistant at CRP Henri Tudor – first working experience in parallel to my final semester as university

Knowledge and Experience

Languages (full business proficiency): Luxembourgish (Mother tongue), German, French and English

Over twenty-five years of experience of working in a multi-cultural environment with RTL, SIEMENS, Nokia Siemens Networks and Open University Business School and Post Luxembourg Group.

Over fifteen years of experience and excellent knowledge of the local ICT ecosystem as telecommunications operator, infrastructure provider and IT integrator.

Over ten years of experience of working with national and international telecommunications operators as a supplier of infrastructures, network solutions and services (Siemens, Nokia Siemens Networks). Experience of working with global IT partners e.g. Cisco, HP, Microsoft, IBM.

Proven success record in ICT integration business, excellent relationships with major customers. Excellent knowledge of PSF (Professionnel du Secteur Financier) requirements and processes.

Proven experience in middle and senior management positions.

Long-standing technical experience and experience in fixed and mobile communication networks and IT services and solutions. Extensive ICT skills in different programming languages, operating systems, on-line tools and services.

Proven communication and presentation skills with extensive experience teaching and tutoring at different levels and different specialities in a multi-national, multi-cultural environment.

Additional teaching and tutoring activities

In addition to my primary professional roles, I have always been interested in learning and developing others and myself. As such, I have been active in different lecturing and tutoring roles for almost twenty years now.

1998 – 2005

Associate Lecturer at University of Luxembourg (Telecommunications and IT department) on technical topics e.g. mobile and optical networks, antennae and radio wave propagation, applications of radio frequencies, informatics etc. Member of Examination Broad for the recruitment of technical engineers as civil servants.

1999 - April 2013

Associate Lecturer at Open University Business School – tutoring Fundamentals in Senior Management in Russia and Germany and Strategy in Belgium or Luxembourg as well a management projects in Austria and Romania. Additional Activities and Assignments with OUBS: residential schools, On-line residential schools, on-line class moderation, monitoring, mentoring, exam marking, critical reading.

Since 2004 Associate Lecturer at Chambre des Métiers and Chairman of different exam boards

Since 2015 Associate Lecturer "Eufom Luxembourg" – Bachelor in Management Programme. Lectures in Management Basics, Services Management and Accounting.

Since 2016 Associate Lecturer "Insitut Supérieur de l'Economie" (www.isec.lu) – Bachelor and Master in Business Management Programmes. Lectures in Management Basics and Marketing.

Since 2017 Associated Lecturer at University de Paris 2 Panthéon-Assas, "Master en projets logistiques". Lectures in Maritime and Airfreight Logistics and Data Mining.

Education

1967-1973 Primary School in Luxembourg

1973-1978 Ecole des Arts et Métiers, Technical Studies as Electrician

1978-1982 Institut Supérieur de Technologie, Technical Engineer with Distinction

1982-1987 **Rheinisch-Westfälische Technische Hochschule Aachen (Germany). Diplom Ingenieur (Master of Science) with Merits**

1994-1995 Professional Certificate in Management, Open University UK (distance learning)
1995-1996 Professional Diploma in Management, Open University UK (distance learning)

- Managing Development and Change
- Managing Resources for the Market – development of business plan for a mobile operator in Luxembourg

1996-1998 **Master of Business Administration, Open University UK (distance learning)**

- Strategic Management
- Corporate Financial Strategy – development of a business plan for a TV operation in Hungary
- International Enterprise – development of strategy to enter Poland with Radio and TV operations
- Creative Management – project for the set-up of a Telecommunications section within RTL

2012-2013 University of Strathclyde (part-time, distance learning). Diploma in Research Methodology

2014-ongoing **Doctor of Business Administration (Part-time, distance) student at Newcastle Business School, Northumbria University**

Appendix 2: The portfolio

Peer reviewed journal articles

1. Binsfeld, N., Whalley, J., & Pugalis, L. (2016a). Competing against yourself: State duopoly in the Luxembourg telecommunications industry. Telecommunications Policy, 40(8), 791–803.

2. Binsfeld, N., Whalley, J., & Pugalis, L. (2017b). Looking beyond official success measures: tales from the field of the complex forces shaping Luxembourg's ICT ecosystem. Journal of Innovation Management, 5(2), 15–25. Retrieved from http://www.open-jim.org/article/view/254.

3. Binsfeld, N., Whalley, J., & Pugalis, L. (2017c). Playing the game: Explaining how Luxembourg has responded to the Networked Readiness Index. Digital Policy, Regulation and Governance, 19(4), DPRG-02-2017-0008.

Reviewed conference presentations and papers

4. Binsfeld, N., Whalley, J., & Pugalis, L. (2014). Luxembourg a bastion of state ownership. In 25th European Regional Conference of the International Telecommunications Society (ITS), Brussels, 22-25 June 2014. Brussels: Econstor.

5. Binsfeld, N., Pugalis, L., & Whalley, J. (2015). ICT ecosystems in small countries: An analysis of Luxembourg. In 26th European Regional Conference of the International Telecommunications Society (ITS), Madrid, 24-26 June 2015. Madrid: www.econstor.eu. Retrieved from http://www.econstor.eu/dspace/handle/10419/127127.

6. Binsfeld, N., Whalley, J., & Pugalis, L. (2016b). Competing through e-skills: Luxembourg and its second level digital divide. In 27th European Regional International Telecommunications Society Conference - Cambridge. Cambridge: Econstor.

7. Binsfeld, N., Whalley, J., & Pugalis, L. (2017a). An analysis of the structure, actors and interrelationships producing Luxembourg's ICT ecosystem. In 28th European Regional International Telecommunications Society Conference - Passau (pp. 1–32). Passau.

Publications in local Luxembourgish technical journals

8. Binsfeld, N. (2013). The Luxembourgish Telecommunications Market. Cahier Scientifique Revue Technique Luxembourgeoise, 1, 24–37.

9. Binsfeld, N., & Whalley, J. (2016). Measuring Luxembourg's State of ICT Development. Cahier Scientifique Revue Technique Luxembourgeoise, 2016(1), 30–47.

Commissioned Study

10. Ant, M., Goetzinger, P., & Binsfeld, N. (2016). E-Skills Study - Strategies for the creation of a virtual e-skills training centre in Luxembourg. Luxembourg.

Binsfeld, N., Whalley, J., & Pugalis, L. (2016a).

Competing against yourself: State duopoly in the Luxembourg telecommunications industry.

Telecommunications Policy, 40(8), 791–803.

Telecommunications Policy 40 (2016) 791–803

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Competing against yourself: State duopoly in the Luxembourg telecommunications industry

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Newcastle Business School, Northumbria University, Newcastle, UK

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ABSTRACT

The Luxembourgish telecommunications market, not too dissimilar to many other advanced industrial countries around the world, is undergoing a process of market liberalisation. However, there are some particular features of Luxembourg's 'informed follower' mode of market liberalisation, which are sociospatially distinct and therefore warrant investigation. In particular, the government of Luxembourg has sought to proactively intervene in the direct provision of telecommunications services, in the form of two competing but 100% state-owned operators, whilst simultaneously supporting market liberalisation. An understanding of the role of the state in this process is clarified through the conceptual lens of the state as *policy-make*r, *regulator* and *operator*. Through examining the multiple roles performed by the Luxembourgish state in the wider context of the EU telecommunications reform packages, the paper reveals the competitive tension that exists between each of the different arms of the state, that is, between POST and Luxconnect. The paper critically appraises the intertwining decisions, factors and considerations that led to this state-controlled duopoly and analyses the outcomes to date of attempts to liberalise the telecommunications market as well. This analysis of the geographical and historical complexity of the Luxembourgish telecommunications sector helps to reveal the powerful role of the state in market liberalisation.

1. Introduction

The European Union (EU), with its Green Paper on telecommunications (European Commission, 1987), launched a process of market liberalisation with the ultimate aim of creating a single European telecommunications market. As a consequence, the Luxembourgish telecommunications market has undergone in recent times a process of liberalisation. However, this has been achieved in a particular way. The government of Luxembourg has sought to proactively intervene in the direct provision of telecommunications services, whilst simultaneously supporting the market liberalisation process is encapsulated by broader neoliberal tendencies, with neoliberalism being a complex, dynamic and mutable constellation of economic policies, political objectives and ideologies that have become widespread since the days of Reagan and Thatcher (Williamson, 2002).

While many aspects of market liberalisation occurring in Luxembourg are similar to those in other advanced industrial countries around the world and in particular in the EU, there are others that appear to be highly distinctive; reflective of

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Luxembourg's unique history, geography, politics and culture. Indeed, such socio-spatial distinctiveness points towards the merits of conducting a country specific case study (Eisenhardt & Eisenhardt, 1989; Yin, 2009). In many EU countries state owned telecommunication operations have since been partially or fully privatised, although there remain several instances, for example, in France and Germany where a financial interest has been retained by the state (OECD, 2013) The situation in Luxembourg is unique: it is the only EU country in which the incumbent telecommunications operator remains wholly state owned (OECD, 2013). In addition, the state has created a second telecommunications operator that provides high-speed fibre connectivity to international Internet peering hubs and datacentres. In other words, the government has simultaneously sought to liberalise the country's fixed business-to-business telecommunications market while developing a wholly state owned incumbent. It is a particular type of state-oriented neoliberal strategy, which hitherto has been neglected within the literature. Therefore, the case of the Luxembourgish telecommunications market is worthy of investigation.

An understanding of the role of the state in this process is clarified through the conceptual lens of the state as a *regulator*, *policy-maker* and *operator*. This is achieved by way of comparative analysis of POST, the incumbent operator established in 1842, and Luxconnect, created in 2006. Examining the different roles performed by the Luxembourgish state in the wider context of the EU telecommunications reform packages, the paper reveals the competitive tension between each of these arms of the state. The comparative analysis is informed by a review of the literature concerning the liberalisation and privatisation of utilities and infrastructure sectors and the changing roles of the state, together with material specific to Luxembourg. This includes a range of secondary sources such as the annual reviews published by the national regulatory authority (NRA), European Commission implementation reports, OECD documentation, and the annual reports and websites of the different operators in the Luxembourg market as well as qualitatively-rich information from the archives of several Luxembourgish newspapers and journals.

The paper is organised into five main sections. In the following section, relevant literature the changing role of the state in infrastructure industries, liberalisation of different utility sectors and models to build next generation networks (NGN) is recounted. Section 3 then provides a brief overview of the importance of ICT for Luxembourg's economy. In Section 4 attention switches to describing the role of the state as a regulator and policy maker but also as a 100% owner of two competing telecommunications operators. The key issues identified are discussed in Section 5, and conclusions drawn in the final section.

2. Market liberalisation in the telecommunications sector

There is a wide range of literature available about market liberalisation and neoliberal tendencies relevant to distinct roles of state actors in infrastructure industries, such as, telecommunications. The following section presents, by way of a critical review, some of the most relevant research findings and discussions related to the liberalisation of telecommunications and the role of the state.

Starting in the late 1970s governments began to liberalise a number of infrastructure sectors and 'open up' state monopolies to private enterprise. Schneider, Fink, and Tenbücken (2005), for example, provide an international comparative analysis of such privatisation activities in infrastructure industries during the last three decades of the 20th century. Their findings revealed that 26 of the countries under study had at least partially privatised their infrastructures. Similarly, Bortolotti, D'Souza, Fantini, and Megginson (2002) analyse how countries have divested themselves, either entirely or partially, from their national telecommunications operators. They found that performance of telecommunications companies improved significantly after privatisation, but attributed this to improvements directly linked to regulatory changes. Lestage, Flacher, Kim, and Kim (2013) discuss whether competition affects state-owned companies in distinct ways than commercial operators. They have concluded that state investments in infrastructures tend to increase with competition whilst private investments tend to decline. Alonso, Clifton, Díaz-Fuentes, Fernández-Gutiérrez, and Revuelta (2013) have analysed whether privatisation led to performance improvements compared to state ownership in an international context but they could not find a significant difference. Pina, Torres, and Bachiller (2014) looked into whether and how service quality in telecommunications is affected by private or public ownership, concluding also that there is no apparent link between ownership and quality.

Focussing on telecommunications, Bauer (2005, 2009, 2010) discusses the changing roles of the state in telecommunications, the potential conflicts that could arise when the state is wholly or partially owner, whilst simultaneously trying to 'open-up' the sector to market competition. Bauer (2009) demonstrates how countries attempt to develop their respective markets through individual policies and direct investments and how this engenders sociospatially distinct telecommunications markets across Europe in terms of the numbers of competitors, the degree to which fixed and mobile markets are competitive, the presence of inter-platform competition and so forth. The findings from the above studies provide inconclusive evidence regarding the effects of the privatisation of telecommunications and they also highlight divergence across different national contexts. In terms of the latter, this augments the need for analysis that focuses on the unique processes of Luxembourg's liberalisation of the telecommunications sector.

With its Green Paper on telecommunications (European Commission, 1987), the EU launched in 1987 a particular process of market liberalisation of telecommunications in Europe with the ultimate aim of creating a single market. This involved market liberalisation of monopolies, the privatisation of state owned companies and the creation of the national regulatory authorities. As this has been extensively discussed, see, for example, Melody (1997b), the literature that follows focuses on a range of issues that can help to illuminate and analyse the situation in Luxembourg.

Ungerer (2013) presents an overview of the process and the different changes to the regulatory environment that have happened over the last 25 years and concludes that recent technological evolutions will need further regulatory adaptations. Henten (2013) describes the evolution of the initial framework from 1987 through different 'telecom packages' of EU directives and argues for future changes to take into account the rapidly advancing technological developments. Cawley (2013), more specifically, investigates how this regulatory mode has helped to develop both mobile and broadband communications and shows that liberalisation has been more effective in the mobile sector. Clifton, Comín, and Díaz-Fuentes (2011), among others, demonstrate how liberalisation, along with privatisation and the introduction of competition into markets, has enabled some of the former state owned incumbent operators to expand their spatial reach and emerge as multinational companies. In contrast, Belloc, Nicita, and Parcu (2013) empirically investigate the nature and outcomes of liberalisation and show the importance of NRAs in this process. Levin and Schmidt (2010) discuss the establishment of NRAs, highlighting how they differ between countries in terms of their competence and ability. Melody (2011, 2013) on the other hand, provides a critical discussion of the contemporary EU regulatory framework and questions whether this is appropriate to create a single market and concludes that it is not because after 25 years since the 'green paper' there is still no common market in place. Building on Melody's conclusions, Lemstra and Van Gorp (2013) argue that further reforms are indeed necessary to achieve a common market, identifying the major barriers that prevent its realisation such as different stages of market development in different member states, as well as the additional economic value that a single EU wide market would generate. Holmes and Young (2002) show how, despite a common EU wide framework, member states took substantially different approaches in implementing this framework, which points towards the crucial role of socio-spatial context.

To improve broadband connectivity and widen the availability of next generation networks, the EU launched its most recent initiative 'Digital Agenda for Europe' (Marcus and Elixmann, 2012), which calls for member states to develop broadband access. Annual progress is monitored against a number of key indicators encapsulated in the 'Digital Agenda Scoreboard' (European Commission, 2013c). This initiative has received increased political attention following the recent global and European economic crises, and member states have been asked to consider investments and industrial policy measures to develop the EU economy, create jobs and reduce the digital divides that exist (Andlauer & Pouillot, 2011; World Economic Forum, 2008, 2010). Reggi and Scicchitano (2014) discuss how this initiative has been implemented in different regional development programmes by looking at the ways structural funds have been using during the period 2007–2013. They found that EU regions tend to invest more resources in improving already existing infrastructures than into creating new ones.

On the other hand, the investments necessary to roll-out next generation networks may not provide an attractive business case for commercial organisations or, if only viable in densely populated areas, raises questions about equality and the digital divide (Srinuan & Bohlin, 2011). Consequently, it has become 'acceptable' once again for the state to be involved in the rollout of these infrastructures. Different approaches to supply side or demand side incentives have been adopted by across the EU (see, for example, Gómez-Barroso & Feijóo, 2010b; Li, 2012; Nucciarelli, Sadowski, & Achard, 2010; Ragoobar, Whalley, & Harle, 2011; Ruhle, Brusic, Kittl, & Ehrler, 2011; Wee, Beltran, & Verbrugge, 2014). Different forms of public–private-partnerships have emerged, with the rationale for public involvement in the telecommunications sector being often geopolitical or strategic more than an economic one (Briglauer, Gugler, & Bohlin, 2013; Gómez-Barroso & Feijóo, 2010a). On a more general level, commentators like Buigues and Sekkat (2010) or Spector (2009), compare and contrast recent government approaches to state subsidies, industrial policies and other market interventions and found the share of GDP spent on public support is lower in the EU than in the US and argue for more research on specific public support policies.

For our purposes, it is possible to draw three conclusions. Firstly, that liberalisation has been implemented in a variety of ways, reflecting differences in national contexts and secondly, that the outcome of liberalisation is sometimes contrary to expectations. Thirdly, the 'Digital Agenda' has resulted in the state once more playing an active role in the provision of telecommunications infrastructure. The following section charts the development of the ICT landscape in Luxembourg since 1997, highlighting both the role of the state and the key initiatives that have been undertaken and some of their consequences.

3. Luxembourg and ICT

Information technologies and e-commerce are growth areas of Luxembourg's economy. ICTs contribute to about 7% of the country's GDP and create about 17,000 direct jobs (STATEC, 2013b). There are about 2000 small and medium size companies directly involved in providing ICT products and services (Service des Médias et des Communications, 2013). Subsequent governments have supported the development of the ICT sector not only as a policy maker applying and adapting the EU wide political framework to Luxembourg, but also as a national regulatory agency and directly as shareholder in telecommunications operators. The government is the 100% owner of two telecommunications operators and has invested directly or indirectly in many ICT related activities. Table 1 provides a summary of the major policy initiatives taken by different government institutions over time. It helps to highlight the importance that subsequent governments have given to the development of the ICT sector in Luxembourg and also the many different government institutions involved.

Luxembourg was the first European country to create a specific, clearly defined and secure legal framework for e-commerce (PWC, 2011) and it also had the lowest standard rate of VAT at 15% on such services within the EU. These attractive rates of taxation, together with efficient communication infrastructure developed by two state owned operators,

Table 1
Major government initiatives over time.
Sources: compiled by authors from several public websites and in discussions with stakeholders.

Date	Activity	Government entities involved
1997	Creation of National Regulatory Agency (Institut Luxembourgeois de Regulation. ILR)	Minister of Communications
1998	Licence application process for the second mobile operator[a], which was organised with the help of Arthur D. Little as a 'beauty contest' based on coverage, service offering and quality (ILR, 2008).	ILR
1999	Market liberalisation of the fixed networks. Definition of different categories of licences[b]	ILR
1999	The incumbent operator (POST) had to publish a first Reference Interconnection and a Reference Unbundling offer	ILR
2000	Introduction of number portability for fixed networks (ILR, 2000)	ILR
2001	eLuxembourg Action Plan—to promote the use of the Internet and to move the public sector towards solely communicating with the public electronically.	Service des Médias et des Communications (SMC)
2005	Introduction of mobile number portability (ILR, 2005)	ILR
2002	First call for applications for four 3G UMTS network licences (ILR, 2009a), which were allocated initially to the two existing 2G mobile operators plus Orange. There was no candidate for the fourth licence	ILR
2003	The remaining fourth licence was advertised again, divided into two and awarded to Luxembourg Online and Astralis	ILR
2004	2004, Orange returned its licence and this was awarded to Luxcommuncations SA who started 3G operations under the name of VoxMobile soon after.	ILR
2004	Prompted by the EU's i2010 initiative, first national action plan for broadband internet access (SMC, 2009). The objective was clear: to reach 95% of population. This goal was quickly achieved, with Luxembourg becoming one of the first OECD countries to achieve 100% DSL-based broadband coverage	SMC
2005	The Government, together with several local banks and the incumbent operator, set up Luxtrust, a local electronic signature system, Luxtrust playing the role of the 'certification authority'	Ministry of Finance
2006	Additional call for applications for 2G Edge and 3G spectrum, which was also awarded to Voxmobile (ILR, 2007)	ILR
2006	Set-up of Luxconnect (Luxconnect, 2013), a second state owned operator with the mission to building national and international alternative fibre optical networks as well as data centres and to offer these to alternative service providers	Ministry of Economy, SMC, ILR
2006	Luxembourg was the first EU member state to transpose the directive regarding e-commerce and electronic signatures into the local context	Ministry of Finance
2007	Two calls for applications for a broadband wireless access network (ILR, 2009a), with a licence being awarded to Luxembourg Online and its partner. They never launched their services with the result that the licence was taken back by ILR in 2009 (ILR, 2009b).	ILR
2008	A legal framework was created to facilitate the management of intellectual property and internet domain names (SMC, 2010b)	SMC
2009	Set-up of Lu-CIX (Henry, 2014a), a commercial Internet peering point to which all of the local operators quickly connected.	SMC
2010	Ultra High Broadband Strategy stating that by 2020 every household should have access to a connection with speeds of 1 Gbit/s upstream and 500 Mbit/s downstream (SMC, 2010a). The following rollout targets were set 25% of population by 2013, 50% of population by 2015 and finally 100% of population by 2020. In addition, an intermediate objective of every household having at least 100 Mbit/s download and 50 Mbit/s upload by 2015 was set.	ILR, SMC, Ministry of Economy
2010	Transposition of the 2009 EU telecom package into national law	Minister of Communications
2010	The Government, as their sole shareholder, asked the incumbent (POST) to invest about €180 million until 2015 to fund the initial rollout. It was agreed that POST would install at least four fibres into each home and grant access to alternative carriers to one or more of these on a non-discriminatory basis (SMC, 2010a).	Ministry of Economy
2011	The Government presents its national cybersecurity strategy (SMC, 2011)	SMC, Ministry of Economy
2012	Study to review the broadband strategy announced in 2010 (BooZ & Co, 2012). A closer collaboration between the incumbent operator and cable-TV operators was proposed with the aim to use the latter's existing networks to offer broadband connectivity in the less densely populated areas in the north of the country.	SMC & Ministry of Economy
2012	The 3 existing mobile operators, POST, Tango and Orange (formerly Voxmobile) receive 4G LTE licences, additional 1800MHz spectrum is released	ILR
2013	Additional funds were made available to speed up the rollout of the broadband infrastructure (Minstère de l'Economie, 2013). Overall over €1bn will be invested over the period from 2013 to 2017 (Minstère de l'Economie, 2013).	Ministry of Economy
2014	Overall strategic initiative called 'Digital Lëtzebuerg' (Gaudron, 2014c, 2014d) in order to better coordinate the different activities in the public sector and invited the private sector to create an single representative body to represent private interest and contribute the government plan (Gaudron, 2014b).	Ministry of State, Ministry of Finance and Ministry of Economy

[a] This was won by Millicom SA and operated under the 'Tango' brand name. The licence fee was linked to the annual turnover of the company.
[b] Licences have subsequently been replaced by declarations.

has led several players in the gaming and gambling sector to establish their headquarters in Luxembourg or even to develop their European technology centres in Luxembourg (PWC, 2011). This has, is turn, encouraged low-latency Internet providers to expand their ICT operations to include Luxembourg (PWC, 2011).

Although global media and Internet brands such as Amazon and PayPal, as well as large telecommunications companies such as Vodafone have all invested in Luxembourg, the fiscal advantages noted above are due to terminate in 2015 as new EU regulations come into force (Fayot & Funck, 2012). This has, however, not prevented the government from actively promoting Luxembourg to the ICT industry. For example, the government has sought to encourage the creation of new businesses, exemplified by initiatives such as 'Luxembourg for Business – Proud to Promote ICT' (Luxembourg for Business, 2014) – and has stated its eagerness to further develop the ICT sector in line with major industry trends (Service des Médias et des Communications, 2013). An ambitious ultra-high broadband access strategy has been decided on (Le quotidien, 2014; SMC, 2010a) as well as a series of major investments in broadband infrastructures (Minstère de l'Economie, 2013). Efforts are also being made to develop ICTs research with a focus on the security, reliability and trustworthiness of ICTs systems and services (Les Echos, 2014). The combination of these efforts has led to a growing ICT sector which currently represents about 7% of the country's GDP, which is considerably higher than for its 3 neighbouring countries (France, Germany, Belgium) (OECD, 2012), and provides about 17,000 jobs (Gaudron, 2014c). Hence, ICT is of critical importance to the Luxembourgish government.

4. The different roles of the state

This section examines the role of the state in the development of the telecommunications sector through the conceptual lens of the state as policy maker applying and adapting the EU wide political framework to Luxembourg, but also as regulator through its national regulatory agency and directly as shareholder in telecommunications operators.

Since the early days of telecommunications in 1842, the state, through its 'Administration of Post and Telecommunications', undertook a range of activities (policy making, regulation and operations). The Green Paper of the European Commission (European Commission, 1987) triggered a major process of change in the European telecommunications sector. Consequently, policy-making was separated from regulation and operation through liberalisation and privatisation. The most intensive periods of liberalisation, however, did not directly correlate with the most intensive periods of privatisation. As a result, some European countries retained an equity stake in operators. The Luxembourgish state decided to establish its former 'Administration of Post and Telecommunications' as a private but 100% state-owned company in 1992 but it was not until 1997 that it fully separated the different roles of policy maker, regulator and owner. The following sub-sections analyse the contemporary situation as well as providing an examination of the historical evolution of the role of the state in its different functions.

4.1. The state as policy-maker

As a Department of the Ministry of State and under the political responsibility of the Prime Minister, the 'Service des Médias et des Communications' (SMC) is the government body responsible for defining and promoting policies concerned with electronic communications, e-commerce, electronic security and media (Gouvernement du Luxembourg, 2014). As a result, its main activities consists of promoting Luxembourg internationally, advising the Prime Minister, supervising the local media sector and representing the government in different national companies and international organisations.

In 2001 the first action plan – eLuxembourg – was initiated to promote the use of the Internet and to move the public sector towards solely communicating with the public electronically (Gaudron, 2014d). However, no specific budget was allocated to the initiative and no single government department was in charge. Hence, it was simultaneously 'everybody's' responsibility and 'nobody's' responsibility. Consequently, this initiative generated limited impact and overtime faded from policy discourse. In 2004, prompted by the EU's i2010 initiative (OECD, 2012), SMC presented a first national action plan for broadband internet access (SMC, 2009). The objective was clear: for 95% of the population to have access to broadband. This goal was quickly achieved, with Luxembourg becoming one of the first OECD countries to achieve 100% DSL-based broadband coverage. In 2005, the government helped several local banks and POST to set up Luxtrust, a local electronic signature system, Luxtrust playing the role of the 'certification authority' (Agefi, 2014). Their technology is extensively used in Luxembourg for e-commerce and e-banking as well as for communications between the state and public.

In 2006, SMC, along with the then Minister of Communications created the legal framework necessary to set up Luxconnect (Luxconnect, 2013). Also during 2006 SMC was actively involved in Luxembourg becoming the first EU member state to transpose the directive regarding e-commerce and electronic signatures into the local context. Two years later, a specific legal framework was created to facilitate the management of intellectual property and internet domain names (SMC, 2010b). In 2009, SMC helped create Lu-CIX (Henry, 2014a), a commercial Internet peering point to which all of the local operators quickly connected.

SMC, together with the Ministry of Economy and the then Minister of Communications, published in 2010 a report outlining Luxembourg's future broadband strategy (SMC, 2010a). They claimed that both productivity and GDP growth requires ultra-high bandwidth connectivity for all households. Broadband connectivity was viewed by the government as being part of the incumbent's mission. Consequently the government through SMC set a target that by 2020 every household should have access to a connection with speeds of 1 Gbit/s upstream and 500 Mbit/s downstream (SMC, 2010a).

The following rollout targets were set: 25% of population by 2013, 50% of population by 2015 and finally 100% of population by 2020. In addition, an intermediate objective of every household having at least 100 Mbit/s download and 50 Mbit/s upload by 2015 was set (SMC, 2010a).

A policy was also devised to develop ultra-high bandwidth business zones; connected by two independent networks in order to guarantee full operational redundancy and highest availability. The government also announced two other, somewhat vague, objectives: to become a 'world leader' in terms of broadband connectivity penetration and to achieve competitive pricing in line with the EU average (European Commission, 2013b). The government instructed POST to invest circa €180 million until 2015 to fund the initial rollout. It was agreed that they would install at least four fibres into each home and grant access to alternative carriers to one or more of these on a non-discriminatory basis (SMC, 2010a). Cable TV operators were encouraged to develop their own networks as an alternative, with its independency of the incumbent's infrastructure ensuring that redundant access to 95% of households in Luxembourg was possible (SMC, 2010a). Several additional measures were agreed. A centralised database detailing network infrastructure across the country would be established, as would a second database focusing on civil works projects. In-house cabling would be made mandatory for all new buildings. Luxconnect also was instructed to push the development of their national networks and in particular to connect to the main 'business zones' while ILR was 'invited' by the government to proceed as quickly as possible with the frequency planning and licensing process for 4G LTE services. For its part, the government transposed the 2009 EU telecommunications package immediately into national law in 2010.

In April 2012, SMC and the Ministry of Economy commissioned a study to review the broadband strategy announced in 2010 (BooZ&Co, 2012). This new study proposed a closer collaboration between POST and cable-TV operators with the aim to use the latter's existing networks to offer broadband connectivity in the less densely populated areas in the north of the country. In May 2013 the Ministry of Economy and Foreign Trade announced that additional funds would be made available to speed up the rollout of the broadband infrastructure (Minstère de l'Economie, 2013). Through doing so, it was hoped that the country's economic recovery would hastened. Overall over €1bn is planned to be invested over the period from 2013 to 2017 (Minstère de l'Economie, 2013).

In 2014, the newly elected government presented a general strategic initiative called 'Digital Lëtzebuerg' (Gaudron, 2014b, 2014c). The aim of this initiative was to better coordinate the different activities in the public sector and invited the private sector to create an single representative body to represent private interest and contribute the government plan (Gaudron, 2014b).This new initiative is intended to address a variety of topics such as infrastructure, e-government, e-skills, ICT for finance, support for innovation and start-ups, as well as the promotion of Luxembourg as an international ICT hub.

4.2. *The state as regulator*

In order to implement the European Directives resulting from the different so-called 'Telecom Packages' (Ungerer, 2013), in the case of Luxembourg this necessitated the creation of an independent national regulatory authority divorced from policy-making functions (Boston Consultancy Group, 2013). Initially set-up in 1997 as 'Institut Luxembourgeois des Télécommunications' (ILR) (ILR, 2008) with two employees drawn from the incumbent telecom operator and an externally recruited director, it has developed by 2014 into a 50 person administrative body regulating utility sectors as well as coordinating the use of radio frequency resources and ensuring consumer protection.

ILR is distinct from some of the more 'aggressive' regulators, such as in Germany, France or some Eastern European Countries (Waverman & Koutroumpis, 2011; Zenhäusern, Schneider, Berner, & Vaterlaus, 2012). The approach of ILR has tended to be cooperative and conciliatory; opting to negotiate compromise solutions that are acceptable to all of the stakeholders involved. It has also sought to avoid making costly 'regulatory mistakes' as well. For example, unlike some EU member states, ILR has not auctioned spectrum but instead preferred to allocate spectrum through a series of beauty contests. By adopting such an approach, ILR avoided the start-up problems and high consumer prices that occurred in those countries that auctioned, for example, their 3G licences. Nevertheless, the European Commission, as part of its regular implementation reviews (European Commission, 2013a) identified that ILR lacked both resources and competences to perform all of its allocated tasks and that the cooperation with other regulatory bodies such as the national competition authority could be improved. Moreover, several infringement procedures against Luxembourg were launched for not implementing some elements of EC directives on time, such as, for example, market analysis (European Commission, 2011).

More recently, ILR's scope of activities has been extended to include railways, airports and the electricity and gas sectors, all of which play a significant role in the Luxembourgish economy (Dard, 2013; ILR, 2013). They also initiated a closer cooperation with the 'National Competition Authority' (Poujol, 2013). There have also been some discussions regarding whether a specific local ex-ante regulatory authority is still needed considering the current policy trends on a European and member state level (Henten, 2013; Henten & Falch, 2014). It has been argued by some that ILR could cooperate more with the national competition authority (Gaudron, 2014a).

It is clear from the above that the NRA in Luxembourg has evolved over time, and gradually became more involved in intervening in the market. As a result, it has helped stimulate market liberalisation and competition.

4.3. The state as operator

The Luxembourg state operates two competing telecommunication companies. The oldest of these is POST, the incumbent operator, while the second is Luxconnect, a new entrant to the sector focusing on two specific markets.

4.3.1. POST Group – the incumbent

Established in 1842 as a public administrator of post and telecommunications, by 1992 POST had evolved into a 100% state owned enterprise. Table 2 identifies the major milestones in the development of POST. The company operates under the political responsibility of the Ministry of Economy, with a board representing the government (eight board members), unions (six) and private sector (two). The company is organised into three divisions: postal, financial and telecommunication services. Although the proportion of total revenues generated by telecommunication services is steadily declining, by approximately 1–2% per year, almost 60% of POST's total revenues are generated by ICT related activities (Poujol, 2014). This decline reflects the increasing competitive nature of Luxembourg's ICT market, a development that has encouraged the company to search for new opportunities. One aspect of this has been the desire of POST to diversify its own operations, while another has been its willingness to acquire companies to broaden the portfolio of services that it offers.

Notwithstanding the competitive pressures that POST is experiencing, the company remains a significant employer within Luxembourg. Altogether the POST group employs around 4000 people (with about working 2000 in ICT), which makes it the fourth largest employer in Luxembourg (STATEC, 2013a).

4.3.2. Luxconnect

Prior to 2000 some national organisations, such as, utilities and media companies, diversified into the telecommunication market while remaining nationally focused. Two factors, however, negatively affected the development of the telecommunications market. The dot.com bust forced some of these operators to focus their activities on their core lines of business and geographical markets (Fransman, 2002). Thus, their diversification plans remained unrealised. Secondly, many of the alternative operators faced day-to-day problems that prevented them from gaining access to public infrastructures that would enable them to build their own infrastructures. Several of the administrations – roads, railways, local communes – were not aware, and perhaps not accepting, of the fact that the market had been liberalised and quite naturally continued to inform only their former colleagues in POST about planned civil and infrastructural works.

Over the course of 2004 and 2005, ILR assessed the fixed network market, focussing on the international and national high-bandwidth connectivity for commercial users. National operators continued to experience difficulties obtaining access 'rights of ways' and accessing existing trenches to install their own fibre optical cables. International operators were often prevented from expanding into Luxembourg and as a result had to use (more costly) leased lines in order to reach the main business areas in Luxembourg City. During international economic missions, the government promoted Luxembourg's tax advantages in order to attract foreign investors. In particular, e-commerce providers, who were required by the European Commission to have a base somewhere in the EU, were targeted (SMC, 2010b). However, many of these initiatives failed because of technical reasons linked to a lack of international connectivity. In addition, with the experience of the dot.com bust and considering the small size of the market, no local or international commercial operator appeared to be willing to invest to create the needed infrastructures.

Table 2
Historical developments of POST.
Sources: Compiled by the authors from POST's web site and a variety of sources.

Year	Development
1842	Creation of the Public Post and Telecommunications Administration
1992	Creation of 'Entreprise des Postes et Télécommunications' as a 100% state owned company
1993	Launch of LuxGSM – the first 2G mobile network
1994	Launch of 'integrated services digital network'
1995	Launch of 'Dial-up' internet access
2001	Commercial launch of broadband internet access
	Launch of Mobile data services
2003	Launch of 3G UMTS network
2005	Launch of 'integral' first 'triple-play' offer, Launch of Blackberry Services, Launch of Public Wifi Hotspots
2006	Teralink – international fibre network
2007	Inauguration of EBRC second data centre
2008	Commercial launch of IP-TV services
2009	Participation in Lu-CIX
2010	Fourth Data centre opened
	3D and HDTV Services offered
2011	Launch of Ultra-high bandwidth Internet access
2012	5th Datacentre opened, First Cloud services
	Full liberalisation of postal services on the 1.1.2013
2013	Changed brand name into POST Luxembourg

Derived from this experience and their situated vantage, the government concluded that the market had failed to deliver both in terms of international and national broadband connectivity and datacentre capacity (Gaudron, 2014d), with the consequence that state intervention was required. Thus, the government decided to establish a second 100% state owned operator in 2006. This new company would:

- Build a national dark fibre network. This would be made available to telecommunications operators so that they can build and enhance their own footprint in Luxembourg.
- Operate a network that connects Luxembourg to the Internet exchanges in Amsterdam, Brussels, Frankfurt and Paris. Distances would be minimised while route and fibre diversity maximised.
- Support the national ICT, media and e-business sectors by providing carrier neutral, state-of-the-art data centre facilities (Luxconnect, 2013).

Luxconnect does not define itself as a telecommunications operator. Indeed, it may be more appropriately described as a 'carrier's carrier' because all its services are provided on a wholesale, business-to-business basis. Its customer base is composed exclusively of telecommunications operators, system integrators, hosting and software-as-a-service companies. The services are offered on a strictly neutral and non-discriminatory way: identical pricing and support are provided to customers accessing the same product or service under matching conditions. It provides raw datacentre capacity as well as dark fibre or high bandwidth connectivity using a cost-plus pricing scheme (Luxconnect, 2013).

Luxconnect was allocated an initial budget of €30 million. By the end of 2013, Luxconnect employed 23 staff, had capital of €75 million and had invested over €120 million developing its business. The major milestones to date in the development of Luxconnect are summarised in Table 3. Operations commenced in 2009 with its first data centre and an international fibre optical network. Since then (see Table 3), the company has arguably been successful in terms of building infrastructures and making them available to service providers (Journal, 2013). Luxconnect has also contributed to the development of a commercial national Internet peering point (Lu-CIX) and facilitated the establishment of a wholesale cloud service, namely Luxcloud (Bova, Plummer, Petri, Malinverno, & Govekar, 2014). By doing so they have contributed to the economic and social development of the country in terms of creating the international and national communications infrastructures and datacentres, stifling competition, reducing barriers to entry for alternative telecommunications services providers, attracting foreign direct investments and eventually by creating jobs at least indirectly. However, according to its published annual accounts, so far the company has not made any profits and not paid a dividend to the state.

In February 2014 the government announced that Luxconnect had sold its network of international communication links to a private telecommunications operator. When announcing the sale, the government claimed that one of its major goals – improving Luxembourg's connectivity with major Internet hubs – had been achieved, and that this network could now be operated more efficiently by a private company (Bettel, 2015; Gaudron, 2015). Not only does this sale provide Luxconnect with fresh funds to invest in its domestic infrastructure operations, but it also reduces the extent to which the state's two telecommunications businesses are competing against one another.

Table 3
Historical developments of Luxconnect.
Sources: Compiled by authors in discussion with CEO and CFO of Luxconnect.

Date	Event/activity
2006	Incorporation of Luxconnect SA
2006	Legal framework passed the Parliament
2007	Service contract signed between Luxconnect and the Government
2008	Start of construction of first datacentre
2008	200 km of fibre cables have been installed in Luxembourg
2009	Legal framework extended – Luxconnect can now also invest in subsidiaries
2009	First Datacentre opens in Bettembourg
2009	Activation of high speed communication links between Luxembourg, Frankfurt and Amsterdam
2009	Participation in LU-CIX – commercial internet peering point
	Participation in LuxCloud service provider
2010	Activation of high-speed communication link between Luxembourg and Brussels
2010	Activation of high-speed communication link between Luxembourg and Paris
2011	Second datacentre opens in Bettembourg
2011	Start of construction of a new datacentre on a different location in the North of the Country (Roost)
2012	New datacentre opens in the North of the Country (Roost)
2012	Activation of high-speed direct communication link between Frankfurt and Paris
2013	Start of construction of third datacentre in Bettembourg
2014	About 800 km of fibres have been installed in Luxembourg
2014	Luxconnect sells its international communication network to third party – claims to have achieved its objective in terms of connecting Luxembourg to major international internet peering points

5. Discussion

Luxembourg's telecommunications sector is rather unique, especially in an EU context, as the Luxembourgish state has chosen an unconventional approach. It has not been at the forefront of neoliberal trends in the EU, but instead has adopted an approach that could be best described as being an 'informed follower'. This may be partially due to the small size of Luxembourg and its telecommunications market that leads to limited competitive pressures and the relatively low interest among larger operators to establish operations. It could, however, also be a consequence of a political desire to develop the incumbent, who, with its 4000 employees, is one of the largest employers in the country and contributes a considerable amount of tax revenue. In addition, the regulatory body, without the benefit of any form of institutional antecedents, has also had to grapple with limited resources and, at least initially, little experience. As a consequence, ILR did not intervene much in the market and also struggled to implement some EU directives on time (European Commission, 2011)

As shown in, for example, Bauer (2010), the EU pushed for the liberalisation of telecommunications markets in Europe and the creation of a single market, but did not impose any specific rules or measures for privatising state owned operators. Nevertheless, in line with the neoliberal paradigm, almost all EU governments decided to sell, either partially or completely, their stakes in such ventures. In some cases, however, governments have retained a minority or controlling stake (Holmes & Young, 2002; OECD, 2013).[1] Yet, in the case of Luxembourg the opposite occurred, as the government not only decided that the incumbent should remain 100% state-owned, but that it should also continue to operate as an integrated company with telecommunications, postal and banking services. It can be argued that due to the small size of Luxembourg and its limited market potential, commercial organisations would not see an attractive enough business case and on a geo-political level the government wanted to continue to control strategic infrastructures such as telecommunications networks.

Since 2004 the development of the ICT sector in Luxembourg has attracted considerable attention from the government in general and the Minister of Communications in particular. International consultants were hired to assess the 'state of play' across the sector, discussing with a wide array of stakeholders.[2] These discussions showed that, whilst the mobile market was operating competitively, the fixed market was still largely dominated by the incumbent (ILR, 2004). In particular, international broadband connectivity and access to the main Internet peering points found to be problematic (ILR, 2004). As a consequence a second state-owned operator, Luxconnect was created in 2006 to address, at least partially, the problems that were being experienced (Luxconnect, 2013).

The creation of Luxconnect has stimulated competition in terms of network infrastructures and datacentre capacity and has allowed several new national and international players to offer services to enterprises. It has also attracted many international e-commerce and game providers to establish technical infrastructures in Luxembourg (see Table 4). The impact of this should not be underestimated: substantial tax revenues and employment in ICT that now accounts for seven per cent of the country's GDP (Service des Médias et des Communications, 2013).

In addition, Luxembourg has achieved a major improvement in terms of available international connectivity routes and capacity and in terms of datacentre capacity for which it is one of the world's largest players for high quality, high reliability data centres. This is reflected in improving positions in different ICT related international comparisons and ranking for example the networked readiness index by the World Economic Forum (Bilboa-Osoria, Dutta, & Lanvin, 2014) or the digital agenda scoreboard (European Commission, 2014). Luxconnect has directly contributed to the economic and social development of the country in terms of creating the international and national communications infrastructures and datacentres. It has also indirectly contributed by stifling competition and reducing barriers to entry for alternative telecommunications services providers (see Table 4). Thus, Luxembourg has been able to attract foreign direct investment and ultimately to create jobs. However, according to its published annual accounts, so far Luxconnect has not been profitable – but losses are steadily decreasing – and has not paid any dividends to the state. It remains to be seen what the state will 'claw back' from the recent sale of Luxconnect's international fibre network, although it could potentially signify a role as an incubator of assets until such a stage when they are deemed to be both attractive to the market and sustainable.

On the other hand, and as shown in Table 4, the local telecommunications market is still heavily dominated by partially or fully state owned companies. There is only limited involvement by local or foreign private investors, though the lack of foreign direct investment may arguably be due to the small size of the Luxembourg market. In that sense, market liberalisation does not appear to have been as successful as in other countries. Moreover, POST continues to play a major role in important market segments and in particular for private fixed network customers. POST still controls approximately half of the mobile market, and almost all of the fixed, Internet and broadband Internet access markets (ILR, 2014). Having said this, the ICT revenues of POST are stable while those of competitors are steadily growing but are still far lower than those of the incumbent (ILR, 2014).

The focus on high quality, highly reliable, Tier IV, datacentres by both state owned operators, has also created some problems. Quite simply, there is over capacity to the extent that some of the recently constructed datacentres are not being fully utilised (Henry, 2014b). Moreover, the emergence of cloud services has changed the market, with customers increasingly demanding simpler services that are not tied to a single underpinning infrastructure. In other words, customers

[1] For example, the French and Germany governments continued to hold sizeable minority in Orange and Deutsche Telekom respectively, while the Belgium government is a majority shareholder in Belgacom. Together the Finnish and Swedish governments own half of TeliaSonera (OECD, 2013).

[2] The wide spread consultative nature of these consultations is evident in the reports (see, for example, BooZ & Co, 2012).

Table 4
Major telecommunications operators and their ownerships.
Sources: Compiled by the authors from a variety of websites, ILR statistical reports and OECD documents.

Operator	Activity	Ownership
Artelis	Regional alternative operator in B2B segment, carriers carrier	VSE AG 53.05% enovos International S.A. 36.95% (in which the state owns 25.44%) Saar LB Saarbrücken 10%
Ebrc	Datacentres	100% owned by POSTt
Eltrona	CATV operator	34% owned by POST, 66% private owners
Hotcity	Municipal Wifi Operator	49% Post, 51% City of Luxembourg
Join Wireless	4^{th} mobile operator, international MVNO	50% owned by POST
Luxconnect	Alternative infrastructure and datacentre provider, Carriers-Carrier	100% State owned
Luxembourg Online	Local alternative operator	100% local private ownership
Numéricable	CATV operator	100% Altice group
Orange	3rd mobile operator	100% owned by Orange/France Télécom
POST	Incumbent fixed operator	100% State owned
POST Telecom	Incumbent mobile operator	100% State owned
Société Européenne des Satellites	World largest satellite operator	Public company, 12.3% state owned
Tango	2nd mobile operator	100% owned by Belgacom
Telecom Luxembourg Private Operator	B2B alternative carrier and integrator	100% local private ownership
Telindus Telecom	B2B alternative carrier, integrator	100% owned by Belgacom
Teralink	International backbone	100% owned by POST
Visual Online	Alternative ISP	51% owned by POST, 49% private Investors

are demanding services that are available wherever they are not just where the physical infrastructure is located (Kushida, Murray, & Zysman, 2012).

Uncertainty persists regarding the independence of both operators in terms of corporate governance and on the impartiality of the regulator. Melody (1997a) has emphasised the importance of this independence both in terms of operational efficiency of the operators and in terms of regulatory impartially and equality treatment for non-state owned actors by the regulator. Civil servants representing different ministries sit on the board of POST, representing the government[3]; the same also applies for Luxconnect, the regulator and SMC. Although care has been taken to avoid direct conflict of interests by not using the same individuals, these civil servants are still working for the same ministries and, therefore, full independence cannot be guaranteed and has been scrutinised on several occasions by EU commission (Gaudron, 2013).

Many government initiatives have been implemented by different government entities over time, but there has been little coordination of these efforts. A first attempt at an overarching strategic plan – eLuxembourg in 2001 – did not produce the expected results, neither in terms of availability nor ICT usage. More recently, a new initiative 'Digital Lëtzebuerg' was announced as a joint effort of the Ministries of State, Finance and Economy (Land, 2014) with the aim to establish an overall and coordinated strategic approach to developing ICT in Luxembourg. This indicates that the state is still seeking to enhance the alignment of disparate, yet potentially complementary, governmental functions. Nevertheless, whether Digital Lëtzebuerg will help to overcome (some) entrenched departmental barriers or fizzle out with little sign of tangible impacts is open to conjecture.

6. Conclusion

This paper has sought to chart and then explore the degree and forms of existing market liberalisation and privatisation that has occurred within the business-to-business segment of the Luxembourgish telecommunications market. Deploying a comparative case study analysis of POST, the incumbent operator, and Luxconnect, it has been demonstrated how the state has and continues to perform a decisive role, distinct from many other advanced industrial nations, through its ownership of 'competing' telecommunications operators. One interpretation would be to conclude that the Luxembourgish telecommunications sector is one of the last bastions of state ownership and, therefore, at odds with prevailing neoliberal trends, practices and processes. On one level this reading has particular resonance, as both POST and Luxconnect are wholly state owned enterprises. Yet, by introducing (public) competition into the Luxembourgish telecommunications market – through the introduction of Luxconnect as well as other operators where the state holds a sizeable stake – is consistent with several of the key tenets of neoliberalism (Peck, 2001). In this sense, the Luxembourgish state has internalised neoliberal strategies, such as outsourcing and privatisation, by way of public entrepreneurship to engender a more competitive telecommunications market. Therefore, on this level the narrative that the Luxembourgish telecommunications sector is one of the last

[3] Details of the board of POST can be found on their website: www.post.lu.

bastions of state ownership is shown to be too simplistic. An analysis of the geographical and historical complexity of the Luxembourgish telecommunications sector helps to reveal the powerful role of the state as practising an 'informed follower' mode of market liberalisation. It is a role that requires long-term planning and state investment to absorb initial costs and internalise risks, which are bereft in many neoliberal strategies pursued by the state.

Through this paper it has been argued that whilst 'competing against yourself' does not seem financially attractive for the state as investor, it has allowed competition to emerge in two key segments of the market: broadband connectivity and data centre capacity. By doing so, Luxembourg has created lower barriers to entry for alternative service providers (Table 4), addressed a major market failure and improved dramatically its position as an ICT enabled country in international rankings such as the networked readiness index published annually by the World Economic Forum (Bilboa-Osoria et al., 2014). This has been achieved by a unique and unconventional approach that has triggered questions relating to the independence of the different roles of the state as a regulator and policy makers, though arguably overall Luxembourg has benefitted from this decision. Perhaps this approach could be adopted in other similar contexts as an alternative model for the development of the telecommunications market or indeed in other utilities or infrastructure markets?

While this paper has focused on the state's involvement in one specific sector in a EU member state, it does suggest several areas for further research. Within Luxembourg, the state is active in many other sectors such as utilities, railways and airports. How the state has participated in these sectors, in terms of both regulation and ownership, is one area where future research is required. Comparisons between sectors and between (small) countries could be undertaken. This paper has also highlighted the lack of research to date that has focused on the ICT sectors of small countries. Such countries face many challenges, such as the relative lack of scale economies and the small pool of capital and expertise that merit further investigation. A third area of further research relates to the continued willingness of many governments to own stakes in companies operating in ICT markets. Why some countries continue to be majority shareholders in telecommunications companies while others have completely divested their stakes remains unclear? The complex interactions that exist between a range of geo-political, economic and historical factors need to be further explored.

References

Agefi (2014). *LuxTrust double son chiffre d'affaire en 2013* (p. 33). Luxembourg: AGEFI.

Alonso, J. M., Clifton, J., Díaz-Fuentes, D., Fernández-Gutiérrez, M., & Revuelta, J. (2013). The race for international markets: Were privatized telecommunications incumbents more successful than their public counterparts?. *International Review of Applied Economics*, *27*(2), 215–236.

Andlauer, S., & Pouillot, D. (2011). The future of telecoms – Strategies for 2020. *Communications & Strategies*, *82*(2), 161.

Bauer, J. M. (2005). Regulation and state ownership: Conflicts and complementarities in eu telecommunications. *Annals of Public and Cooperative Economics*, *76*(2), 151–177.

Bauer, J. M. (2009). Regulation, public policy, and investment in communications infrastructure. *Telecommunications Policy*, *34*(1–2), 49.

Bauer, J. M. (2010). *Changing roles of the state in telecommunications* (pp. 1–36). East Lansing.

Belloc, F., Nicita, A., & Parcu, P. L. (2013). Liberalizing telecommunications in Europe: Path dependency and institutional complementarities. *Journal of European Public Policy*, *20*(1), 132–154.

Bettel, X. (2015). Connectivité internationale du Luxembourg : mission accomplie pour LuxConnect. Luxembourg: Gouvernement Du Luxembourg.

Bilboa-Osoria, B., Dutta, S., & Lanvin, B. (2014). *The global information technology report 2014 Rewards and risks of big data*. Geneva.

BooZ&Co. (2012). *National strategy for very high speed networks*. Luxembourg.

Bortolotti, B., D'Souza, J., Fantini, M., & Megginson, W. L. (2002). Privatization and the sources of performance improvement in the global telecommunications industry. *Telecommunicartions Policy*, *26*(5–6), 243–268.

Boston Consultancy Group (2013). *Reforming Europe's telecoms regulation to enable the digital single market*. Brussels.

Bova, T., Plummer, D.C., Petri, G., Malinverno, P., & Govekar, M. (2014). *Cool vendors in cloud services brokerage enablers* (Vol. 2013, pp. 1–7).

Briglauer, W., Gugler, K., & Bohlin, E. (2013). Regulatory approaches and investment in new communications infrastructure. *Telecommunications Policy*, *37*(10), 815–818.

Buigues, P.-A., & Sekkat, K. (2010). Public subsidies to business: An international comparison. *Journal of Industry, Competition and Trade*, *11*(1), 1–24.

Cawley, R. A. (2013). EU regulation and the development of mobile and broadband services. *Info*, *15*(2), 39–61.

Clifton, J., Comín, F., & Díaz-Fuentes, D. (2011). From national monopoly to multinational corporation: How regulation shaped the road towards telecommunications internationalisation. *Business History*, *53*(5), 761–781.

Dard, D. (2013). L'ILR n'a pas chômée en 2012. *Le Quotidien Luxembourg*, p. 5.

Eisenhardt, K. M., & Eisenhardt, M. (1989). Building theories from case study research. *The Academy of Management Review*, *14*(4), 532–550.

European Commission. (1987). *Towards a dynamic European Economy Green Paper on the Development of the Common Market for Telecommunications Services and Equipment* (p. 256). Brussels.

European Commission. (2011). 16th *Implementation Report on the telecommunications market in Luxembourg* (pp. 1–9). Brussels.

European Commission. (2013a). *Digital Agenda Scoreboard 2013* (p. 136).

European Commission. (2013b). *Digital Agenda Scoreboard 2013 Electronic communications market indicators : Definitions, methodology and footnotes on Member States*. Brussels.

European Commission. (2013c). *Digital Agenda Scoreboard key indicators*. Retrieved from ⟨http://digital-agenda-data.eu/datasets/digital_agenda_scoreboard_key_indicators/indicators⟩.

European Commission. (2014). *Digital agenda scoreboard 2014 – Digital performance of Luxembourg*. Brussels.

Fayot, F., & Funck, L. (2012). Luxembourg's TMT sector. In J. P. Panka (Ed.), *The technology media and telecommunications review* (3rd ed.). Luxembourg: Law Business Research Ltd.

Fransman, M. (2002). *Telecoms and the internet age - from Boom to Bust to…* 1st ed.). Oxford: Oxford University Press.

Gaudron, J.-M. (2013). *Communications électroniques : Luxembourg en faute*. Paperjam.

Gaudron, J.-M. (2014a). *Concurrence cherche voies d'amélioration*. Paperjam. Luxembourg.

Gaudron, J.-M. (2014b). *ICTluxembourg : « Une contrepartie homogène »*. Paperjam. Luxembourg.

Gaudron, J.-M. (2014c). *Quel rôle pour l'État ? Paperjam*. Luxembourg.

Gaudron, J.-M. (2014d). *Un nouveau visage se dessine*. Paperjam. Luxembourg.

Gaudron, J.-M. (2015). *Telecom Luxembourg s'offre un bout de Luxconnect*. Paperjam. Luxembourg.
Gómez-Barroso, J. L., & Feijóo, C. (2010a). A conceptual framework for public-private interplay in the telecommunications sector. *Telecommunications Policy*, *34*(9), 487–495.
Gómez-Barroso, J. L., & Feijóo, C. (2010b). Unveiling the intricate public–private interplay in next generation communications. *Telecommunications Policy*, *34*(9), 483–486.
Gouvernement du Luxembourg. (2014). *Le gouvernement du grand-duché de luxembourg 2013*. Luxembourg: Gouvernement Du Luxembourg.
Henry, R. (2014a). *A wonderful 5th anniversary for LU-CIX*. IT Nation. Luxembourg.
Henry, R. (2014b). *La cartographie complète des datacentres en France et au Luxembourg*. IT Nation. Luxembourg.
Henten, A., & Falch, M. (2014). The future of telecom regulation – the case of Denmark. In *International Telecommunications Society Regional Conference* (pp. 1–24). Brussels.
Henten, A. (2013). The telecom reform process in Europe and the upcoming challenges: Overview of the issues and papers in this special edition. *Info*, *15*(2), 3–13.
Holmes, P., & Young, R. A. (2002). Liberalizing and Re-regulating Telecommunications in Europe: A common framework and presistent differences (No. 159). Hamburg.
ILR (2000). *Rapport Annuel de l'Institut Luxembourgeois de Régulation 2000*. Luxembourg.
ILR (2004). *Rapport statistique succinct Année 2004*. Luxembourg.
ILR (2005). *Rapport statistique des télécommunications au Luxembourg pour l'année 2005*. Luxembourg.
ILR (2007). *Rapport statistique des télécommunications au Luxembourg pour l'année 2007*. Luxembourg.
ILR (2008). *10 Years Institut Luxembourgeois de Régulation*. Luxembourg.
ILR (2009a). *Institut Luxembourgeois de Régulation – Appels de candidatures*. Retrieved 11.08.13, from 〈http://www.ilr.public.lu/services_frequences/appelscandidatures/index.html?highlight=3g〉.
ILR (2009b). *Rapport statistique des télécommunications Luxembourg pour l'année 2009*. Luxembourg.
ILR. (2013). *ILR: un comparateur du marché de l'électricité*. Paperjam. Luxembourg.
ILR (2014). *Rapport statistique des télécommunications du Luxembourg de l'année 2013*. Luxembourg.
Journal. (2013). *LuxConnect – et de quatre*. Journal, p. 28. Luxembourg.
Kushida, K., Murray, J., & Zysman, J. (2012). The gathering storm : Analyzing the cloud computing ecosystem and implications for public policy. *Communications & Strategies*(85)).
Land (2014). Digital Letzebuerg. *Land* (p. 9). Luxembourg.
Le quotidien. (2014). L'Ultra haut débit avance. *Le Quotidien* (p. 4). Luxembourg.
Lemstra, W., & Van Gorp, N. (2013). Telecommunications reform and the internal market in Europe. *Info*, *15*(2), 73–90.
Les Echos (2014). Les ambitions du« Luxembourg 3.0 ». *Les Echos*, pp. 30–33.
Lestage, R., Flacher, D., Kim, Y. Y., & Kim, J. (2013). Competition and investment in telecommunications: Does competition have the same impact on investment by private and state-owned firms?. *Information Economics and Policy*, *25*(1), 41–50.
Levin, S., & Schmidt, S. (2010). Telecommunications after competition: challenges, institutions, regulation. *Info*, *12*(2), 28–40.
Li, G. (2012). The return of public investment in telecommunications: Assessing the early challenges of the national broadband network policy in Australia. *Computer Law & Security Review*, *28*(2), 220–230.
LuxConnect. (2013). *Welcome to LuxConnect | LuxConnect*. Retrieved 11.08.13 from 〈http://www.luxconnect.lu/〉.
Luxembourg for Business (2014). *Luxembourg's ICT and e-commerce environment 2014* (*Q2 update*) (Vol. 2014). Luxembourg.
Marcus, J. S., & Elixmann, D. (2012). *Re-thinking the Digital Agenda for Europe (DAE): A richer choice of technologies* (pp. 1–84).
Melody, W. H. (1997a). On the meaning and importance of ' independence ' in telecom reform. *Telecommunications Policy*, *21*(3), 195–199.
Melody, W. H. (1997b). *Telecom reform - Principles, policies and regulatory practices* 2001st ed.). Lyngby: Den Private Ingeniorfond, Technical University of Denmark.
Melody, W. H. (2011). Viewpoint: the closing of the liberalization era in European telecommunication. In N/A (Ed.), *Competition and Regulation in Network Industries* (pp. 218–235). London: Intersentia. Retrieved from http://www.crninet.com/pdf_file/intersentia/CRNI_13_03_0218.pdf.
Melody, W. H. (2013). Moving beyond liberalization: Stumbling toward a new European ICT policy framework. *Info*, *15*(2), 25–38.
Minstère de l'Economie (2013). *« Plan Marshall » pour le Luxembourg*. Retrieved 11.08.13, from 〈http://www.eco.public.lu/salle_de_presse/com_presse_et_art_actu/2013/05/Marshall/index.html〉.
Nucciarelli, A., Sadowski, B. M., & Achard, P. O. (2010). Emerging models of public–private interplay for European broadband access: Evidence from the Netherlands and Italy. *Telecommunications Policy*, *34*(9), 513–527.
OECD (2012). *OECD internet economy outlook*. Paris: OECD Publishing. p. 299.
OECD (2013). *Communications outlook*. Paris: OECD Publishing.
Peck, J. (2001). Neoliberalizing states: thin policies/hard outcomes. *Progress in Human Geography*, *25*(3), 445–455.
Pina, V., Torres, L., & Bachiller, P. (2014). Service quality in utility industries: The European telecommunications sector. *Managing Service Quality: An International Journal*, *24*(1), 2–22.
Poujol, V. (2013). Concurrence : fusion ou rapprochement avec l'ILR ? Paperjam.
Poujol, V. (2014). *Post : environnement difficile et résultats mitigés*. Paperjam. Luxembourg.
PWC (2011). *Luxembourg: An e-hub for Europe Opportunities and actions on the horizon 2015*. Luxembourg.
Ragoobar, T., Whalley, J., & Harle, D. (2011). Public and private intervention for next-generation access deployment: Possibilities for three European countries. *Telecommunications Policy*, *35*(9–10), 827–841.
Reggi, L., & Scicchitano, S. (2014). Are EU regional digital strategies evidence-based? An analysis of the allocation of 2007–13 structural funds. *Telecommunications Policy*, 1–9.
Ruhle, E.-O., Brusic, I., Kittl, J., & Ehrler, M. (2011). Next Generation Access (NGA) supply side interventions—An international comparison. *Telecommunications Policy*, *35*(9–10), 794–803.
Schneider, V., Fink, S., & Tenbücken, M. (2005). Buying out the state: A comparative perspective on the privatization of infrastructures. *Comparative Political Studies*, *38*(6), 704–727.
Service des Médias et des Communications (2013). *Luxembourg & ICT – A snapshot*. Luxembourg.
SMC (2009). *Plan d'action national en matière de TIC et de haut-débit*. Luxembourg.
SMC (2010a). *Stratégie nationale pour les réseaux à « ultra-haut » débit*. Luxembourg.
SMC. (2010b). *Why Luxembourg ? A comprehensive overview of the regulatory, economic and lifestyle advantages for ICT and media companies*. Luxembourg.
SMC (2011). *Stratégie nationale en matière de cyber sécurité* (pp. 1–10).
Spector, D. (2009). State aids : Economic analysis and practice in the European Union. In X. Vives (Ed.), *Competition Policy in the EU* (pp. 176–202).
Srinuan, C., & Bohlin, E. (2011). Understanding the digital divide: A literature survery and ways forward. In *22nd European Regional Conference of the International Telecommunication Society* (ITS2011), Budapest, 18–21 September 2011.
STATEC. (2013a). *Les principaux employeurs au Luxembourg d'après l'effectif* (Vol. 2013, pp. 1–39). Luxembourg.
STATEC. (2013b). *Luxembourg Figures 2013*.
Ungerer, H. (2013). Back to the roots: the 1987 telecom green paper 25 years after – Has European telecom liberalization fulfilled its promise for Europe in the internet age?. *Info*, *15*(2), 14–24.

Waverman, L., & Koutroumpis, P. (2011). Benchmarking telecoms regulation – The Telecommunications Regulatory Governance Index (TRGI). *Telecommunications Policy*, *35*(5), 450–468.
Wee, M. Van Der Beltran, F., & Verbrugge, S. (2014). Evaluating the impact of financing structure decisions on FTTH deployment. A comparison between New Zealand and Europe. In *Telecommunications Policy Research Conference*. Washington.
Williamson, J. (2002). What Washington means by policy reform. In J. Williamson (Ed.), *Latin American adjustment: How much has happened*? (pp. 1–9).
World Economic Forum. (2008). *The Lisbon Review 2008Measuring Europe ' s Progress in Reform*.
World Economic Forum. (2010). *The Lisbon review 2010 towards a more competitive Europe* ?.
Yin, R. K. (2009). Case study research: Design and methods. In L. Bickman, & D. J. Rog (Eds.), *Essential guide to qualitative methods in organizational research*, Vol. 5 (p. 219). London: Sage Publications.
Zenhäusern, P., Schneider, Y., Berner, S., & Vaterlaus, S. (2012). *Polynomics regulation index 2012*. Olten (CH).

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Looking beyond official success measures: tales from the field of the complex forces shaping Luxembourg's ICT ecosystem

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Abstract. Information and communication technologies (ICT) are increasingly becoming an important component of economic development. Luxembourg's ICT sector is usually characterized as performing admirably - it is often at the top-end of different indices and international league tables. Nevertheless, headline statistics and high-level assessments often disguise the complexities of dynamic relations. Ecosystems are one way of understanding complex interactions and relationships. It is in this respect that this paper deploys the concept of ecosystems to investigate Luxembourg's ICT sector. The layered ecosystem model, devised by Martin Fransman, was utilized to map key actors that comprise Luxembourg's ICT ecosystem, following which a program of unstructured interviews were conducted. This empirical material, combined with documentary analysis, provides the basis for an analysis of the interrelated elements that are shaping the development of Luxembourg's ICT ecosystem. The study has identified the main forces that affect the ICT ecosystem and concluded that Luxembourg's strengths are related to its well-developed ICT infrastructures such as international fiber and national ultra-high broadband connectivity and high quality datacenters and its political vision for ICT that has led to a supportive policy environment. Its main weaknesses are related to an inappropriate educational system in which technical and scientific training is less developed, missing e-skills such as coding, application development, technical IT know-how as well a non-entrepreneurial mind-set and a risk averse culture. The paper highlights the importance of the different socio-economic, political, strategic and technological forces that shape the ICT ecosystem of a small country in order to provide a comprehensive basis for its policy makers. An empirical focus on a small country helps to redress the research imbalance, whereby small countries are often overlooked by scholars. Nevertheless, we contend that such "smallness" engenders a unique opportunity for research engagement with a majority of primary actors in ecosystems, which might be unfeasible in larger countries.

Keywords. ICT ecosystems, Luxembourg, qualitative analysis.

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1 Introduction

Luxembourg has one of the most developed telecommunications infrastructures within the European Union (European Commission, 2013a). Broadband and Next Generation Networks (NGN) are available to 100% of the population. The latest mobile networks technologies are present almost everywhere and the country operates about 20% of the world's high resilience datacenter capacity (Luxembourg for Business, 2013). According to the Ookla netindex[1], in 2015, Luxembourg was positioned 9th out 113 countries with mobile download speed of 23 Mbits/s, and 19th out of 202 countries with about 40 Mbits/s download speed in fixed networks. Information technologies and e-commerce are seen as growth areas for Luxembourg (PWC, 2011). ICT technologies are widely used by households and businesses and about 17.000 people work directly in ICT and many more in the related financial industry. Over the last 15 years, governments have supported the development of the ICT sector as a policy maker, as a regulator but also as ICT service provider as the Government is a 100% owner of two telecommunications operators and has invested directly or indirectly in many ICT related activities (Binsfeld, Whalley, & Pugalis, 2013, 2015).

All of these activities have helped to create a dynamic ICT ecosystem (Rafique, Yuan, Tareen, Saeed, & Hafeez, 2012). In addition, Luxembourg has improved in the last 15 years its relative ratings in international indices, such as, for example, the networked readiness index published annually by the World Economic Forum (World Economic Forum, Dutta, Geiger, & Lanvin, 2015) in which Luxembourg is now placed among the top 10 most "network ready" countries in the world. Nevertheless, Luxembourg's ICT ecosystem also exhibits some frailties not always captured or transparent in international league tables.

This paper deploys a layered ecosystem model approach as proposed by Fransman (2010) as a means to identify the main actors in Luxembourg's ICT ecosystem. By applying this model, the authors aim to map the different actors in the ICT sector and analyse the relationships between the actors within the ecosystem in order to better understand how the ICT ecosystem in a small country like Luxembourg has developed over the last 15 years and more generally what are the internal and external factors that have helped to shape it over this period in time. These factors have been identified by direct interactions through extensive unstructured interviews with over 50 relevant stakeholders.

With this study, we intend to make both a contribution to better understanding the forces that shape ICT ecosystems in small countries as such countries are widely overlooked in literature and to provide an illustration of how the Fransman model may be used in practical terms. Luxembourg proves to be of particular interest for academic research and for policy making (in terms of implications) because it is a small but very open economy which is one of the most successful in the world. Luxembourg is located very centrally in Europe, is one of the founding members of the EU and is often cited in the top league international rankings. Furthermore, it can be compared to a region of larger countries and it may therefore provide some useful insight for small and open economies with similar features e.g. Singapore. In the other hand, Luxembourg does

[1] See http://explorer.netindex.com/maps?country=Luxembourg accessed 15.5.2015 – discontinued since

present some interesting peculiarities such as for example a very heavy reliance of the services sector.

The remainder of the paper is structured as follows. Section 2 presents different approaches to analyse an ICT economy and introduces the Fransman ecosystem model. Section 3 provides a brief overview of the ICT ecosystem and presents some of its major developments over the last 15 years. Section 4 argues the case to develop a better understanding of the situation by conducting a qualitative exploratory analysis and presents the methodology used. Section 5 presents the outcomes of this analysis and the final section discusses this outcome and draws some conclusions.

2 From Value Chains to Ecosystems

This paper builds on the definition of the ICT sector and the underlying classification suggested by OECD (2011) for "measuring the information society". This definition of ICT includes IT goods and services, information content as well as telecommunications goods and services including manufacturing and production of these.

There is a wide range of models available to make sense of the structure of the ICT industry. Many of these apply or develop the Porter's value chain to the ICT environment or parts of it (Maitland et al., 2002) or have extended this model to a so-called value net (Li & Whalley, 2002, Peppard & Rylander, 2006, Rafique et al., 2012). This idea which has also been taken up and developed further by, for example, Hallikas et al. (2008) or Oestreicher et al (2012). Similarly, Porter's model about competitive forces (Porter, 1990) has been adapted to the ICT environment (Karagiannopoulos, Georgopoulos, & Nikolopoulos, 2005). Along the same lines, Briglauer (2004) has developed a generic reference model in order to assess competition in different communications markets focusing on a regulatory viewpoint. Additional work has been done in characterizing the ICT Ecosystem as a network (Garcia & Vicente, 2012), as well as looking into how such networks are built and maintained (Partanen & Möller, 2011).

These models are essentially linear ones, but today's business environment is complex and dynamic and presents multiple relationships where companies are interacting to deliver their products and services. As a consequence, the ICT sector is increasingly characterized as a socio-technological (eco)system facing asymmetric and delayed feedback structures, which lead to turbulent changes (instability/existence of multiple equilibria) and high uncertainty.

Koslowski, Longstaff, Vidal & Grob (2012) see the ICT sector as an ecosystem of many heterogeneous organizations that are woven into a web of links and respond interactively to forces in the environments. Understanding the dynamics of one domain in isolation from the other is impossible, and demands both a systemic and evolutionary view to be adopted. According to Kim, Lee, & Han (2010) an ecosystem can be defined as an economic community involving many companies working together to gain comparative advantages as a result of their symbiotic relationships. They also argued that ecosystems permit companies to create new values that no company could achieve alone. Likewise, they identified symbiotic relationships that can provide some benefits for related parties such as consumers and partners. A recent discussion about using the ecosystems model to analyze the ICT sector is provided in Basole, Park, & Barnett (2015).

Hence, it is important to examine ICT ecosystems in order to understand the co-evolution between technological and economic as well as regulatory forces and developments and to provide a comprehensive basis for policy makers, For the purpose of understanding the structure of the ICT ecosystem in Luxembourg, it is suggested here to use a layer model described by Martin Fransman (Fransman, 2001, 2002a, 2002b, 2004, 2006, 2014). This model allows a clear identification of the different categories of actors within the system as well as the "interfaces" and relationships between those actors and thus provides a simple yet effective way to gain a good understanding of the different types of actors, their respective roles and importance to the sector as well the interrelations between them (see figure 1).

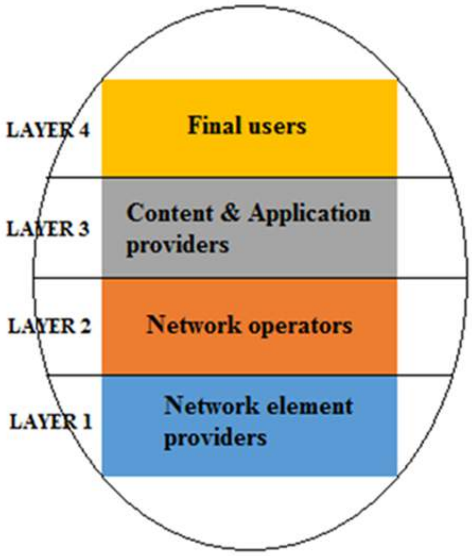

Fig. 1. The four-layer model

Fransman deliberately used the term ecosystem to stress the importance of the links between the various ICT actors. When looking at the supply side of the ICT ecosystem, four types of actors can be distinguished:

Layer I:	Network element providers (e.g. Cisco, Samsung, Alcatel-Lucent, Ericsson, Nokia Networks)
Layer II:	Network operators (fixed and mobile) (e.g. BT, Deutsche Telekom, Vodafone)
Layer III:	Content & application providers (e.g. Google, Apple, YouTube)
Layer IV:	Final consumers

In the "new ICT ecosystem" (i.e., post-internet), users are gaining a presence on the supply side of the system by co-creating with suppliers. In contrast to the so-called "old ICT ecosystem" (i.e. pre-internet), which could be described as a closed innovation system with the most important links being between network operators and network suppliers (Layers I and II), the new ICT ecosystem is more open, more dynamic and more complex. In recent years, the focus has shifted to the interaction between platform, content and application providers (Layer III) and the ecosystem has become more dynamic with the relationships between the different actors and the environment also becoming more complicated.

Acknowledging these developments, Fransman (Fransman 2007, 2010, 2011), in more recent works, has focused on the role of the dynamic, or as he calls them "symbiotic", relationships between the different layers and their role for innovation (Fransman, 2014). These relationships can be described as multi-dimensional representing financial and material flows as well as information and input flows into the innovation processes within the ecosystem (see figure 2).

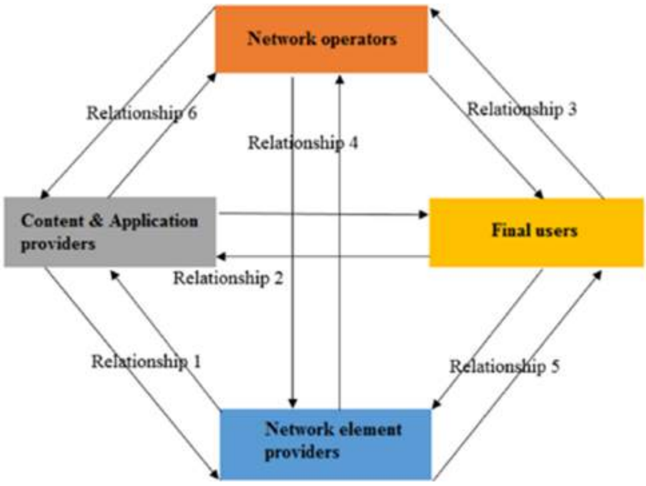

Fig. 2. Symbiotic relationships with the four-layer model

The Fransman model is not used very often by researchers in the field. Yet it is relatively simple and straightforward to apply as it builds on an ISO standardized layer model[2] which is largely used by IT engineers to explain interworking of computer and telecommunications networks. As such it provides a well-documented way of identifying the different actors and their activities which can easily be shared amongst ICT professionals as it is built on a common understanding. Furthermore, it allows to describe and identify the links and relationships between the different layers.

An example of how this model can be used to understand the interactions between different actors is provided by, for example, Arlandis & Ciriani (2010). It also includes a detailed database of players in the different layers but takes a high level view by looking at different economic cluster such as the EU, the US and Asia. Another application of the Fransman model can be found in Veugelers (2012). Here the model is used to understand why Europe's ICT companies are lagging behind the US with regards to the "leading platform providers who are capturing most of the value in the ICT ecosystem". It is argued that a very fragmented EU market, lack of entrepreneurial mind-set, as well as lack of risk capital are the main stumbling points to the

[2] https://www.iso.org/standard/16011.html accessed 8.4.2017

development of the ecosystem.

3 A brief introduction into Luxembourg's ICT ecosystem

There is an ongoing debate about what actually constitutes a small country and a summary of this discussion can be found, for example, in Roolaht (2012). Often indicators like size, population or GDP are applied. According to all of these indicators Luxembourg would actually constitute a very or even extremely small country and indeed it is one of the smallest within the EU with a land area of only 2,586 km2 and a population of 524,900 inhabitants (STATEC, 2013). When it comes to GDP/capita however, Luxembourg is one of the richest countries in the world (Thelen, 2012).

Following the OECD definition of ICT mentioned above, 7% of Luxembourg's Gross Value added is generated within the sector. This share is considerably above the EU-27 average which is around 4.6% of the total GVA and is the highest among EU member states (European Commission, 2013b). The country has not only a high proportion of highly skilled workers, but has also one of the highest shares of ICT-using occupations among OECD countries. The Luxembourg labour market has one of the largest shares of knowledge-intensive activities[3] in Europe, with 56% of all the jobs in 2011 falling into this category (Service des Médias et des Communications, 2013). With regard to ICT infrastructure and connectivity (Fransman's layers 1 and 2) Luxembourg has invested a considerable amount to build and efficiently operate multiple state-of-the-art high capacity fibre networks (see figure 3). This is to ensure national and international connectivity and connecting Luxembourg to major hubs in Europe (Service des Médias et des Communications, 2013).

By 2009 100% of Luxembourg's population was covered with 3G mobile networks, whereas in 2012 64% of the population were covered by the 4G network. Similar considerations apply to broadband connectivity and will be further developed, as, in its national strategy for very high-speed networks, issued in April 2010 (SMC, 2010a), the Government intends to increase the speeds of the existing networks, and provide, in the medium term, access to optical fibre in the entire territory. It is the Government's intention to transform Luxembourg into the first "fibred" country of the EU, if not in the world. Luxembourg has also grown into the premium location for data centre parks in Europe, with more than 19 data centres are operational (SMC, 2010b).

The 2015 STATEC bulletin on ICT in households and among individuals in 2014 (Bodson & Frising, 2015), highlights the recent expansion of social networks and cloud activities, especially among young people. In 2014, 60% of residents aged 16 to 74 participated in social networks, of which Facebook was the most popular as 57% of residents were active.

The Luxembourgish government has recognized the important role that ICT plays in national economic development. Luxembourg has, in recent years, experienced a major advancement with the accelerated development of the country's innovative technology companies, whether in the media sector, e-commerce, digital content, cloud computing,

[3] An activity is defined as being knowledge-intensive if the tertiary-educated persons employed represent more than 33% of the total employment in that activity (European Commission, 2013c)

big data or electronic payments (Kitchell, 2010).

The ICT sector has also become an economic player in its own right, attracting substantial foreign direct investments (see overview of main actors in figure 5) and is not merely limited to its function as a services provider to other economic sectors. In both ways, as an economic sector by itself and as a vector of competitiveness for all other socio-economic sectors, the ICT sector will play an important part in the modernisation, performance, competitiveness and efficiency of the country.

In order to strengthen and consolidate the country's position in the field of ICT and to transform its ICT sector into a 'high tech' centre of excellence, the Luxembourg government, in conjunction with ecosystem stakeholders, has recently presented a new digital strategy called “Digital Lëtzebuerg” (Bettel, 2014). This programme encompasses subjects as diverse as the computerization of government services and the development of new niche markets for new markets (big data, health technologies, innovation in services to the financial sector ("FinTech") as well as virtual currencies. The government accepts this strategy and has consistently sought to implement it across all its relevant policy areas (Gouvernment du Luxembourg, 2014b).

4 Methodology

Whilst all of the aforementioned tends to show that the ICT ecosystem in Luxembourg has developed very well over the course of the last 15 years, it is it not clear what have been the main reasons for this relative success and whether this evolution will continue in the future. Therefore, we have applied the Fransman model in order to explore the ICT ecosystem and to identify the different forces and relationships at hand.

In a first step, the main categories of actors have been identified (see table 1) in the different layers as well as the institutions that shape and influence the relationship between the different layers using a focus group of 9 experts. The outcome of this work resulted in a summary overview of the ICT sector in Luxembourg. This model was then discussed with different stakeholders and further developed by the lead author in an interactive and iterative manner which led to the model that is presented in figure 3 (below).

Applying Fransman to this model and focusing on the above mentioned “symbiotic relationships” within the ecosystem, it is possible to identify actors at the governmental and political level that shape the regulatory and policy environment for ICT within the framework of the regulatory packages set by EU (European Commission, 2014a). Similarly, the model also allowed us to identify the different state-owned agencies and institutions that provide support to the ICT sector in terms of public funding, awareness raising and training (upper box in figure 3).

The next level of actors concerns regulation in the broadest sense, including the National Regulatory Authority, the Competition Authority, the National Standards Agency, the Data Protection Commission as well as regulatory authorities for the financial sectors (right box in figure 3). The ICT ecosystem is also supported by R&D activities and organizations such as University of Luxembourg, public research centers but also venture capitalists and incubators (lower box).

Looking closer into the ecosystem itself, it is possible to identify ICT enablers that provide the underlying infrastructures, these include network element providers and network operators corresponding to the layers 1 and 2 of Fransman's model. Building on this, one can find the ICT service enablers that would fit within Fransman's third layer and the customers or users of ICT, of which some have been identified in the diagram above, correspond to Fransman's fourth layer. They include most of the actors in Luxembourg's well developed financial sector (KPMG, 2013). Finally, we can also identify several institutions or organizations, private and public, that are active in promoting the sector both nationally and internationally.

Building on the figure below, we have chosen to conduct a qualitative exploratory analysis (Cresswell, 2014; Easterby-Smith, Thorpe, & Jackson, 2012) using extensive unstructured and face-to-face interviews (Schultze & Avital, 2011) with a representative subset of the major stakeholders within the ICT ecosystem as identified through applying Fransman's model. The objective was to study the forces that shape the ICT ecosystem and to understand the interactions between the different layers and actors (symbiotic relationships).

A two stage approach was adopted, using the above mentioned focus group consisting of major industry and institutional players in order to establish an initial template through a SWOT analysis (Anderson, 2010; King, 1998). This SWOT analysis was then used to design open-ended questions to start the interviews and to assist in the later coding process of the outcome of these.

Using a qualitative approach has some limitations in terms of drawing generally applicable conclusion as discussed for example in Lincoln (1995) or Yin (2009). However, because of the small size of Luxembourg, it has been possible to interview a very wide and therefore representative set of stakeholders.

4.1 Identification of relevant actors

When identifying the different actors, the following criteria have been applied: size and relevance of actor, number of employees, specialization, access to key stakeholders, nationality (local or international), start-up or established actor, years of presence in Luxembourg, public or private ownership (full list in table 1 below).

Care was also given to take into the structure of ICT ecosystem which is presented in greater detail in for example Krylova (2015, p 41). She claims that "the majority of companies in the ICT sector are small (less than 50 employees), whereas the number of big companies contribute to less than 3% of market share". It was also considered that the number of actors in layer 2 and 3 is far higher than in layer 1.

4.2 Data collection and analysis

The recordings of the interviews, which usually lasted around 1 hour, were then imported into NVIVO, a computer aided qualitative data analysis software, to be processed (Bazeley & Jackson, 2007; Beekhuyzen, 2010; Neill, 2013; Welsh, 2002; Wong, Medicine, & Lumpur, 2008). As NVIVO allows the coding of the data directly in either text, pdf, audio or video files, it was decided to code straight on the audio content, transcribing and translating the main ideas and topics into text as well. Due to the multilingual workforce of Luxembourg, interviews have been conducted in four languages - Luxembourgish, French, German and English - and were partially translated. An advantage of NVIVO is that is allows almost instant access to any of the underlying data so that everything that has been said can be traced back directly from coded outcomes.

Coding started with the initial template from the aforementioned SWOT analysis but evolved over time. If and when a new topic emerged a new theme (code) was added in NVIVO. Interviews have been conducted until no further new codes or topics arose. Translation, partial transcription and coding took about 4 hours per interview. The use of NVIVO gives a lot of facilities, for example it allows immediate display all the codes per interviewee, it allow basic statistical analysis for example on frequency of codes, time spent on a specific message, how often a certain code or indeed expression has been used. It also allows for a graphical representation of interviews, the topics covered as well as the relationships between codes.

On the other hand, understanding and setting up the tool can be cumbersome, the raw data generate large files that are difficult to handle, the coding takes a lot of time and is necessarily somewhat subjective. As a consequence, based on some samples, coding verification has been undertaken. The tool, however, also has an "autocoding" function that could unfortunately not be used because of the respondents' use of different languages.

Table 1. Companies and institutions interviewed

Fransman's layer	Interviewed Organizations and Institutions	Individuals
I – network element providers	Alcatel-Lucent, Cisco, HP, Unify	4
II – network operators	Broadcasting Center Europe, British Telecom, Cegecom/Artelis (2), Eltrona (2), Fédération des Opérateurs Alternatifs Luxembourg, HotCity, Join Wireless, Post (2), Société Européenne des Satellites,Telecom Luxembourg	13
III - content and application providers	Association des professionels du secteur financier, Association des professionels du secteur de l'information, CTTL, Data4, Datacentre Luxembourg, Ebrc, Itrust, Luxconnect (3), Luxcloud, Netcore, Systemat, Telindus (2)	15
IV – consumers	Appolo Strategies, Association des Banques et Banquiers, Exxus (2), Gartner, Ikano, Fédération des Artisants,,Luxembourg Business Federation, ProNewTech, PwC	10
Outside influencers – finance, regulation, standardization	Interdisciplinary Centre for Security Networking and Trust (2), Institut Luxembourgeois de Regulation, Luxinnovation, Luxembourg Institute of Technology, Ministère de l'Economie, Moskito, Service des Médias et des Communications	8

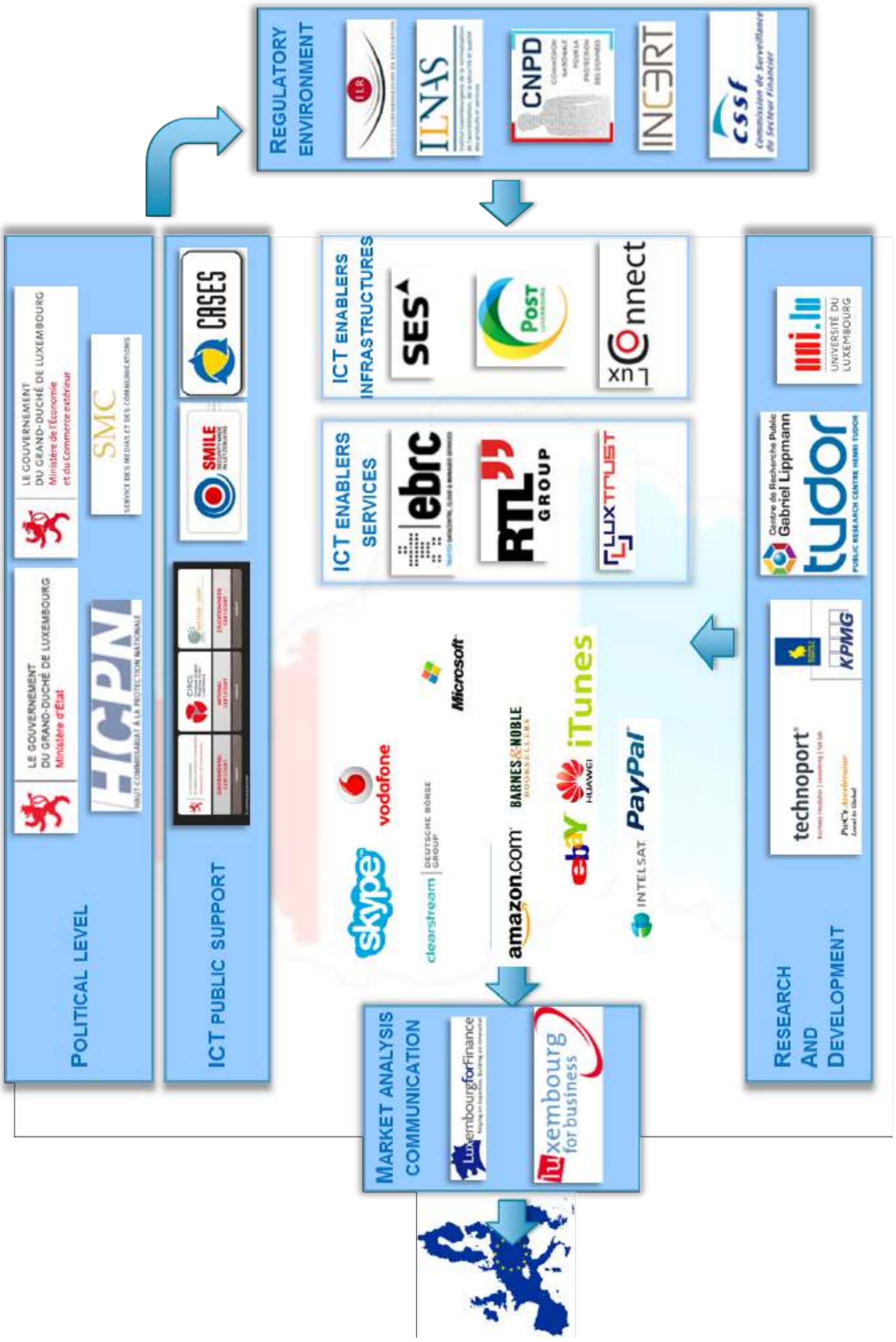

Fig. 3. Luxembourg's ICT Ecosystem (with a subset of major players) 5. Main forces shaping the Ecosystem

5 Main forces shaping the Ecosystem

The following section presents the outcome of the interviews with the different stakeholders identified in table 1. In a first analysis, the different issues mentioned were simply counted and the diagrams below show how often a given topic was mentioned. It is assumed that the frequency at which a certain topic was mentioned acts as a fair indicator for the relevance or importance of the issue. In addition, quotes have been extracted from the data and are also presented below in order to highlight and illustrate the importance of some of the major issues identified. A large majority of interviewees suggested that to make a difference between factors that Luxembourg and the actors in the ecosystem might have some control over (endogenous factors) and those that were "outside" of the ecosystem and driven mainly by the wider EU regulatory and the geopolitical competitive environment (exogenous factors). This structure is followed below.

5.1 Exogenous Factors

As shown in table 2 below, the interviewees identified primarily EU regulations as well as international competition as the major two external factors affecting the development of the local ecosystem.

Table 2. Examples of exogenous factors

"Our competitors are more aggressive, in particular the Dutch are real salesmen". "For security related topics Switzerland is a major competitor, they follow the same strategy as Luxembourg" **Head of international sales, incumbent operator**	"We should follow closely what is happening at EU level and implement changes quickly to gain a competitive advantage compared to other countries e.g. Big data, trust, security, this was traditionally a strength of Luxembourg and we should build on this" **CEO of cloud service provider**
"The Netherlands are more aggressive and more dynamic, Luxembourg is more "down to earth" **CEO Alternative Telecom Op.**	"The EU is pushing for single market, this means more competition within Luxembourg but we are not big enough to exploit the international opportunity" **Representative of alternative operator association**
"Almost all major European Cities are competing with Luxembourg" **Member of Management board of bankers association**	"Does Europe not have a general problem here - what is still left for us? " **CEO of small consulting company**
"The question is not what should the government do, but what are they still allowed to do" in terms of industrial policy "Luxembourg needs to do more lobbying at different levels in Brussels" **Representative of Business Federation**	"Low VAT has attracted a lot of customers, but this money has not been invested wisely and has not helped to develop IT sector" **CEO alternative telecom operator**

"EC is putting pressure on Luxembourg because of IP, but there are countries that do provide more tax advantages" **Director at one of the "big 4" consultants**	"EU regulations might limit what Luxembourg can do in the future ....even PSF might not be allowed. Why do we not push it on the EU level?" **Country director global telecom equipment provider**
"The whole competitiveness issue being discussed in Europe is really disadvantageous to small countries" **Representative of Luxembourg's university**	

The influence of EU regulations. A large majority of the stakeholders are well aware that the Luxembourgish ICT ecosystem is heavily influenced and evolves within the framework of the different EU regulatory packages (see, for example, European Commission, 1987, or European Commission, 2013b). These programs that have been put in place mainly in order to stimulate competition and the move towards a digital single market (European Commission, 2010).

This topic was mentioned on over 50 occasions. It was felt that often these EU regulations are not working in favor of the ICT ecosystems of a small country like Luxembourg and the pressure towards a single EU wide market favors large or indeed global players. In this context, the discussion about reducing or abolishing roaming charges for mobile communications within the EU was mentioned on 12 occasions and is widely reported in the press, see, for example, De Fooz (2014a) or Henry (2014b) The fact that there exist many restrictions with regards to access to on-line content and geo-blocking is largely applied by major content owners was also mentioned especially by stakeholders involved with TV offers (CATV or IPTV). This prevents Luxembourgish consumers from accessing such content legally (Boston Consultancy Group, 2013).

On the other hand, several stakeholders and, in particular, those more closely linked to the financial sector, mentioned the effect of the different VAT regimes on electronic commerce. This has had, so far, a positive influence on the development of the industry (PWC, 2011). However, these stakeholders were also aware that this effect is currently about to disappear in line with EU rules (Post Telecom, 2014).

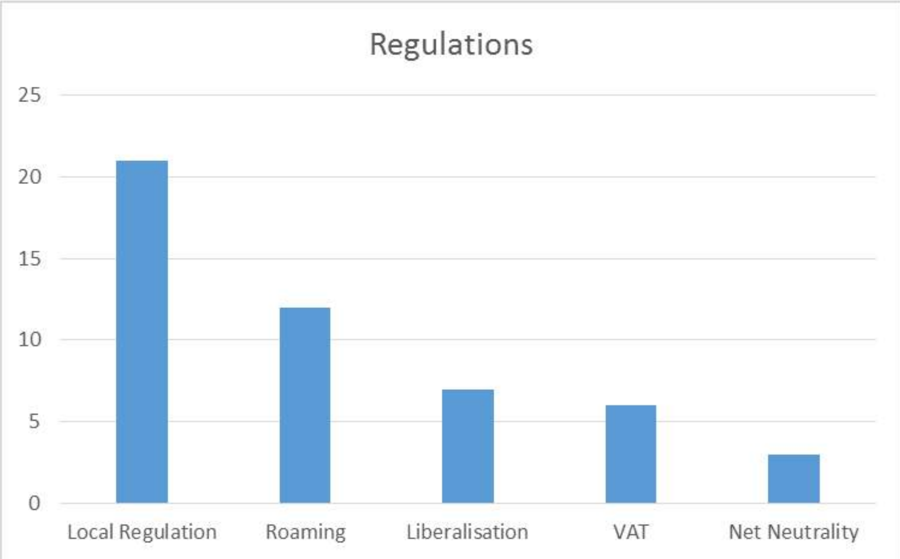

Fig. 4. Number of citations of different external regulatory/policy measures

Over 20 stakeholders identified issues related to the local implementation of the EU regulations and, amongst other things, it was felt that the national regulatory authority did not actively enough intervene in the market and did not have the necessary resources. This issue is also widely reported in the local press (Dard, 2013; Gaudron, 2011; ILR, 2013a; Le Jeudi, 2015; Poujol, 2013, 2014a) and is of particular importance to the telecommunications operators in Fransman's layer 3.

Growing international competition. In addition, international competition from different EU member states, both to attract ICT activities and on the export level, were also identified by about 20 interviewees and were said to be of growing importance. In this context, the main competitors identified were the Netherlands, Ireland as well as Luxembourg's immediate geographically neighboring countries (see figure 5 below). It was felt that competition was generally becoming more intense and that recent events around "Luxleaks" (Paperjam, 2014b; Raizer, 2014b), as well as Luxembourg's image as a "tax heaven", were negatively affecting Luxembourg's position (Guardian, 2014). It also becomes increasingly difficult to identify and communicate Luxembourg's unique selling points, with some actors commenting that a new marketing and communication strategy might be urgently needed (Bervard, 2015; Fondation Idea, 2014; Gouvernement du Luxembourg, 2014) and that the current promotion efforts needed to be better coordinated.

Overall, participants felt that both of these sets of external factors had a major influence on the ecosystem and suggested that Luxembourg, due to its small size, might be more vulnerable or exposed to the these forces that the Fransman model gives less emphasis to, as it focuses more on endogenous factors and the relationships internal to the ecosystem.

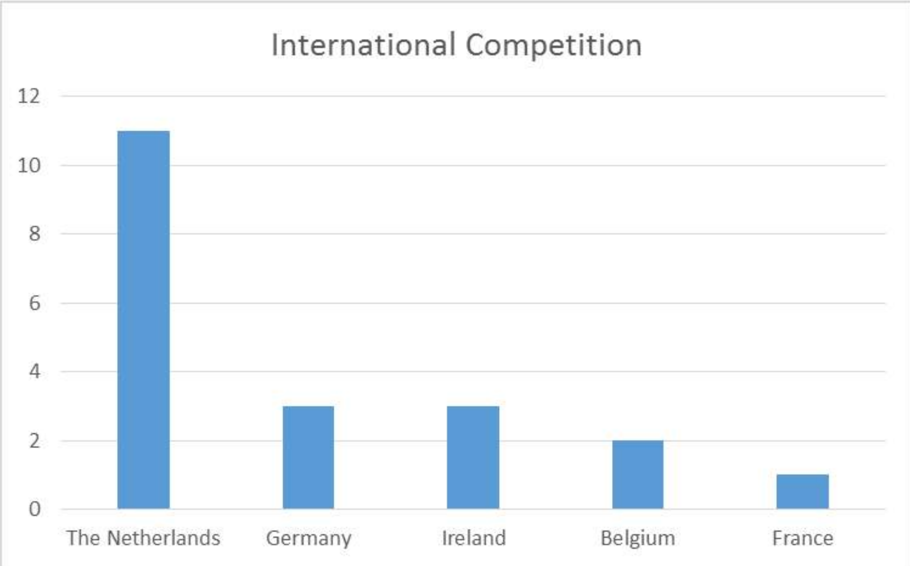

Fig. 5. International competition according to different countries

5.2. Endogenous Factors

Figure 6 below shows the endogenous factors that were mentioned by the different stakeholders as well as their frequency. It can be seen that these issues were mentioned far more often than the exogenous factors and the list of endogenous factors is much longer. It will, therefore, in the context of this study, not be possible to address them all in depth. Instead the objective of this paper, is to provide a broad overview and thus the following discussion will be structured by order of the importance expressed as measured by the number of times a certain topic was mentioned.

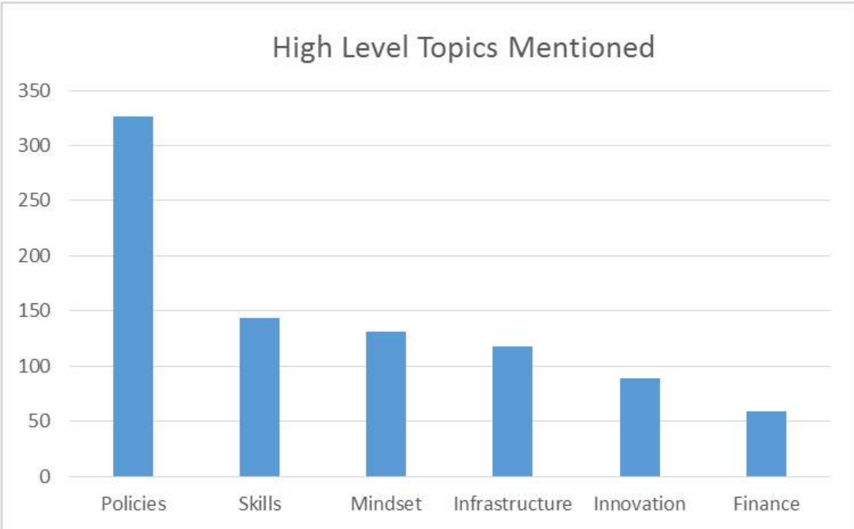

Figure 6 - Most important endogenous forces by number of mentions

Government Policies. A wide range of different policy initiatives have been identified and commented on as this subject was mentioned over 300 times. Examples of some of the main messages are presented in table 3 below.

There was, however, a large and general agreement that successive governments had taken ICT seriously and developed, as expressed by the World Economic Forum (World Economic Forum et al., 2015), a "vision for ICT" and launched a wide range of initiatives that have helped the sector to develop.

Table 3. Examples of policy issues mentioned

"A lot of efforts are made by the government to diversify the economy, there is a strong link as well between government and industry players due to the small size of the country." **Country director Gartner**	"We have different interfaces to the Government - we are not really represented on the important European Level etc....we only have a limited set of experts but we do not use them efficiently enough" **Professor at German University**
"The new government has a different approach and they seem to be more willing to find solutions to improve Luxembourg's position". **CEO Satellite Service Provider**	"Luxembourg is still very flexible and quick in creating the legal environment, perhaps we should have more resources to spot quickly enough the new opportunities" **Head of international sales incumbent operator**
"We have good infrastructures, a legal and in particular fiscal environment that is favourable but we need to improve	"Luxembourg is lacking a bit the creativity - it is not enough to focus on "Legal or regulatory" niches.

constantly" "Would E-archiving have been a good niche to enter into - well it took a lot of time to set up the legal environment and we still have nothing finalised" "One of the strengths of Luxembourg was and still is to a certain extend its ability to adapt quickly and flexibly the EU regulations (e.g. tax rulings)" **CIO global IT service provider**	"We have invested a lot in Biotech - this is not a very good investment - there is no local ecosystem and no industry that could take advantage of the research in this area" **CEO satellite service provider**
"We should develop our image as European Trusted Information Centre" **Country manager global telco equipment provider**	"Vision for ICT is there - there are some good ideas - we need more courage, we need more ambitions, a mindset change is needed" **Serial entrepreneur in ICT**
"We are missing an overall strategic plan although the government is shareholder in all 3 companies (RTL, SES, POST)" **Representative of Business Federation**	"We are flexible and small, access to politicians is easy, but what happens then?" **CEO datacentre provider**

Having said this, it was felt that more could have been done in terms of marketing and promotion of Luxembourg to the outside world and that the sector also needed a more coherent approach in terms of its representative bodies. Indeed, too many associations, forums, federations, clusters and agencies are claiming to represent their individual members' interests, but there is a lack of overall representation of the sector, both nationally as an interface to policy makers and internationally. In that respect, participants welcomed the recent creation of an overarching federation called ICT Luxembourg (Gaudron, 2014) as well as a new government strategic plan called Digital Lëtzebuerg (De Fooz, 2014b; Land, 2014) and expressed their hopes (and fears) that these initiatives might improve the situation.

Figure 7 (below) provides further details in terms of the policies initiatives that have been commented upon. Many participants, and in particular foreigners working and living in Luxembourg, identified its "smallness" as a major factor. This smallness leads to a high quality of life (low pollution, safety, nature, high standard of living) and, most importantly, to easy access to political decision makers implying the potential to react flexibly and quickly. On the other hand, many stakeholders also mentioned that this high standard of living also leads to high living costs and, consequently, high employment costs. In particular, housing has become extremely expensive making it difficult for young entrepreneurs to move to Luxembourg (Sorlut, 2014).

Several specific government initiatives were positively commented on. These included: the creation a specific status and certification for services providers to the financial sector (Deloitte, 2013), the focus on security, trust and data protection (Trân, 2013), initiatives around the usage and exploitation of big data (KMPG, 2014) and the legal framework on intellectual property rights (Raizer, 2014a). However, some people commented negatively on the fact the Luxembourg had still not managed to create a legal framework for "e-archiving"[4] (Cencetti, 2014a; Ministère de l'Economie et du Commerce Exterieur, 2013). Some participants also felt that more could have been achieved in terms of "e-government" (Gouvernement du Luxembourg, 2005) and "e-health" (Henry, 2014a; PWC Luxembourg, 2013). It was also suggested that too much effort and money was spent on biotechnologies (Gouvernement du Luxembourg, 2013) as Luxembourg had experienced difficulties positioning itself in this competitive industry.

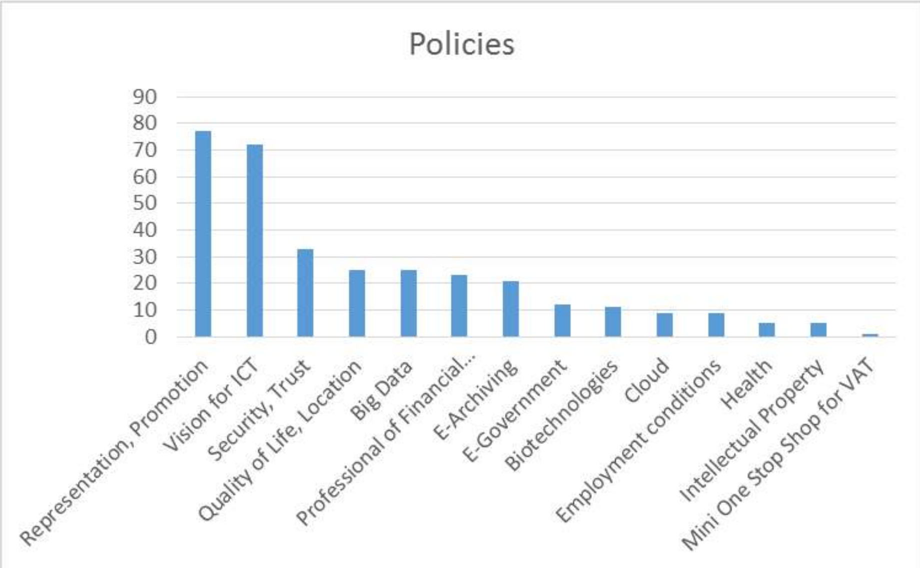

Figure 7 - Government policies identified according to number of mentions

Education and e-skills. The interviewees also insisted on the importance of relevant skills, both on a technical and scientific level but more generally the e-skills necessary to make the best use of ICT. It was found that Luxembourg has performed particularly badly on these "softer" elements. Participants actually complained about the fact that it became increasingly difficult to recruit the necessary employees on the local and even regional market, and that substantial effort was needed to attract such employees to Luxembourg. One or two interviewees identified missing e-skills as a major hindrance to their further growth and development. Several national studies are available to confirm this situation (Fedil, ABBL, & CLC, 2014; Gouvernement du Luxembourg, 2011). However, this topic also appears to be a major issue in surrounding countries and generally in Europe (European Commission, 2014b; Gareis et al., 2014).

[4] The relevant law finally passed the parliament in July 2015 (Poujol, 2014b)

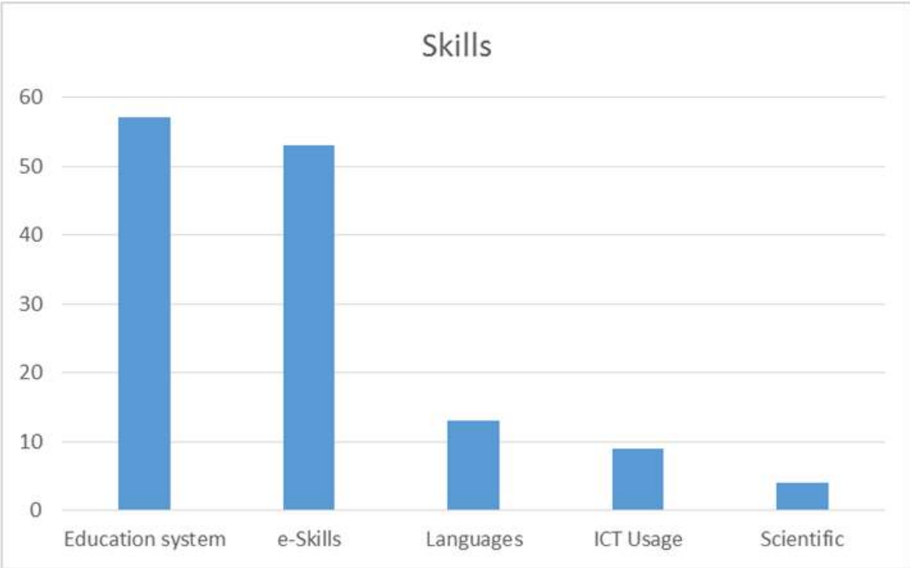

Fig. 8. Major issues related to education and skills according to number of mentions

Moreover, participants mentioned the lack of appropriate training and education within Luxembourg both in terms of software programming but also more generally in terms of technical and scientific education (European Schoolnet, 2012). Some also commented more broadly on the efficiency and effectiveness of Luxembourg's educational system, a system that is based on "tri-language" education and which needs some adaptations in the light of the quickly evolving social and technological environment (Gouvernment du Luxembourg, 2014a; OECD, 2014). Many of the participants highlighted the urgency of this issue and hoped that the government's new strategic plan would help to ease the situation (De Fooz, 2014c).

As an illustration of above, table 4 (below) provides a transcription of the statements made by some of the interviewees. This clearly shows that the topic is relevant at all level of the ecosystem and is also recognized by some of the education providers. Despite this apparent agreement, there is little agreement about what actually needs to be done and who should take this matter forward. Some participants argued for an initiative to be driven by the ecosystem actors themselves rather than by the different government ministries in charge. Independent from this discussion, all participants agreed that urgent action was needed as potential changes to the educational system could take several years before any noticeable effects emerge.

Table 4. Some of the main messages related to education and skills

"To develop the "digital business" we need first and foremost energy and cooling but in addition we have to be able to attract young talents full of ideas and competencies. The difficulty of Luxembourg is that it lacks attractiveness	"We need to promote the fact that there are 6 universities around us and that we have our own. But there is little companies that are created by these universities (seed-fund), there is no process, the professors are not motivated

for these people, they want to work hard and play hard, they want fun – we need to be able to attract them" **CEO Docler Holding**	to act in such a way" **CEO Data Centre provider**
"Parents are oriented their children into non-technical jobs" **Head of Sales Luxconnect**	To find the right people – quickly, this is the main issue" **CTO ICT Integrator**
"We are not hiring any local people anymore" **COO Media Services Provider**	"The is no cooperation between the educational system and industry" **CEO ICT Integrator**
"The Educational systems does not serve ICT" **University of Luxembourg**	"our schools are not producing the right profiles" **CTO ICT Integrator**
"English language should be more developed - rather than being multi-lingual we should be more international - we tend to become regional focussing on French, German and Luxembourgish, Public school in English would increase attractiveness tremendously" "We have a problem recruiting Non-EU staff, sometimes the process can take over six months" **Unit Manager University of Luxembourg**	" Our education system is expensive but not efficient, languages are still an advantage but there is an issue with English" **CEO Data Centre provider**

Mind-set. Stimulating entrepreneurship and facilitating the creation of start-ups were also mentioned as important elements for the development of the ICT ecosystem.

It was found that Luxembourg lacks both the necessary processes and procedures but, more importantly, an entrepreneurial mind-set and this subject was mentioned more than a hundred times in different guises.

Participants also identified a general mind-set issue in terms of the risk awareness particularly of the local population. Indeed, a lot of young people prefer a job as a civil servant in an administration or local community to, a sometimes less well paid, job in the private sector.

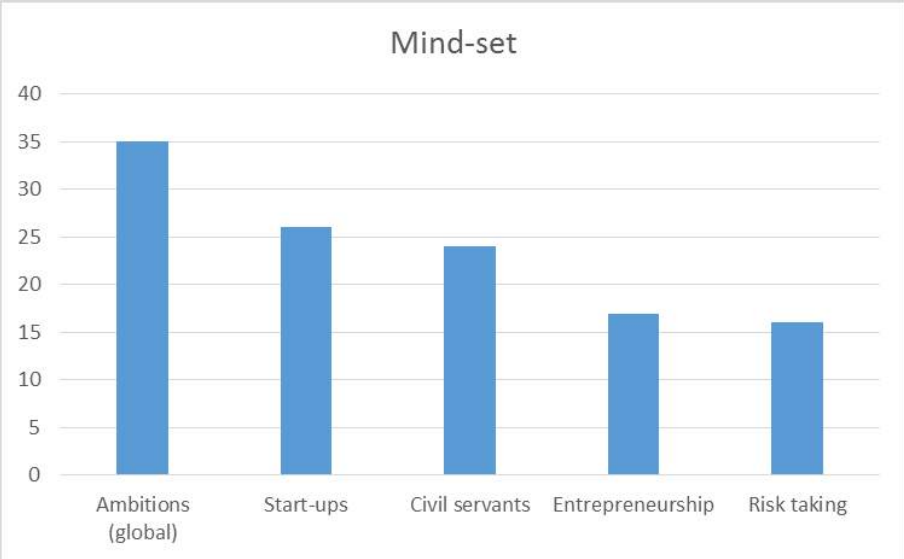

Fig. 9. Lack of entrepreneurial "spirit" according to number of citations

As for the education discussion detailed above, table 5 (below), provides examples of the comments collected during the interviews or collected from public statements. Again, all levels of the ecosystem are aware and somehow affected by this issue and it is interesting to note that even Luxembourg's prime minister is also aware of it.

Table 5. Some of the main messages related to "mind-set"

We are not ambitious enough - on an international scale we can do more. We have Luxembourg trade and investment offices in many places but we are not making best use of them. There is a lot of bright people but we are not using them. We are not clear what markets/customers to target? Where can we deliver an added value? **CEO Network Equipment provider**	"We are focussing too much on ourselves and we believe to be better than we actually are. We should question ourselves more because otherwise after a while it might be too late" "In Luxembourg unions are very strong and have major influence on political decisions" **CIO IT Service provider for IKEA**
"Luxembourg can only overcome its internal inertia with the help of foreigners but Government meetings tend to be closed to non-Luxembourgers because of language issues" **Head of MVNE Alternative Mobile Operator**	"Major projects are driven by civil servants that do not want to make any mistakes rather than by managers that see the business value for Luxembourg" **Member of management board of bankers association**
"Risk taking culture and mind-set is literally in-existent" **CEO Alternative Telecom Op.**	"We want to stay what we are" **Unknown – Luxembourgish saying**
"Luxembourgish people prefer a job as	"if a start-up fails everybody looks down

civil servant" **CEO Satellite Operator**	on it and it is very difficult to get another chance" **Prime Minister**

Innovation. Luxembourg's university, which is only 12 years old, was felt by many participants not yet to be fully aligned with the requirements of Luxembourg's economy (Paperjam, 2014a). It was also suggested that the same was true for the country's public research centers (Lambotte, 2014b). Technical, and in particular ICT education programs, are missing or very narrowly focused. There is also no business school attached to these programs (Luxemburger Wort, 2015).

There also have been only very limited creations of spin-offs or start-ups created through these institutions. It was felt that organizations facilitating these processes were not working efficiently (Cencetti, 2014b; Luxinnovation, 2013; Machuron, 2014) and that better coordination between them was needed. Many of the statements made have been recently confirmed in an OECD study about innovation policies in Luxembourg (OECD, 2015).

Luxembourg's financial center is well developed (Bourgain, Pieretti, & Høj, 2009; Merker, 2013) and this may explain that access to finance was not generally found to be major issue (IT One, 2014). Access to initial, high risk, venture capital was identified as being of some importance but overall the main problems seems to be the lack of initiatives and ideas for new start-ups rather than their financing (Antzorn, 2014b; Lambotte, 2014a; Machuron, 2014)

Infrastructures. Developing ICT infrastructures has been confirmed as an important building block for a successful ICT ecosystem. Participants agreed that Luxembourg has been doing very well on these elements, with extensive high-quality, high-resilience data center capacity (Service des Médias et des Communications, 2013), low-latency international connectivity and broadband internet access are in place and used both by private individuals and professionals - see table 6 for examples of statements.

Table 6. Some of the main messages related to infrastructures

"Perhaps we have focussed too long on infrastructures only. This is of course a very important element but an element only -without it we would not exist on the internet map" **Global CIO of IT service provider for IKEA**	"We have attractive electricity prices so far - this is a real advantage on an international scale. We do not produce electricity but we buy the cheapest and we have a small network leading to low transport charges" **CEO Cloud service provider**
"we focus too much on infrastructures, we are doing well in international rankings but the reality is a bit more nuanced". "we have everything we need to create an international media hub (RTL, SES, POST), why are we not developing this?" **Representative of Business Federation**	"Logistics is also an issue, relatively poor flight connections, more and more traffic jams" "Why have we spent that much money in T4 datacentres? This leads to a pressure to "sell-off" because the overcapacities are merely costing money. We have no clear strategy and positioning." **Head of International Sales incumbent telecom**

	operator
"The broadband plan was created for the residential market - but this is again strengthening POST, as indeed the CATV networks are not associated to this development, this was only again an "alibi" plan to explain to the EU that we are following the rules as we should" **Representative of alternative operators' association**	Infrastructures? Yes we are not experiencing any problem with this - however there is too much focus on the Tier4 datacentre segment - we also need lower availability solutions - which are then cheaper **CEO Security service provider**
"Datacentres - a very good initiative by the Government - Luxconnect is a real success, DRP sites are needed by all of the banks" **Representative of bankers association**	"…is there still a business for the pure international connectivity? is this not just a commodity, is this really a major differentiator?" **CEO international datacentre provider**
"Infrastructure is ok but Luxembourg risks to become a bit-pipe provider only. we have problems to deliver VAS" **CEO of public Wifi network provider**	

These need to be supported, however, by investments in complementary infrastructures such as transportation (Antzorn, 2014a) and energy distribution networks (ILR, 2013b). Some participants made critical comments about unused capacity, both in terms of international communication links and data centers and mentioned the lack of space for larger data centers of a lower quality standard (Labro, 2015). Some also suggested that perhaps too much focus had been given to providing fiber connectivity to each household as part of the government's broadband strategy (SMC, 2010a). A more focused approach, making more use of the already existing CATV networks, might have been more effective (Henry, 2013; OPAL, 2013).

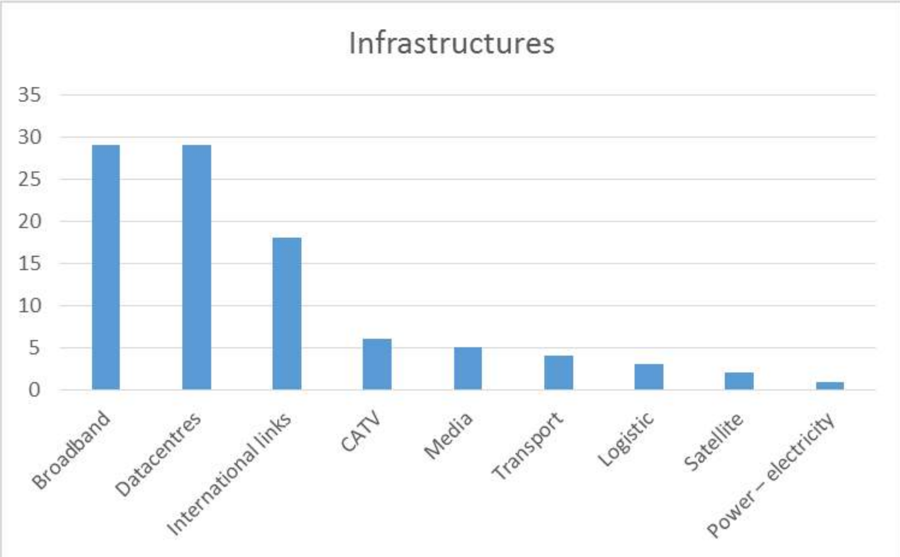

Fig. 10. Infrastructure related topics by number of citations

Participants were also asked how they saw the structure of the market following several years of liberalization and privatization efforts. It was felt by the participants to be very important to have an adequate mix of public and private investments, but that the incumbent operator after years of liberalization of the market was still very dominant. This could prevent both local investments as well as foreign direct investment par major ICT or telecommunications actors.

6 Discussions and conclusions

In this paper we have applied the layered model of Fransman to identify major industry participants within the different layers. An exploratory qualitative analysis building on interviews with over 50 participants in the ICT ecosystem in Luxembourg was undertaken.

Figure 11 (below) summarizes the main findings of the analysis. These have been derived using an inductive approach from the statements made by the interviewees. Interviewees have identified the different underlying internal and external forces. For some factors (green) the participants felt, to a large extend, that Luxembourg was performing well and that the ICT infrastructure as well the government's "vision for ICT" were considered to be particular strengths of Luxembourg. Educational topics, e-skills and the missing "entrepreneurial mindset" were identified as major weaknesses. Growing international competition was identified as the main external threat that the ICT ecosystem is currently facing.

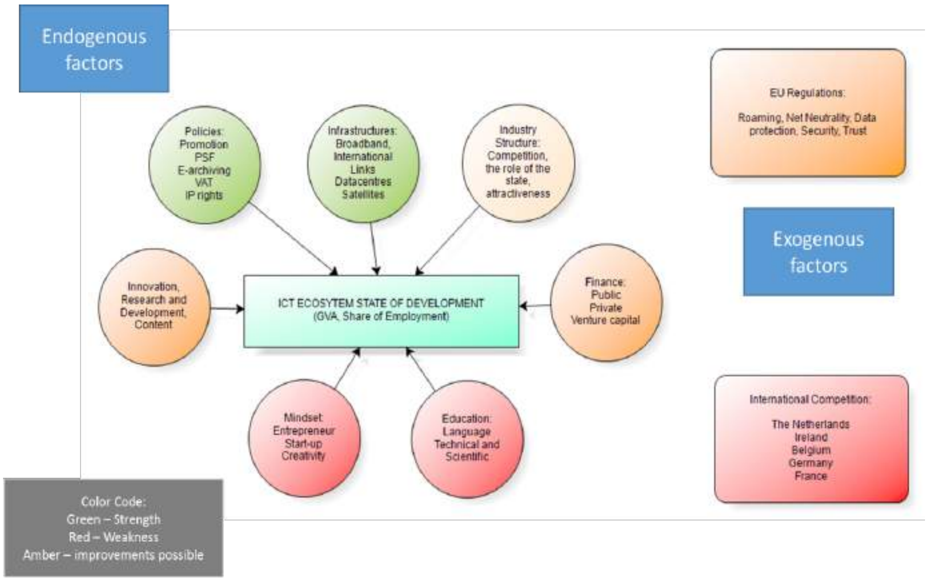

Fig 11. Summary overview of main forces affecting Luxembourg's ICT ecosystem

Participants confirmed that, according to them, Luxembourg has been successful in developing its ICT sector over the past 15 years, which is reinforced by international rankings and comparisons and 'official' reports. The government's initiatives have contributed to developing the underlying ICT infrastructures in terms of international connectivity, broadband and ultra-high broadband access as well as datacenter infrastructures. However, several participants also discussed the fact the success should not be defined and measured in terms of infrastructures alone and raised questions about the sustainability of this "kind of success". This was also confirmed by a recent public debate about the demand for datacenters (Labro, 2015) and uptake of broadband connectivity (Thiel, 2015).

Participants also confirmed that the industry structure has changed over time and that competition in several segments of the sector has increased. This competition has resulted in innovative products and services being offered at appropriate pricing levels, and these services have been adopted by both private users and enterprises. This, in turn, has led to the creation of jobs and added value for Luxembourg's economy. On the other hand, participants acknowledged that new challenges have appeared over time and that past policy initiatives may not be enough to sustain the sectors present set of competitive advantages. Clearly, Luxembourg is impacted by changes in EU rules and regulations which make it increasingly difficult to offer financial or tax advantages to companies investing in Luxembourg, and the government has faced some strong international pressures recently in that respect (Lecadre, 2014; Paperjam, 2014b; Raizer, 2014b, 2014c, 2014d). Consequently, it becomes more difficult to position Luxembourg successfully in the context of increased EU and even global competition and Luxembourg needs to make changes to its ICT ecosystem (Bervard, 2015).

Innovation, entrepreneurship, the willingness to take risks and to start new ventures also appear to be underdeveloped. This issue was also confirmed by OECD (2015). Most importantly, participants felt that changes would be needed to innovation policies and R&D orientation of Luxembourg, as well as to the legal and regulatory environment to better facilitate or event stimulate the creation of start-ups. This was also confirmed by a previous study in which, Meyer (2008) discussed the difficulties to establish for example a "productive" R&D environment in a small country like Luxembourg and concluded that it was very dependent on contributions from outside. There was also a wide consensus amongst participants that the strategy and vision of Luxembourg's university should be revisited and better adapted to the needs of local industry (Lalieu, 2015) and, in particular, its financial sector (Cencetti, 2015; Luxembourg for Finance, 2015).

Many factors could potentially contribute to the creation of 'unique selling points' for Luxembourg, but participants expressed concern that Luxembourg has been over reliant on developing its ICT infrastructures in terms national and international fiber connectivity and datacenters. Derived from interviews, we have also identified that Luxembourg has been unable, to date, to institutionalize an educational framework equipped to "produce" the necessary IT skills on a local basis due to a natural inertia in adapting the curriculums. Instead it has relied on importing knowledge from neighboring countries whilst focusing on its language skills and legal, financial and humanities education. In that respect the recent publication of the EU's digital economy and society index positioned Luxembourg in last position in the EU in terms students interested in technology, science and mathematics (Mateus, 2015). Different initiatives are now under discussion both on the supply side (new training programs, private schools, professional development) and on the demand side (promotion of Luxembourg as an attractive place to live and work) but all of these will take time to develop.

Finally, participants mentioned the relative lack of exploitation of the so-called "symbiotic relationships". One would expect that, due the small size of the country and the fact that access to political decision makers is quick and easy, ecosystem actors would be able to work closely together and establish both private and public-private partnerships and networks to develop the sector together as for example argued in Roolaht (2012). In practice, however, this is often not really the case as many of the larger actors are foreign and strategic decisions are taken outside of Luxembourg (Meyer, 2008). The government tries to improve this situation by, for example, the setting-up of several cluster initiatives (Federspiel et al., 2013) or the organization of common marketing and promotion activities in the context of economic missions (Luxembourg for Business, 2014).

6.1 Managerial and policy implications

Overall, the case of Luxembourg illustrates that it is important to examine the exogenous and endogenous dynamics of ICT ecosystems, which can reveal some nuances erased from international indices and high-level analyses, which could aide policymakers. The above analysis provides a first step and part of a wider effort to better understand the ICT ecosystem in Luxembourg, or in other small economies. The results are provisional as the research is on-going. Indeed, there is a need for deeper analysis of interview material for example by looking more deeply into the potentially different answers from actors within specific layers.

On the other hand, the conceptual framework presented in figure 11 can be applied in different settings and serve as a generic model to better identify and analyze the forces which shape for example ICT ecosystems within other small countries within the European Union.

6.2 Limitations and avenues for further research

The paper has benefitted from applying Fransman's model, which proved useful in identifying key stakeholders at different layers of the ICT ecosystem. It allowed the development of an overall summary diagram of the ecosystem (figure 3). It also allowed generating a representative sample of interview partners by strictly following the layer model.

The vast amount of qualitative data collected calls for a more in-depth analysis of the positions of actors within the different Fransman layers. Are there any similarities or differences in their respective views? Are some of the issues identified more important for actors of given layer? Are there any priorities that can be identified? A comparative analysis between the different layers might allow an even deeper understanding of the forces at play within Luxembourg's ICT ecosystem and the authors are currently developing their analysis further in that respect.

The Fransman model also had some limitations. It did not allow for example, the identification of all of the different subcategories that might have substantially different views and requirements within the different layers. Moreover, it is, by its very nature static and does not adequately cope with the dynamics of the ecosystem and recursive interrelationships that are manifold even during the short period covered by the study. Moreover, stakeholders can be – and are often –players in one, two or even more of the different layers and adopt a different position depending on the layer concerned. In addition, the model does not in itself give sufficient importance to external factors such as regulations or international competition. It does not, therefore, allow for the clear positioning of any supporting institutions and supporting agencies, such as for example, "Luxembourg for Business" or the different regulatory bodies as shown in figure 3.

These limitations notwithstanding, to the best of our knowledge, this is the first time that an in-depth analysis of Luxembourg's ICT ecosystem has been performed. This helps to redress the research imbalance, whereby small countries are often overlooked by scholars. Nevertheless, we contend that such "smallness" engenders a unique opportunity for research engagement with a majority of primary actors in ecosystems, which might be unfeasible in larger countries.

Comparative analysis, making use in particular of the conceptual framework in figure 11, of ICT ecosystems of small countries might be an interesting avenue of further research.

Furthermore, the general approach presented above, might also be transposed to other sectors or industries within Luxembourg and beyond.

7 References

Anderson, C. (2010). Presenting and evaluating qualitative research. *American Journal of Pharmaceutical Education*, *74*(8), 141. Retrieved from http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=2987281&tool=pmcentrez&rendertype=abstract

Antzorn, F. (2014a, March 4). 31 heures de temps perdu dans les bouchons. *Paperjam*. Luxembourg.

Antzorn, F. (2014b, June 24). L ' écosystème des start-up en à peine 300 clics. *Paperjam*. Luxembourg.

Arlandis, A., & Ciriani, S. (2010). How Firms Interact and Perform in the ICT Ecosystem? *Communications & Strategies*, *79*(3), 121–141.

Basole, R. C., Park, H., & Barnett, B. C. (2015). Coopetition and convergence in the ICT ecosystem. *Telecommunications Policy*, *39*(7), 537–552.

Bazeley, P., & Jackson, K. (2007). *Qualitative Data Analysis with NVivo*. *Sage Publications* (Vol. 2nd). Retrieved from http://www.loc.gov/catdir/enhancements/fy0728/2006936346-d.html

Beekhuyzen, J. (2010). The Nvivo Looking Glass : Seeing the Data Through the Analysis. *Qualitative Research*, 1–12.

Bervard, L. (2015, May 9). Es gibt kein Wundermittel mehr. *Luxemburger Wort*, p. 24. Luxembourg.

Bettel, X. (2014, October 20). Xavier Bettel présente l ' initiative " Digital Lëtzebuerg ." *Gouvernement Du Luxembourg*. Luxembourg.

Binsfeld, N., Whalley, J., & Pugalis, L. (2013). *Luxembourg – a bastion of state-ownership in Europe*. *International Telecommunications Society Regional Conference*. Brussels.

Binsfeld, N., Whalley, J., & Pugalis, L. (2015). Competing against yourself: State duopoly in the Luxembourg telecommunications industry. *Telecommunications Policy*.

Bodson, L., & Frising, A. (2015). *Les TIC dans les ménages et chez les particuliers en 2014*. Luxembourg.

Boston Consultancy Group. (2013). *Reforming Europe's Telecoms Regulation to Enable the Digital Single Market*. Brussels.

Bourgain, A., Pieretti, P., & Høj, J. (2009). *Can the Financial Sector continue to be the Main Growth Engine in Luxembourg ?* (No. 660). Paris. Retrieved from www.oecd.org

Briglauer, W. (2004). Generic reference model for the analysis of relevant communications markets: fundamental competition concepts. *Info*, *6*(2), 93–104.

Cencetti, J. (2014a, July 21). L ' archivage électronique, une nouvelle source économique. *IT Nation*. Luxembourg.

Cencetti, J. (2014b, September 24). Pour une meilleure coopération FNR et Luxinnovation. *IT Nation*. Luxembourg.

Cencetti, J. (2015, February 27). Fintech in Luxembourg – Powering a Paradigm Shift. *IT Nation*. Luxembourg.

Cresswell, J. W. (2014). *Research Design* (4th ed.). London: Sage Publications.

Dard, D. (2013, July 20). L'ILR n'a pas chômée en 2012. *Le Quotidien*, p. 5. Luxembourg.

De Fooz, A. (2014a, October 6). La fin du roaming, vraiment? *Soluxions*, pp. 14–15. Luxembourg.

De Fooz, A. (2014b, October 21). Digital Lëtzbuerg, en avant! *Soluxions*. Luxembourg.

De Fooz, A. (2014c, October 22). "e-jobs", manque de "soft skills"! *Soluxions*. Luxembourg.

Deloitte. (2013, November 27). PSF en 2013 : panorama et perspectives d ' un secteur en résilience. *Paperjam*. Luxembourg.

Easterby-Smith, M., Thorpe, R., & Jackson, P. (2012). *Management Research* (4th ed.). London, UK: Sage Publications.

European Commission. (1987). *Towards a dynamic European Economy Green Paper on the Development of the Common Market for Telecommunications Services and Equipment*. Brussels. Retrieved from http://ec.europa.eu/green-papers/pdf/green_paper_telecom_services__common_market_com_87_290.pdf

European Commission. (2010). *A Digital Agenda for Europe*. EU.

European Commission. (2013a). *Digital Agenda Scoreboard 2013 Electronic communications market indicators : Definitions , methodology and footnotes on Member States*. Brussels.

European Commission. (2013b). Digital Agenda Scoreboard key indicators. Retrieved from http://digital-agenda-data.eu/datasets/digital_agenda_scoreboard_key_indicators/indicators

European Commission. (2013c). *Measuring innovation output in Europe: towards a new indicator*. Retrieved from http://ec.europa.eu/research/press/2013/pdf/indicator_of_innovation_output.pdf

European Commission. (2013d, September 11). Commission adopts regulatory proposals for a Connected Continent. *Memo*. Brussels.

European Commission. (2014a). *Digital Agenda Scoreboard 2014 – Digital Performance of Luxembourg*. Brussels.

European Commission. (2014b). *e-SKILLS IN EUROPE Luxembourg Country report*.

European Schoolnet. (2012). *Survey of Schools: ICT in Education Country Profile Luxembourg*.

Federspiel, L., Martin, G., Dentzer, T., Hengen, J.-P., Klesen, M., Meisch, F., & Renotte, M. (2013, October 7). Luxembourg Cluster Initiative. *IT Nation*, pp. 1–29. Luxembourg. Retrieved from www.itnation.lu

Fedil, ABBL, & CLC. (2014). *Les TIC, ton job d'avenir! Edition 2014*. Luxembourg. Retrieved from http://www.tic-tonjobdavenir.lu/brochure/

Fondation Idea. (2014, July 2). "Nation Branding" - nouveau positionnement du Luxembourg. *Idée Du Mois 3*, pp. 1–16. Luxembourg.

Fransman, M. (2001). Evolution of the Telecommunications Industry into the Internet Age. *Communications & Strategies*, (43), 57–113.

Fransman, M. (2002a). Mapping the evolving telecoms industry: the uses and shortcomings of the layer model. *Telecommunications Policy*, *26*(9–10), 473–483.

Fransman, M. (2002b). *Telecoms and the internet age - from Boom to Bust to…* (1st ed.). Oxford: Oxford University Press.

Fransman, M. (2004). The telecoms boom and bust 1996-2003 and the role of financial markets. *Journal of Evolutionary Economics*, *14*(4), 369–406.

Fransman, M. (2006). *Global Broadband Battles*. (M. Fransman, Ed.) (1st ed.). Stanford: Stanford University Press.

Fransman, M. (2007). Innovation in the New ICT Ecosystem. *International Journal of Digital Economics*, (68).

Fransman, M. (2010a). The New ICT Ecosystem. *The New ICT Ecosystem: Implications for Policy and Relation*, (68).

Fransman, M. (2010b). *The New ICT Ecosystem - Implications for Policy and Regulation* (New and re.). Cambridge: Cambridge University Press. Retrieved from www.cambridge.org/9780521171205

Fransman, M. (2011). The evolving ICT industry in Asia and the implications for Europe. *JRC Technical Notes*, *63986*, 78. Retrieved from http://ipts.jrc.ec.europa.eu/

Fransman, M. (2014). *Models of Innovation in Global ICT Firms : The Emerging Global Innovation Ecosystems* (No. EUR 26774 EN). (M. Bodganowicz, Ed.). Luxembourg: European Commission.

Garcia, A. S., & Vicente, M. R. (2012). *ICT Technologies in Europe : A Study of Technological Diffusion and Economic Growth under Network Theory* (No. WP-AD 2012.21).

Gareis, K., Hüsing, T., Birov, S., Budlova, I., Schulz, C., & Korte, W. B. (2014). *E-skills for jobs in Europe: Measuring progress and moving ahead*.

Gaudron, J.-M. (2011, March 18). L' ILR change de tête. *Paperjam*. Luxembourg. Retrieved from www.paperjam.lu

Gaudron, J.-M. (2014, July 15). ICTluxembourg : « Une contrepartie homogène ». *Paperjam*. Luxembourg.

Gouvernement du Luxembourg. (2005). *Plan directeur de la gouvernance électronique*. Luxembourg.

Gouvernement du Luxembourg. (2011). Luxembourg e-skills 2011 repertory. Luxembourg: Gouvernement du Luxembourg.

Gouvernement du Luxembourg. (2013, October 10). Inauguration de LuxFold, société de biotechnologie, première start-up financée par le fonds Advent Life Science. *Press Release*. Luxembourg.

Gouvernement du Luxembourg. (2014, June 24). Francine Closener au sujet du " Nation branding ." *Gouvernement Du Luxembourg*. Luxembourg.

Gouvernment du Luxembourg. (2014a, February 10). Claude Meisch : “ Dem Bildungskrich en Enn setzen .” *Gouvernement Du Luxembourg*.

Gouvernment du Luxembourg. (2014b, June 5). Lancement de la stratégie “ Digital Lëtzebuerg ” par le Conseil de gouvernement des 3 et 4 juin 2014. *Gouvernement Du Luxembourg*. Luxembourg.

Guardian, T. (2014, November 5). Luxembourg tax files: how tiny state rubberstamped tax avoidance on in industrial scale. *The Guardian*. London.

Hallikas, J., Varis, J., Sissonen, H., & Virolainen, V. M. (2008). The evolution of the network structure in the ICT sector. *International Journal of Production Economics*, *115*, 296–304.

Henry, R. (2013, November 28). L’OPAL mitigiée sur le déploiement du ultra-haut débit. *IT Nation*.

Henry, R. (2014a, March 25). L’adoption de services e-santé progresse trop lentement en Europe. *IT Nation*.

Henry, R. (2014b, April 3). Le Parlement européen met fin au roaming. *IT Nation*. Luxembourg.

ILR. (2013a, September 25). ILR: des litiges à resoudre en un clic. *Paperjam*. Luxembourg. Retrieved from www.paperjam.lu

ILR. (2013b, September 26). ILR: un comparateur du marché de l’électricité. *Paperjam*. Luxembourg. Retrieved from www.paperjam.lu

IT One. (2014, April 15). Luxembourg, un environnement propice pour les start-ups. *IT One*. Luxembourg.

Karagiannopoulos, G. D., Georgopoulos, N., & Nikolopoulos, K. (2005). Fathoming Porter’s five forces model in the internet era. *Info*, *7*(6), 66–76.

Kim, H., Lee, J.-N., & Han, J. (2010). The role of IT in business ecosystems. *Communications of the ACM*, *53*(5), 151.

King, N. (1998). Template analysis. In *Qualitative methods and analysis in organizational research A practical guide* (pp. 118–134).

Kitchell, M. (2010). *Luxembourg as a Center for Online and ICT Business*. Luxembourg. Retrieved from http://www.investinluxembourg.lu/ict/download-free-reports-page?sid=632

KMPG. (2014, January 31). If Big Data is the new gold, could Luxembourg be the perfect safe? *KPMG Blog*.

Koslowski, T. G., Longstaff, P. H., Vidal, M., & Grob, T. (2012). Resilience Analysis of the ICT Ecosystem. In *23rd European Regional International Telecommunication Society conference; Vienna* (pp. 1–18).

KPMG. (2013). *Luxembourg Banks Insights 2013*. Luxembourg. Retrieved from http://www.kpmg.com/LU/en/IssuesAndInsights/Articlespublications/Pages/LuxembourgBanks-Insights2013.aspx

Krylova, S. (2015). *The ICT inventory in Luxembourg*. Université du Luxembourg.

Labro, T. (2015, March 18). Les datacenters à l’épreuve. *Luxemburger Wort*, p. 1+12,13. Luxembourg.

Lalieu, J.-M. (2015). Débat pour une Uni 2.0. *Paperjam*, pp. 20–22. Luxembourg.

Lambotte, S. (2014a, April 8). Start-up : forces et faiblesses du Luxembourg. *Paperjam*. Luxembourg.

Lambotte, S. (2014b, December 18). En tête de LIST. *Paperjam*. Luxembourg.

Land. (2014, June 6). Digital Letzebuerg. *Land*, p. 9. Luxembourg.

Le Jeudi. (2015, May 14). Opal tance l'ILR. *Le Jeudi*, p. 20. Luxembourg.

Lecadre, R. (2014, December). Luxleaks: J'ai agi par conviction, la cohérence était d'assumer. *Liberation*. Paris.

Li, F., & Whalley, J. (2002). Deconstruction Of The Telecommunications Industry : From Value Chains to Value Networks. *Telecommunications Policy*, *44*(9–10), 451–472.

Lincoln, Y. S. (1995). Emerging Criteria for Quality in Qualitative and Interpretive Research. *Qualitative Inquiry*, *1*(3).

Luxembourg for Business. (2013). *LUXEMBOURG and ICT : a snapshot*. Luxembourg. Retrieved from http://ict.investinluxembourg.lu/ict/luxembourg-and-ict-a-snapshot

Luxembourg for Business. (2014, October). Luxembourg's ICT and E-commerce environment. *Luxembourg for Business*.

Luxembourg for Finance. (2015). *FinTech in Luxembourg*. *Luxembourg for Finance Magazine*. Luxembourg.

Luxemburger Wort. (2015, August 19). Luxembourg Chamber of Commerce plans business college. *Wort*. Luxembourg; Rennes.

Luxinnovation. (2013, October 16). Luxinnovation: plus qu'une nouvelle image. *Paperjam*. Luxembourg. Retrieved from www.paperjam.lu

Machuron, C.-L. (2014, March 6). Luxinnovation : la boutique des start-up. *Silicon Luxembourg*, pp. 1–6.

Maitland, C. F., Bauer, J. M., & Westerveld, R. (2002). The European market for mobile data: evolving value chains and industry structures. *Telecommunications Policy*, *26*(9–10), 485–504.

Mateus, A. (2015). *DESI 2015 Digital Economy and Society Index Methodological note*. Bruxelles.

Merker, J. (2013). A sectoral approach to the Luxembourg economy The financial sector. In *Exploring the social. political and business environment of Luxembourg*. Luxembourg: AMCHAM, Luxembourg School of Commerce.

Meyer, M. B. (2008). The dynamics of science in a small country: the case of Luxembourg. *Science and Public Policy*, *35*(5), 361–371.

Ministère de l'Economie et du Commerce Exterieur. (2013, January 22). Archivage électronique : Étienne Schneider présente le projet de loi. *Paperjam*. Luxembourg. Retrieved from www.paperjam.lu

Neill, M. O. (2013). *The NVivo Toolkit*. Retrieved from http://explore.qsrinternational.com/nvivo-toolkit

OECD. (2011). *OECD Guide to Measuring the Information Society 2011*. OECD Publishing.

OECD. (2014, September 9). Regards sur l'éducation 2014: le Luxembourg dans la comparaison internationale. *Gouvernement Du Luxembourg*. Luxembourg.

OECD. (2015). *OECD Reviews of Innovation Policy Luxembourg 2015*. Paris.

Oestreicher, K., Walton, N., & Grove, H. (2012). *New Internet-Based Technology Ecosystems*. Worcester.

OPAL. (2013, November 28). Opérateurs alternatifs: «Ne nous oubliez pas!». *Paperjam*.

Paperjam. (2014a, June 10). Uni.lu: un déménagement sur fond de polémique. *Paperjam*. Luxembourg.

Paperjam. (2014b, November 6). LuxLeaks: le moment des ripostes. *Paperjam*. Luxembourg.

Partanen, J., & Möller, K. (2011). How to build a strategic network: A practitioner-oriented process model for the ICT sector. *Industrial Marketing Management*, *In Press,* 1–14.

Peppard, J., & Rylander, A. (2006). From Value Chain to Value Network : Insights for Mobile Operators From Value Chain to Value Network : Insights for Mobile Operators. *European Management Journal*, *24*(2).

Porter, M. E. (1990). Competitiveness: Challenging the Conventional Wisdom. *Harvard Business Review*, *68*(3), 190–192.

Post Telecom. (2014, July 20). Cutting through EU VAT Complexity. *Post Telecom Blog*. Luxembourg.

Poujol, V. (2013, December 10). Concurrence : fusion ou rapprochement avec l'ILR ? *Paperjam*.

Poujol, V. (2014a, June 16). ILR : 5 mois d â€™ attente puis plus de représentant privé. *Paperjam*. Luxembourg.

Poujol, V. (2014b, September 4). e-Archiving : une loi pour décembre au plus tard. *Paperjam*. Luxembourg.

PWC. (2011). *Luxembourg: an e-hub for Europe Opportunities and actions on the horizon 2015*. Luxembourg. Retrieved from http://www.pwc.lu/en/information-communication-technology/publications.jhtml

PWC Luxembourg. (2013, December 23). L'e-santé , bien plus qu'un projet informatique, un véritable enjeu de société. *Communiqué de Presse*. Luxembourg.

Quatraro, F. (2009). Martin Fransman: the new ICT ecosystem. Implications for Europe. *Journal of Evolutionary Economics*, *20*(2), 321–328.

Rafique, K., Yuan, C., Tareen, A. W., Saeed, M., & Hafeez, A. (2012). Emerging ICT Ecosystem - from Value Chain to Value Ecosystem. In *8th International Conference on Computing Technology and Information Management (ICCM),* (pp. 95–100).

Raizer, T. (2014a, August 22). Propriété intellectuelle : l'union fera la force. *Paperjam*. Luxembourg.

Raizer, T. (2014b, November 7). LuxLeaks: la deuxième lame du gouvernement. *Paperjam*. Luxembourg.

Raizer, T. (2014c, December 3). Corruption: Luxembourg progresse, avant LuxLeaks. *Paperjam*. Luxembourg.

Raizer, T. (2014d, December 14). LuxLeaks: l'inculpé s'explique. *Paperjam*. Luxembourg.

Roolaht, T. (2012). Innovation Systems in Small Catching-Up Economies. In *Innovation Systems in Small Catching-up Economies: New Perspectives on Partice and Policy* (pp. 21–38). New York: Springer.

Schultze, U., & Avital, M. (2011). Designing interviews to generate rich data for information systems research. *Information and Organization*, *21*(1), 1–16.

Service des Médias et des Communications. (2013). *Luxembourg & ICT - a snapshot*. Luxembourg. Retrieved from http://ict.investinluxembourg.lu/ict/luxembourg-and-ict-a-snapshot

SMC. (2010a). *Stratégie nationale pour les réseaux à « ultra-haut » débit*. Luxembourg. Retrieved from http://www.mediacom.public.lu/institutions/Institutions_nationales/smc/20100309_ngn/Strategie_nationale_pour_les_reseaux_a_ultra-haut_debit.pdf accessed 15th of January 2013

SMC. (2010b). *Why Luxembourg ? A Comprehensive Overview of the Regulatory, Economic and Lifestyle Advantges for ICT and Media Companies*. Luxembourg. Retrieved from http://www.investinluxembourg.lu/ict/download-free-reports-page?sid=632

Sorlut, P. (2014, January 23). «Les coûts, le défi au Luxembourg». *Paperjam*.

STATEC. (2013). *Luxembourg Figures 2013*. Retrieved from http://www.statistiques.public.lu/catalogue-publications/luxembourg-en-chiffres/luxembourg-figures.pdf

Thelen, C. (2012, December). PIB: interpréter les données avec prudence. *Paperjam*. Retrieved from www.paperjam.lu

Thiel, M. (2015). Das Glasfasergrossherzogtum. *Wort*, p. 22. Luxembourg.

Trân, A. (2013, June 10). Security as an infrastructure. *IT Nation*. Luxembourg. Retrieved from www.itnation.lu

Veugelers, R. (2012). *New ICT sectors: Platforms for European Growth?*

Welsh, E. (2002). Dealing with Data: Using NVivo in the Qualitative Data Analysis Process. *Forum Qualitative Sozialforschung / Forum: Qualitative Social Research*, *3*. Retrieved from http://www.qualitative-research.net/index.php/fqs/article/view/865/1880

Wong, L. P., Medicine, F., & Lumpur, K. (2008). Data Analysis in Qualitative Research: A Brief Guide to Using NVivo. *Malaysian Family Physician*, *3*, 14–20.

World Economic Forum, Dutta, S., Geiger, T., & Lanvin, B. (2015). *The Global Information Technology Report 2015*. (S. Dutta, T. Geiger, & B. Lanvin, Eds.). Geneva. Retrieved from www.weforum.org/gitr

Yin, R. K. (2009). *Case Study Research: Design and Methods*. (L. Bickman & D. J. Rog, Eds.)*Essential guide to qualitative methods in organizational research* (Vol. 5). London: Sage Publications.

Binsfeld, N., Whalley, J., & Pugalis, L. (2017c).

Playing the game: Explaining how Luxembourg has responded to the Networked Readiness Index.

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Playing the game: explaining how Luxembourg has responded to the Networked Readiness Index

Nico Binsfeld, Jason Whalley and Lee Pugalis

Abstract

Purpose – *Over the past decade or so, successive Luxembourgish governments have sought to develop the country's information and communication technologies (ICT) sector. In this paper, the authors will aim to examine how Luxembourg's relative position in the "Networked Readiness Index" (NRI), a key international benchmarking exercise published by the World Economic Forum, has evolved over time as these ambitions have been achieved. The paper also explores what policy initiatives could be implemented to further improve Luxembourg's ranking in the NRI.*

Design/methodology/approach – *A longitudinal case study-based approach, drawing on secondary data and the annual publication of the NRI between 2003 and 2016, was adopted.*

Findings – *Luxembourg's position in the NRI has improved from 27th in 2003, so that it now ranks among the top ten countries in the world. In particular, Luxembourg has substantially improved its position with regards to "infrastructure" and "international connectivity". However, there are also areas, mainly linked to education, the provision of human resources and policies that allow for and stimulate entrepreneurship where further improvements appear possible.*

Social implications – *The paper highlights the need for an overall, holistic, ICT development strategy. Such a strategy would cover not only cover infrastructural and technical aspects but also educational, social, regulatory and economic issues as well.*

Originality/value – *The paper charts the evolution over time of Luxembourg's position in an important international ICT index and identifies its current strengths and weaknesses in terms of the different elements that constitute the NRI. This paper represents the first attempt to investigate the position of a small country, which are often overlooked in the literature, in terms of its changing position and the policies developed and enacted by a national government.*

Keywords *Government policy, Case studies, Luxembourg, ICT sector, Networked Readiness Index*

Paper type *Research paper*

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1. Introduction

Academics and practitioners alike have given considerable attention to the measurement of "information" for policy, development and investment decisions. Many national and international organisations, such as the International Telecommunication Union (2015), Mateus (2015), OECD (2015) or the Partnership on Measuring information and communication technologies (ICT) for Development[1], produce rankings and assessments about the development of national ICT capabilities and infrastructure. These ranking indices can perform powerful policy-shaping roles, as the media fanfare and debates stimulated often provoke policy responses from governments. Moreover, politicians and policy makers often refer to such assessments to justify their decisions (De Fooz, 2014; Henry, 2014; Sorlut, 2014) or promote the comparative advantages of their country in relation to their international competitors (European Commission, 2015a, 2015b; Katz *et al.*, 2014; Lechman, 2009).

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For the measurement of the "information society", many proxies or indicators have been developed using aggregate statistics and the application of largely quantitative methods to gain insights into, amongst other things, e-Readiness, e-Leadership or the "digital divide". Taylor (2006) provides an introduction into the history of ICT indices starting in the early 1960s and the ongoing search for different information age indicators, which were subsequently called information technology indicators, including telecommunications, the internet, broadcasting and computing technology. Taylor notices that most of these indicators use statistical analytics to correlate multiple factors to identify relationships between information stocks, information flows and technology as well as other economic and social factors. Many indicators combine national and international empirical data sources. This raises the question of how to group these factors, how to define their relative weightings[2] and how to build combinations of these. Taylor (2006, p. 15) concluded that "the identification of approaches likely to yield meaningful data for developing an exploratory and predictive understanding of the interactions of key information proxies with other selected factors in the human environment" constitutes a "grand challenge" and subsequently argued for an organised collective effort and the development of a "coherent academic field of study" and in a first step to "establish mechanisms by which the relevant documents and datasets could be more easily accessed and become readily available, the various approaches systematically mapped, those interested could meet and exchange ideas and develop cooperative ventures, and stakeholders could discuss their needs and appraisal of the instruments and findings" (Menou and Taylor, 2006; Taylor and Zhang, 2007).

In this paper, we provide an overview of some of these indicators or indices and discuss their inherent limitations before looking in-depth at one of the most popular of such indicators, the Networked Readiness Index (NRI) that is published annually by the World Economic Forum (Baller *et al.*, 2016; Bilbao-Osorio *et al.*, 2014; World Economic Forum, 2015). We do this in the specific context of Luxembourg, one of the smallest countries in the world because Luxembourg has been trying over several years to improve its position within the NRI. Luxembourg's officials closely monitor the NRI and set the ambitious goal of positioning the country in the "top 10" of this index (Cencetti, 2014). Luxembourg is often overlooked in research despite its open and service-based economy, its central location in Europe, its influence in the EU as one of the founding members and its leading position in many international league tables in areas such as gross domestic product (GDP)/capita or quality of life (STATEC, 2016). Furthermore, Luxembourg could be compared to an economic or metropolitan region of larger countries, and, thus, looking at Luxembourg might help to provide insights into other small and open economies with similar features such as, for example, Singapore. We also provide a contribution to a better understanding of the ICT sector in Luxembourg to fill this gap in existing research. Finally, we provide an illustration of what governments might be able to achieve when coordinating their policy and financial efforts to improve their countries' positions in international rankings.

Government efforts and significant funds channelled to ICT developments (Binsfeld, 2013; Binsfeld *et al.*, 2014; SMC, 2010) have indeed allowed Luxembourg to reach, in 2015, a position among the top ten countries in the world in terms of the NRI (Gouvernement du Luxembourg, 2015b; Dutta *et al.*, 2015; Zoenen, 2015) as well as in the International Telecommunication Union's ICT Development Index (Henry, 2013; International Telecommunication Union, 2015; Iochem, 2014). The main objective of this paper is to identify Luxembourg's major strengths and weaknesses according to the NRI to draw lessons about the relevance of this index for understanding the ICT ecosystem and to identify areas in which additional policy initiatives could help further strengthen Luxembourg's position within this index.

The remainder of the document is structured as follows. The next section provides an overview and discussion of the literature regarding different ICT-related measurements and indexes. Section 3 discusses the NRI and its limitations, whereas Section 4 presents the evolution of Luxembourg's NRI ranking as well as its strengths and weaknesses according to the most recent NRI publications. Section 5 moves on to discuss the outcomes of this analysis and provides conclusions and recommendations for additional policy initiatives with the hope that these recommendations might help Luxembourg's officials to further improve its NRI position and thereby contribute to develop its ICT sector. The final section explores some wider implications and suggests avenues for further research.

2. Measuring information society: a grand challenge?

There is an extensive range of literature available on different ICT-related indices, and it is only possible to present here a small subset here[3]. In this section, therefore, we focus mainly on the discussion of the generic classification of indices, their underlying limitations and proposals for improving them, with the objective to illustrate the complexities and limitations of such indices.

Hanafizadeh *et al.* (2009b) established a detailed taxonomy of "E-readiness" measures. Like others before them, they identified the problem of defining what to measure and for what purpose and presented several different approaches. They classified measurement methods into measures that use questionnaires, measures that use statistical methods and mathematical analysis of secondary data; measures, which draw on historical analysis most for a specific country (or group of countries) and measures that use best practices and experiences from other countries. They identified sources of data according to six "dimensions", that is, infrastructure and access, access to and use of ICT by households and companies, E-Business, E-education, E-government and basic enabling and social indicators. A wide range of references and data sources are provided as well as a detailed list of indicators for each dimension. As such, this taxonomy is an excellent starting point for any discussion of ICT indicators.

Golinski (2012, p. 4) argued that the "monitoring of traditional telecommunications was relatively easy as there were a limited number of providers of services and two groups of consumers: private and business subscribers". Initially, the analysis of IT was straightforward because of less diverse hardware and limited "convergence" between different technologies. He builds on the "grand challenge" notion mentioned above and provides a typology of indicators according to whether these are ICT related, non-ICT related, quantitative or qualitative, hard or soft, demand or supply side related. He provides a good initial overview of the different sources and actors in ICT-related measurements, for example, the national statistic offices, regulatory authorities, international organisations and commercial companies. The main issues identified are improperly documented methodologies, weak and not generally agreed definitions, the lack of data sources in some countries, the lack of standards and the competition between authors of studies. Golinski (2012) further argued that it is probably best to use large sets of indicators from different sources to address not only the technological but also the related social, economic and political aspects. This multifaceted approach seems to be more appropriate for capturing the reality behind ICT, and this method seems to be the currently preferred one that is applied by many (official) institutions[4]. However, these sets of indicators are difficult to obtain, and this has led to a tendency of establishing so called composite indicators (CI).

Freudenberg (2003) presents and compares some of these indicators and discusses the positive and negative aspects of CI. He concludes with a comparison of the most popular composite indices in terms of their theoretical foundations, their structure, the quality of the underlying data, the difficulties in their interpretation and their ability to be independently verified. He finds evidence that, whilst there are some tools for evaluative research, which are worth being published and promoted, there also some popular indices for which the marketing aspects seem to dominate over their factual knowledge.

Vaezi and Bimar (2009) classified "E-readiness assessment models[5]" into "E-economy" and "E-society" oriented ones. They argued that there is no single most suitable approach but that the right tool is contingent on the user's needs. All models have limitations, but, ideally, indices "should provide a set of measurements for the range of factors that influence e-readiness, they should describe how these measurements can be used, they should clearly describe how to apply the tool depending on the different users' needs and it should indicate how to use the results, including identifying potential difficulties with implementation" (Vaezi and Bimar, 2009, p. 8).

Along the same lines, several authors have commented on the many limitations of ICT indicators. Minges (2005), for example, focussing on Latin America and the Caribbean, also provided a summary of the main e-indices available at the time. He also compared the underlying "purposes and objectives" for different models and discussed the question whether a "general framework" would exist and came up with the following categorisation: infrastructure (networks, pricing, quality), usage (intensity and type), education (literacy, school enrolment, ICT labour), policy/regulatory environment (specific to ICT and also more general in nature), ICT sector (output, productivity, investment) and socio-economic (GDP, governance).

Minges (2005) also pointed to some methodological issues like subjectivity, limited availability of data, questions about underlying data collection processes and unclear definitions of what to measure[6], statistical flaws, errors made in data transformation and calculation of rankings and most important the weightings (implicit or explicit) of the different sub-indices or individual indicators.

Similarly, the Global Information Society Watch, an organisation for the collaborative monitoring of implementation of international (and national) commitments made by governments towards the creation of an inclusive information society, has discussed in several documents the limitations of the ICT indicators (de Munck, 2009, 2010; Jensen and Mahan, 2008; Mahan, 2007). They focussed on the use and potential misuse of such indicators for advocating policies or political approaches and showed that indicators are not neutral. They provide, for example, illustrations of the missing consideration of gender, human rights issues, press freedom or green ICT and propose adaptations to include such topics into existing frameworks. They show that ICT indicators can depend on the authors' beliefs, intentions and limited knowledge. The numerical expression of underlying issues creates an impression of objectivity, which may be misleading.

Schlichter and Danylchenko (2014, p. 1) also looked at four specific indices (including the NRI) and concluded "that they fail to highlight the deep meaning of ICT usage and to distinguish between its manifests". Consequently, they propose an integrated framework that incorporates the actual levels of ICT usage to obtain a better understanding of the level of information society development within a country.

Many researchers have not only discussed the limitations of ICT indicators but also proposed extensions or improvements to the models of which Table I (below) provides a non-exhaustive summary. It can be seen, through the many adaptions proposed, that academics have adopted over time increasingly sophisticated approaches and techniques to rank countries. Whilst these initiatives present some potential for improving information society measures, they have not yet led to internationally accepted methodologies and generally available data sets. For some of these proposals, it is far too cumbersome to collect the underlying data on a recurring basis so that no comparisons over time are possible. Often, the underlying data may not be available for all countries. It can be questioned, therefore, whether all these efforts have really helped to lead to a better understanding of the digital economy and what the ranking of the different countries really means.

Table I Examples of some extensions and improvements proposed over time

Author(s)	*Adaptations proposed*
Grigorovici and Taylor (2004)	Use of advanced statistical techniques like structured equation modelling (SEM) to address the issue of weighting of sub-indices and factor analysis to reduce the amount of input variables
Vehovar *et al.* (2006)	A multivariate log-linear modelling, compound indices, a time distance approach, as well as more inclusion of qualitative methods
Barzilai-Nahon (2006)	Argued for the use of "compound" or "comprehensive" indicators over the "mono-topical"
Mutula and Van Brakel (2006)	Developed an "information rich" tool with different "segments": enterprise e-readiness segment, human resources e-readiness segment, information readiness segment, ICT readiness segment and external environment readiness segments
Al-mutawkkil *et al.* (2009)	Inclusion of broadcasting infrastructures, parametric approach using factor analysis for the weightings
Hanafizadeh *et al.* (2009a)	Used 37 other information society and digital divide models and used the knowledge embedded in these models as proxies for expert's opinions to define the weighting to the different contributing indicators
Hanafizadeh *et al.* (2009b)	Use advance data mining methods, Markov Chain Monte Carlo for aggregating the indicators and multi-stage factor analysis for aggregating the indicators avoiding thus the use of equal weighting or the need to rely on experts' opinions
Kyriakidou *et al.* (2013)	Applied structured equation modelling to define their ICT maturity level index based on three sub-indices: access, use and skills
Hilbert *et al.* (2010)	Argued for the need to extend the scope of analysis beyond equipment or infrastructure availability to include information processing power
Mateus (2015)	Digital Economy and Society Index tries to assess the actual uptake and use of the digital technologies and infrastructures by identifying five different aspects: connectivity, human capital, use of internet, integration of digital technology and digital public services
Gerpott and Ahmadi (2015)	Use a partial least square structural equation modelling approach to construct the weighting of 11 "first-level" indicators into the "telecommunications development index"

3. The Networked Readiness Index

Bearing in mind the difficulties and limitations identified above, we focus in the rest of the paper on the NRI. It was published for the first time in 2001 and developed by the Harvard Business School with a survey of initially 75 countries. From 2002 (Dutta *et al.*, 2003), this survey was extended and coordinated by INSEAD and is published on an annual basis along with comments and discussions of various topics in the so-called *Global Information Technology Report* (Baller *et al.*, 2016; Bilbao-Osorio *et al.*, 2013; Bilboa-Osoria *et al.*, 2014; Dutta *et al.*, 2015).

Since 2003, Luxembourg has also been included in the list of countries assessed, and, since 2009, the full details of the NRI and its different underlying variables are available free of charge[7]. The NRI and the Global Information Technology report receive a lot of attention in the media (Iochem, 2014) and are often regarded by the media and politicians as being the most authoritative and comprehensive assessment of how ICT shapes the competitiveness and wellbeing of nations.

The NRI measures the propensity for countries to exploit the opportunities offered by ICT. The index seeks to better understand the impact of ICT on the competitiveness of nations and is a composite of three components:

1. the environment for ICT offered by a given country or community (market, political, regulatory and infrastructure environment);
2. the readiness of the country's key stakeholders (individuals, businesses and governments) to use ICT; and
3. the usage of ICT among these stakeholders.

A set of variables is collected and divided into four sub-indexes or pillars:

1. the general political, regulatory, business and innovation environment;
2. readiness defined in terms of infrastructure and digital content;
3. affordability and skills, usage by individuals, businesses and government; and since 2012; and
4. economic and social impacts (Dutta and Bilboa-Osoria, 2012).

The different indicators are derived from quantitative data such as Eurostat, International Telecommunications Union, OECD and as well from qualitative surveys and interviews that are conducted globally by local partner organisations. The exact number of indices as well as the split between survey and statistical sources vary from year to year, as does the number of countries included in the survey. A ranking is established based on the combination of the different sub-indexes not considering any specific weighting (other than the number of indicators per sub-index). World Economic Forum (WEF) does not provide all details of their underlying methodology, which makes it difficult to replicate the results while providing WEF with a "competitive advantage" over those who would wish to replicate it. This, of course, somewhat hides its underlying objectives and purposes and makes it a bit difficult to criticise its methodology.

Nevertheless, the NRI has received a wide range of criticism. Minges (2005) and Vehovar *et al.* (2006), for example, have pointed out the methodological issues related to aggregated indexes: subjectivity, limited availability of data, the underlying data collection processes and unclear definitions of what to measure, statistical flaws, errors made in data transformation and calculation of rankings. Perhaps the most important criticism has been reserved for the weightings (implicit or explicit) of the different sub-indices or individual indicators. Quite simply, how are they determined and susceptible are the outcomes to (minor) changes in the weights?

More specifically, Goswami (2006) questioned the relevance of some of the underlying indicators and identified some that were, from his perspective, missing such as, for example, the degree of competition in the market or the performance of the national regulatory authority. Schlichter and Danylchenko (2014) argue that the NRI focusses too much on "readiness" measures and does not sufficiently consider the actual "ICT usage" by individuals or companies.

Along the same lines, the Austrian national regulatory authority for the telecommunications sector (RTR, 2011) criticised the scaling between 1 and 7 of most of the indicators and the fact the categories between 0 and 1 and between 6 and 7 are not achieved. They also questioned the "objectiveness" of the surveys conducted by the local partners as these can have an important impact on the outcome of the study. How are, for example, the interviewees chosen and what were the actual questions asked? How skilled are the interviewers as these are different persons in each country? Another key question raised about the methodology reflects the fact that the interviewees will not be the same persons over time, so, quite simply how comparable are the answers given? What about those respondents that are only sent a questionnaire and not even interviewed, which is the case for Luxembourg?

On the other hand, some of the indicators are very difficult to influence through political or business decisions, and some might take a long time before changes can be measured.

The implicit weighting of the different indicators is also a matter of criticism, for example, in the 2010 version only three indicators were used to measure usage of governments as opposed to 16 for businesses and 17 for individuals. For some indicators, the measurement range varies from year to year, as it is set by the lowest and the highest value achieved in a specific year. Additional problems arise with the ranking as a confidence interval (two standard deviations) must be considered, and this is dependent on the actual sampling size. Sometimes the absolute differences between countries are very small and thus the ranking may not be statistically correct.

Kauffman and Kumar (2005) also question the validity of some of the underlying indicators used, as these may come from different sources and, therefore, may not be entirely comparable internationally. On a more general note, Luyt (2006) questioned the whole idea of a competitive ranking between different countries and commented that the business aspects seem to be more prominent than the needs of individuals.

Despite of these limitations and criticisms, the NRI is a popular tool for policy and business decision makers as well as when drawing comparisons between different countries. It is well documented in the media[8], as it provides a single CI to measure ICT performance and to establish a country ranking. It is published annually by a well-established and renowned body and covers a wide range of countries with the consequence that it is useful for benchmarking and rankings. It can also be accessed freely and its constituent indicators are disclosed although the methodology is only partially documented. In particular, Luxembourg's officials have closely monitored its evolution (Diederich, 2001) and set the ambitious goal to position the country in the top 10 of this index (Cencetti, 2014; Gouvernement du Luxembourg, 2015b)[9].

4. The evolution of Luxembourg's Networked Readiness Index position between 2003 and 2016

In the following section, we focus on Luxembourg and present the NRI and its evolution over time for Luxembourg with the objective of identifying how Luxembourg's position has changed over time and what have been or are its strengths and weaknesses according to the different NRI pillars. As discussed above, this time series analysis needs to be treated with care as the methodology, the number of countries and the split between quantitative and qualitative measures has considerably evolved and continues to change nearly every year.

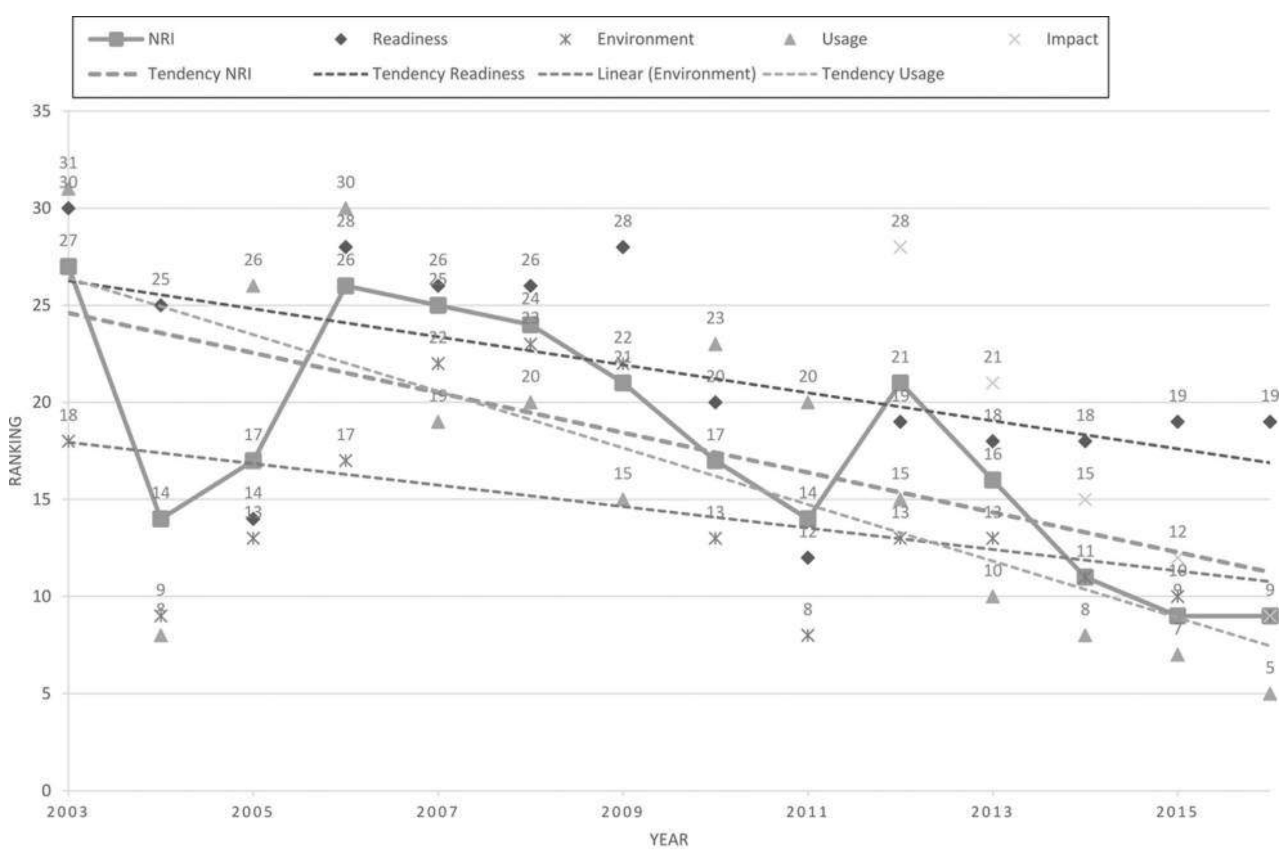
At this stage, it is also worth highlighting some operational details about the underlying data collection process and its limitations, which are not disclosed publicly but which we have been able to collect directly form the organisation involved in the data collection process in Luxembourg. Indeed, the data are being collected on an annual basis, using an online survey, as subset of the much more extensive "global competitiveness report" (Schwab, 2013). An online questionnaire is sent out to about 700 people that are supposed to constitute a representative sample of the Luxembourgish economy. However, only about 100 of these respond to the survey. Therefore, the outcome constitutes a snapshot of the "feelings" of the different respondents, and there is no guarantee that year-on-year the same 100 people respond to the survey. It would appear from the results that Luxembourgish natives tend to be more critical about the local situation, whereas foreigners living and working in Luxembourg take overall a more optimistic view. Given the relatively small sample size, it is not impossible to influence the results by actively contacting some of the respondents and discussing their views with them. It was also reported that some countries are indeed analysing the underlying measures in depth and try to create a policy environment that is aligned with the questions posed such as, for example, the number of days to set-up a business.

Bearing this in mind, Table II and Figure 1 show the actual values of the NRI and for its sub-indexes environment, readiness, usage and (since 2012) impact, as well as the rankings in the different pillars. A percentage change has been calculated between 2003

Table II Networked readiness index evolution over time (source: World Economic Forum)

NRI and its pillars	*2003*	*2004*	*2005*	*2006*	*2007*	*2008*	*2009*	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*	*2016*	*% change 2003-2016 (or latest year)*
NRI	4.55	4.76	1.04	0.8	4.9	4.94	5.1	5.02	5.14	5.22	5.37	5.53	5.6	5.7	*25*
Rank	*27*	*14*	*17*	*26*	*25*	*24*	*21*	*17*	*14*	*21*	*16*	*11*	*9*	*9*	
Environment	4.81	4.64	1.44	1.24	4.62	4.67	4.82	5.33	5.5	5.27	5.25	5.31	5.4	5.5	*14*
Rank	18	9	13	17	22	23	22	13	8	13	13	11	10	9	
Market Environment	3.79	4.27	1.14	0.86	4.46	4.86	5.02	5.4	5.41						43
Rank	33	8	19	22	24	20	16	4	3						
Political and regulatory environment	5.03	5.17	1.4	1.19	5.31	5.44	5.39	5.99	6.06	5.79	5.77	5.73	5.8	5.9	17
Rank	15	10	13	22	22	18	13	4	5	5	4	4	3	1	
Infrastructure environment	5.59	4.48	1.78	1.67	4.1	3.71	3.84	4.59	5.02						−10
Rank	3	18	10	12	22	35	29	19	18						
Business and Innovation environment										4.75	4.73	4.9	5	5	5
Rank										27	34	29	27	27	
Readiness	4.93	4.96	0.94	0.51	5.05	5.29	5.26	5.09	5.17	5.86	5.79	5.91	5.9	5.9	*20*
Rank	*30*	*25*	*14*	*28*	*26*	*26*	*28*	*20*	*12*	*19*	*18*	*18*	*19*	*19*	
Individual readiness	5.07	5.04	0.85	0.83	6.05	6.07	5.95	5.22	5.44						7
Rank	32	28	20	24	18	24	27	25	22						
Business readiness	5.12	5.19	0.54	0.29	4.82	4.79	4.78	4.82	4.76						−7
Rank	22	25	27	35	29	38	39	30	22						
Government readiness	4.61	4.65	1.44	0.42	4.29	5.01	5.05	5.23	5.32						15
Rank	28	28	7	33	32	21	18	10	7						
Infrastructure and digital content										6.17	6.43	6.29	6.3	6	*−3*
Rank										13	12	17	18	26	
Affordability										5.74	5.61	5.73	5.7	6	5
Rank										36	48	56	50	36	
Skills										5.66	5.33	5.73	5.8	5.9	4
Rank										31	33	27	18	20	
Usage	3.9	4.67	0.75	0.66	5.02	4.87	5.21	4.65	4.74	5.26	5.62	5.73	5.8	5.9	*51*
Rank	*31*	*8*	*26*	*30*	*19*	*20*	*15*	*23*	*20*	*15*	*10*	*8*	*7*	*5*	
Individual usage	4.57	6	1.36	1.66	4.93	4.72	5.69	5.82	6.05	5.91	6.47	6.43	6.5	6.8	*49*
Rank	8	1	13	13	9	9	4	5	3	7	4	5	6	2	
Business usage	3.56	4.62	0.8	0.74	5.38	5.18	5.29	3.94	4.16	5.03	4.97	5.27	5.4	5.4	52
Rank	49	19	25	30	26	27	23	28	18	18	16	13	11	15	
Government usage	3.56	3.4	0.09	−0.42	4.76	4.7	4.64	4.19	4	4.83	5.41	5.48	5.4	5.4	52
Rank	52	43	48	73	31	25	27	41	42	20	13	10	11	9	
Impact										4.5	4.81	5.17	5.3	5.4	*20*
Rank										28	21	15	12	9	

Figure 1 Evolution of NRI over time



Source: World Economic Forum

and 2016 – calculating intermediate values was problematic as even the scaling has changed over time. It can be seen that on most indicators, as well as on the so-called pillars, Luxembourg has improved over time and on some occasions this improvement has been substantial. There are only four pillars for which this not the case: infrastructure environment – which is surprising as most of the government initiatives have gone into the development of infrastructure – business readiness and skills. With regards to the affordability pillar, Luxembourg's position has stayed more or less constant since 2003, which shows that the pricing levels of the underlying services have not really decreased.

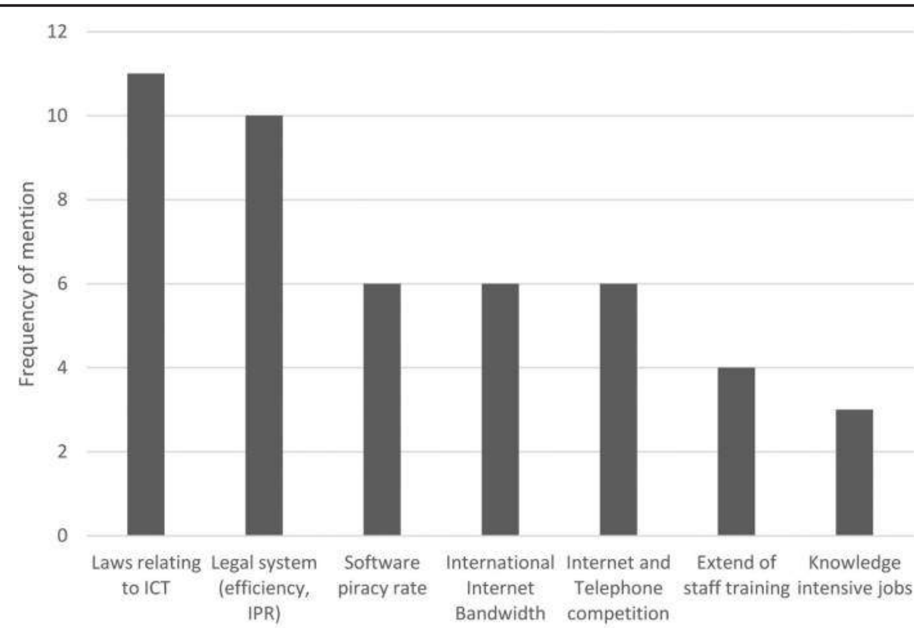
In terms of the absolute ranking, the long-term tendencies are also pointing towards improvement and Luxembourg's position has improved from 27 to among the top 10 countries in the world. However, in the period between 2005 and 2010 this did not appear to be the case. Luxembourg, although improving in absolute terms, declined relative to its competitors. It would, however, appear that the efforts made by politicians and regulators have been able in recent years to counter this trend and have put Luxembourg amongst the top ten countries in the world (Dutta *et al.*, 2015). Examining the policy initiatives that subsequent governments have taken over time (Binsfeld *et al.*, 2015), it can be seen that this was the period when Luxconnect, a second state-owned telecommunications operator, was established and became operational. Indeed, in 2006, the government decided to directly invest into telecommunications networks infrastructures by creating a network operator and providing it with the necessary capital to build alternative national and international fibre optical networks as well as data centres.

This public intervention can be considered as a general economic policy to increase Luxembourg's ICT competitiveness, and, considering the upcoming financial crises in 2008/2009, it was also expected to be a counter cyclical investment that would stimulate the recovery of the economy. For a more detailed discussion about this process see, for example, Binsfeld *et al.* (2014) and Zahlen (2016). Apparently, this initiative has helped to improve Luxembourg's overall position substantially, as it did create a significantly improved national and international connectivity as well as datacentre capacity. This stimulated competition, which, in turn, attracted many new telecommunications operators and service providers (Binsfeld, 2013). In addition, the government also initiated its ultra-high broadband strategy that sought to develop large scale fibre connectivity to almost all of the country's business and private users (SMC, 2010).

4.1 Strengths

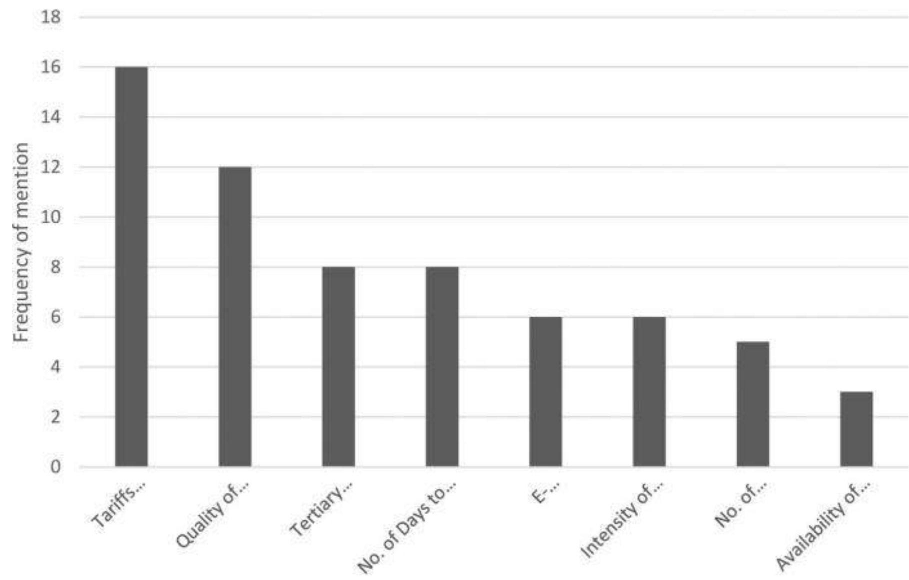
By looking in more detail into the individual components of the four pillars[10], it is possible to identify Luxembourg's main strengths (Figure 2) and weaknesses (Figure 3) and the Appendix. According to the 2016 report (Baller *et al.*, 2016), Luxembourg's main strengths seem to be related to its small size and its flexibility in adapting to market changes and its telecommunications infrastructure. This is demonstrated by the fact that most households, businesses and the government administrations are using computers and the internet. The government's willingness and vision to develop ICT appears to have been successful as documented by the fact that laws relating to ICT, the government's vision and the efficiency of the legal system are identified several times amongst Luxembourg's strong points between 2009 and 2015[11]. In addition, the availability of the latest technologies – next generation broadband access, 4G – as well international connectivity are also mentioned several times as is the high percentage of knowledge-intensive jobs that might be due the

Figure 2 Main strengths between 2009 and 2016 according to the number of times mentioned



Source: World Economic Forum

Figure 3 Major weaknesses identified between 2009 and 2016 according to the number of times mentioned



Source: World Economic Forum

requirements of the financial sector. Finally, Luxembourg is amongst the top ten countries with regard to specific laws for intellectual property exploitation (Figure 2).

4.2 Weaknesses

On the other hand, many of the weaknesses (as shown in Figure 3) appear to be linked to education as Luxembourg scores badly on "tertiary education, management schools", "tertiary education gross enrolment data" and the "overall quality of the educational system". Although these issues are not directly linked to ICT, they appear to have had a major impact on Luxembourg's current NRI position. So far, this issue has not received prominent attention on the digital policy agenda in Luxembourg. It is only quite recently that the government launched a new overall strategic initiative called "Digital Lëtzebuerg" (Antzorn, 2014; Bettel, 2014; Land, 2014) and tried to address this with specific actions such as "Digital4Education" (Gouvernement du Luxembourg, 2015a) at the level of formal education and continuous professional development. These initiatives may contribute to improving the situation in the years to come but will not have any immediate effect at it generally takes a long time before curricula are adapted and students re-oriented towards new areas.

In addition, the prices of some ICT services are comparatively high and, therefore, could limit the uptake of such services. This issue seems to be linked to the fact there is only limited competition in specific segments of the market, which may be the consequence of the small size of the country. Another important weakness appears to be linked to establishing a new business venture as it is reported several times that Luxembourg performed poorly on the "number of days to start a business" indicator. This can take a long time and there are cumbersome procedures in place that must be gone through to establish a business in Luxembourg.

Finally, electricity production has been identified to be, or to potentially become in the future, a major issue. Luxembourg does not produce any electricity locally and this makes the country dependent on electricity generation elsewhere in Europe (Figure 2).

5. Discussion

The analysis undertaken in previous sections has shown how Luxembourg has successfully improved its position on the NRI over the course of the past 13 years. In both 2015 and 2016 Luxembourg was ranked by the World Economic Forum as being among the top ten networked ready countries globally. Drawing on this analysis, it is possible to identify a series of lessons, some of which are limited to the specific context in which Luxembourg finds itself, whereas others are of more general interest.

A series of government initiatives have contributed to the development of the underlying ICT infrastructure, in terms of international connectivity, broadband and ultra-high speed broadband as well as datacentres (Binsfeld *et al.*, 2014). Competition in several segments of the ICT ecosystem has increased, which has led to more appropriate pricing levels and a good level of take-up of these services. This can largely be attributed to the creation of Luxconnect as a second state-owned operator with the consequence that the state competes with itself rather than relying on market forces (Binsfeld *et al.*, 2015). Luxembourg has, however, not developed local electricity production capability and instead relies on imports from surrounding countries. Currently, this can be seen as an advantage as the local energy prices are amongst the lowest in the EU (Enovos Luxembourg, 2014). However, in the long run, this may not be sustainable as the country is completely dependent on foreign electricity providers. Thus, the first lesson we can draw is the importance of infrastructure based competition for improving a country's NRI position. Significantly, this infrastructure is wider than ICT.

Luxembourg has not been able to establish the needed educational programmes and institutions that would allow to produce the necessary IT skills on a local basis. Instead Luxembourg has relied on the importation of knowledge from neighbouring countries whilst focussing on its language skills and legal, financial and humanities education. This is increasingly a significant obstacle to continuing the further development of the ICT sector and further improvement of Luxembourg's position on the NRI. In a recent publication of the Digital Economy and Society Index (European Commission, 2015c), Luxembourg appeared last amongst EU member states in terms of the percentage of students embarking on the technical, scientific or mathematical studies that are often considered to form the basis of ICT skills. Different initiatives are under discussion within Luxembourg (Bettel, 2014; Land, 2014), both on the supply side (new training programmes, private schools, continuous professional development and vocational training) and on the demand side (promotion of Luxembourg as an attractive place to live and work, stimulation of e-skills amongst young age children). These will, however, take time before they become effective and provide the necessary skills. Thus, a second lesson that can be drawn is that skills are equally as important as infrastructure.

Concerning changes in the legal and regulatory environment that would facilitate the start-up of new businesses, the situation is a bit similar as a major change in terms of commercial law would be required. Currently, if an entrepreneur goes bankrupt, he or she is forbidden by law from starting a second (new) venture. Such a change would have to be accepted by all relevant stakeholders and political parties. It would, once again, take time to get these stakeholders on board and make the necessary changes to the legal framework. This gives rise to a third lesson that can be drawn, namely, the need to engage with all relevant stakeholders.

Overall, the case of Luxembourg's position in the NRI illustrates that to be in the ICT "premier league" a holistic policy approach is necessary. It is not enough to rely on the development of basic ICT infrastructures and the fostering of competition. The development of complementary infrastructures such as electricity generation is also necessary and, perhaps most importantly, efforts are required on a social level in terms of, for example, education systems and priorities, the promotion of ICT usage and the development of e-skills.

6. Conclusions

Through examining the NRI this study has allowed an initial, albeit high level, assessment of the forces at hand within the ICT ecosystem and provides an indication of how successful or not Luxembourg has been in developing its ICT sector over the course of the past dozen years. This analysis has been based on focussing on the evolution of Luxembourg's NRI position. This paper represents, to the best of our knowledge, the first attempt to investigate the position of a small country, which are often overlooked in the literature, in terms of its changing position and the policies developed and enacted by a national government.

Given the many critiques and limitations of ICT-related aggregated indices in general, and the specific limitations of the NRI, this analysis is far from definitive and needs to be confirmed by additional research. This additional research could take the form of including the views and opinions of actors in the ICT ecosystem in Luxembourg (Binsfeld *et al.*, 2015). While the small size of Luxembourg has facilitated direct access to the sector's major stakeholders and decision makers, the scope of this research could be expanded. Luxembourg's position on the NRI index could be compared with other indices such as those published by the ITU or EU. This, however, must be done with care, as the underlying information may not be readily available for different countries or regions on a yearly basis.

On the other hand, the analysis has also shown how publicly available secondary information might be used to understand and assess underlying policy decisions and how this information can help to set the scene for further, more in-depth investigations. It is, therefore, questionable whether it is productive to develop, as illustrated in Table I, an ever more complex and specific indices and measurement tools to understand the digital economy. Often these evaluations are based on underlying data that could be difficult to collect and compile and may end up being of poor quality. For some of these complex indices, it can be far too cumbersome to collect the underlying data on a recurrent basis so that no comparisons over time are possible. Also, the underlying data may not be available for different countries so that internationals comparisons may not be very reliable or meaningful. It can be questioned, therefore, whether all these efforts have really helped to lead to a better understanding of the digital economy and what the ranking of the different countries really means. Thus, care needs to be taken when drawing comparisons, not only on the same indices but also between them. This should not be taken as suggesting that drawing high level comparisons should cease but rather carefully entered into.

Bearing in mind these comments, the present paper provides an illustration of how a widely available index such as the NRI can be used to extract potentially valuable conclusions for policy makers and politicians. There are, however, not many such studies currently available in the academic literature, with one such example being (Park *et al.*, 2014) who look at South Korea and use its digital divide index. The relative paucity of such studies suggests that there is certainly scope for additional research.

Notes

1. See www.itu.int/en/ITU-D/Statistics/Pages/intlcoop/partnership/default.aspx
2. For example by expert's opinions or some elaborate statistical methods such as structured equation modelling (Hair *et al.*, 2010).
3. Over 50 different ICT-related indicators are presented in, for example, Pena-Lopez (2009) which is an excellent and complete reference document.
4. National Regulatory Authorities, National and international statistical offices, International organisations.
5. Of which the NRI is one example.

6. For example, models include from 3 to 12 different indicators for the relatively straightforward aspect of infrastructure.
7. See www.weforum.org/reports (accessed 9 July 2016).
8. For example, a Google search for the term revealed over 160,000 results, accessed 8th of January 2017.
9. This was confirmed via an interview with the head of Service des médias et des communications (SMC) in May 2014.
10. Detailed data are only available between 2009 and 2015 (inclusive).
11. The data are only available for free for this period in time.

References

Al-mutawkkil, A., Heshmati, A. and Hwang, J. (2009), "Development of telecommunication and broadcasting infrastructure indices at the global level", *Telecommunications Policy*, Vol. 33 Nos 3/4, pp. 176-199.

Antzorn, F. (2014), "Feu vert pour la stratégie ICT et Digital Lëtzebuerg", *Paperjam*, 4 June.

Baller, S., Dutta, S. and Lanvin, B. (Eds) (2016), *The Global Information Technology Report 2016: Innovating in the Digital Economy*, World Economic Forum, Geneva, available at: www3.weforum.org/docs/GITR2016/WEF_GITR_Full_Report.pdf

Barzilai-Nahon, K. (2006), "Gaps and bits: conceptualizing measurements for digital divide/s", *The Information Society*, Vol. 22 No. 5, pp. 269-278.

Bettel, X. (2014), *Xavier Bettel présente l'initiative 'Digital Lëtzebuerg'*, Gouvernement Du Luxembourg, Luxembourg.

Bilbao-Osorio, B., Dutta, S. and Lanvin, B. (Eds) (2013), *The Global Information Technology Report 2013: Growth and Jobs in a Hyperconnected World*, World Economic Forum, Geneva, available at: www3.weforum.org/docs/WEF_GITR_Report_2013.pdf

Bilboa-Osoria, B., Dutta, S. and Lanvin, B. (Eds) (2014), *The Global Information Technology Report 2014: Rewards and Risks of Big Data*, World Economic Forum, Geneva, available at: www3.weforum.org/docs/WEF_GlobalInformationTechnology_Report_2014.pdf

Binsfeld, N. (2013), "The Luxembourgish telecommunications market", *Cahier Scientifiques Revue Technique Luxembourgeoise*, Vol. 1, pp. 24-37, available at: www.revue-technique.lu

Binsfeld, N., Whalley, J. and Pugalis, L. (2014), "Luxembourg a bastion of state ownership", *25th European Regional Conference of the International Telecommunicatons Society (ITS)*, Brussels, 22-25 June 2014.

Binsfeld, N., Whalley, J. and Pugalis, L. (2015), "Competing against yourself: state duopoly in the Luxembourg telecommunications industry", *Telecommunications Policy*, Vol. 40 No. 8, pp. 791-803.

Cencetti, J. (2014), "Comment positionner le Luxembourg en top 10 de l'IT?", *IT Nation*, 4 September.

De Fooz, A. (2014), "Xavier Bettel veut faire de Luxembourg une 'smart nation'", *Soluxions*, 19 November.

de Munck, S. (2009), "Measuring progress", *Global Information Society Watch 2009*, Association for Progressive Communications (APC) and Humanist Institute for Cooperation with Developing Countries (Hivos), pp. 43-45, available at: www.giswatch.org/sites/default/files/GISW2009.pdf

de Munck, S. (2010), "Indicators for measuring green ICT", *Global Information Society Watch 2010*, Association for Progressive Communications (APC) and Humanist Institute for Cooperation with Developing Countries (Hivos), pp. 43-55, available at: www.giswatch.org/sites/default/files/GISW2010.pdf

Diederich, J. (2001), "The 10 critical success factors", *Paperjam*, 2 May.

Dutta, S. and Bilboa-Osoria, B. (Eds) (2012), *The Global Information Technology Report 2012: Living in a Hyperconnected World*, World Economic Forum, Geneva, available at: www3.weforum.org/docs/Global_IT_Report_2012.pdf

Dutta, S., Geiger, T. and Lanvin, B. (Eds) (2015), *The Global Information Technology Report 2015: ICTs for Inclusive Growth*, World Economic Forum, Geneva, available at: www3.weforum.org/docs/WEF_Global_IT_Report_2015.pdf

Dutta, S., Lavin, B. and Fiona, P. (Eds) (2003), *Global Information Technology Report 2002-2003: Readiness for the Networked World*, Oxford University Press, Oxford, available at: http://ictlogy.net/bibliography/reports/projects.php?idp=401

Enovos Luxembourg (2014), "Gaz et électricité au plancher", *Paperjam*, 20 March, p. 1.

European Commission (2015a), *A Digital Single Market for Europe*, European Commission, Brussels.

European Commission (2015b), *Digital Agenda Scoreboard 2015: Luxembourg*, European Commission, Brussels.

European Commission (2015c), *Digital Economy and Society Index 2015 Country Profile Luxembourg*, European Commission, Brussels.

Freudenberg, M. (2003), *Composite Indicators of Country Performance: A Critical Assessment, No. 16, DSTI/DOC(2003)16*, OECD, available at: www.itu.int/osg/spu/ni/wsisbridges/linked_docs/Background_papers/otherdocs/OECD_WP_2003_16.pdf

Gerpott, T.J. and Ahmadi, N. (2015), "Advancement of indices assessing a nation's telecommunications development status: a PLS structural equation analysis of over 100 countries", *Telecommunications Policy*, Vol. 39 No. 2, pp. 93-111.

Golinski, M. (2012), "Measuring the information society – state of the art of the 'grand challenge'", *International Journal of Digital Information and Wireless Communications*, Vol. 1 No. 2, pp. 314-331.

Goswami, D. (2006), "A review of the Network Readiness Index", *World Dialogue on Regulation for Network Economies*, available at: https://web.archive.org/web/20080208123055/http://www.regulateonline.org/content/view/823/32

Gouvernement du Luxembourg (2015a), *Digital4Education*, Gouvernement du Luxembourg, Luxembourg.

Gouvernement du Luxembourg (2015b), "Rapport mondial sur les technologies de l ' information 2015: le Luxembourg dans le Top 10". *Communiqué de Presse*, 17 April.

Grigorovici, D.M. and Taylor, R.D. (2004), "InfoMetrics: a structural equation modeling approach to information indicators and 'e-readiness' measurement", *15th Bienanial Conference of the Internation Telecommunication Society*, Berlin.

Hair, J.F., Black, W.C., Babin, B.J. and Anderson, R.E. (2010), *Multivariate Data Analysis – A Global Perspective*, Pearson Education, Upper Saddle River, NJ.

Hanafizadeh, P., Hanafizadeh, M.R. and Khodabakhshi, M. (2009a), "Extracting core ICT indicators using entropy method", *The Information Society*, Vol. 25 No. 4, pp. 236-247.

Hanafizadeh, P., Hanafizadeh, M.R. and Khodabakhshi, M. (2009b), "Taxonomy of e-readiness assessment measures", *International Journal of Information Management*, Vol. 29 No. 3, pp. 189-195.

Henry, R. (2013), "Luxembourg dans le top mondial de UIT", *IT Nation*, 8 October, available at: www.itnation.lu

Henry, R. (2014), "Xavier Bettel promet la révolution ICT", *IT Nation*, 11 April.

Hilbert, M., López, P. and Vásquez, C. (2010), "Information societies or 'ICT equipment societies?': measuring the digital information-processing capacity of a society in bits and bytes", *The Information Society*, Vol. 26 No. 3, pp. 157-178.

International Telecommunication Union (2015), *Measuring the Information Society Report 2015*, International Telecommunication Union, Geneva, available at: www.itu.int/en/ITU-D/Statistics/Documents/publications/misr2015/MISR2015-w5.pdf

Iochem, T. (2014), "Luxembourg dan le top 10 des pays les plus connectés", *Paperjam*, 24 November.

Jensen, M. and Mahan, A. (2008), "Towards better measures of global ICT adoption", *Gobal Information Society Watch 2008*, pp. 47-52, available at: www.giswatch.org/sites/default/files/gisw2008.pdf

Katz, R., Koutroumpis, P. and Callorda, F.M. (2014), "Using a digitization index to measure the economic and social impact of digital agendas", *Info*, Vol. 16 No. 1, pp. 32-44, available at: www.emeraldinsight.com/doi/full/10.1108/info-10-2013-0051

Kauffman, R.J. and Kumar, A. (2005), *A Critical Assessment of the Capabilities of Five Measures for ICT Development*, Mimeo, MIS Research Centre, University of Minnesota, Minneapolis, MN.

Kyriakidou, V., Michalakelis, C. and Sphicopoulos, T. (2013), "Assessment of information and communications technology maturity level", *Telecommunications Policy*, Vol. 37 No. 1, pp. 48-62.

Land (2014), *Digital Letzebuerg*, Land, Luxembourg, p. 9.

Lechman, E. (2009), *Development Divide vs Digital Divide – Cross Country Study*, Gdansk University of Technology, available at: http://mpra.ub.uni-muenchen.de/37770/

Luyt, B. (2006), "Defining the digital divide: the role of e-readiness indicators", *Aslib Proceedings*, Vol. 58 No. 4, pp. 276-291.

Mahan, A.K. (2007), "ICT indicators for advocacy", *Global Information Society Watch 2007*, pp. 77-95, available at: www.giswatch.org/sites/default/files/gisw_indicators_advocacy.pdf

Mateus, A. (2015), *DESI 2015 Digital Economy and Society Index Methodological Note*, EU Commission, Bruxelles.

Menou, M.J. and Taylor, R.D. (2006), "A 'grand challenge': measuring information societies", *The Information Society*, Vol. 22 No. 5, pp. 261-267.

Minges, M. (2005), *Evaluation of e-Readiness Indices in Latin America and the Caribbean*, United Nation's Economic Commission for Latin America and the Caribbean (ECLAC), available at: www.cepal.org/socinfo/publicaciones/xml/8/24228/w73.pdf

Mutula, S.M. and van Brakel, P. (2006), "An evaluation of e-readiness assessment tools with respect to information access: towards an integrated information rich tool", *International Journal of Information Management*, Vol. 26 No. 3, pp. 212-223.

OECD (2015), *OECD Digital Economy Outlook 2015*, OECD Publishing, Paris.

Park, S., Kim, G.J. and Jae Kim, G. (2014), "Lessons from South Korea's digital divide index (DDI)", *Info*, Vol. 16 No. 3, pp. 72-84, available at: www.emeraldinsight.com/doi/full/10.1108/info-07-2013-0042

Pena-Lopez, I. (2009), *Measuring Digital Development for Policy-making: Models, Stages, Characteristics and Causes*, Universitat Oberta de Catalunya, Barcelona.

RTR (2011), "Messung von informatorischer und technologischer Reife", *Schriftenreihe Der Rundfunk and Telekom Regulierungs GmbH*, p. 156, available at: www.kig.gv.at/Portal.Node/kig/public/Content/files/berichte/NRI.pdf

Schlichter, B.R. and Danylchenko, L. (2014), "Measuring ICT usage quality for information society building", *Government Information Quarterly*, Vol. 31 No. 1, pp. 170-184.

Schwab, K. (2013), *The Global Competitiveness Report 2013-2014*, World Economic Forum, available at: www3.weforum.org/docs/WEF_GlobalCompetitivenessReport_2013-14.pdf

SMC (2010), *Stratégie nationale pour les réseaux à ≪ ultra-haut ≫ débit*, SMC, Luxembourg, available at: www.mediacom.public.lu/institutions/Institutions_nationales/smc/20100309_ngn/Strategie_nationale_pour_les_reseaux_a_ultra-haut_debit.pdf (accessed 15 January 2013).

Sorlut, P. (2014), "Bettel, l'Irlande comme modèle", *Paperjam*, 8 March.

STATEC (2016), *Luxembourg in Figures 2016*, STATEC, Luxembourg.

Taylor, R.D. (2006), "The nature and measurement of information: two 'grand challenges' for the field", *16th Biennial Conference of the International Telecommunications Society*, Beijing.

Taylor, R.D. and Zhang, B. (2007), "Measuring the impact of ICT: theories of information and development", *Telecommunications Policy Research Conference*, Washington DC, 26-28 September, pp. 1-39.

Vaezi, S.K. and Bimar, H.S.I. (2009), "Comparison of E-readiness assessment models", *Scientific Research and Essay*, Vol. 4 No. 5, pp. 501-512.

Vehovar, V., Sicherl, P., Hüsing, T. and Dolnicar, V. (2006), "Methodological challenges of digital divide measurements", *The Information Society*, Vol. 22 No. 5, pp. 279-290.

Zahlen, J.M. (2016), *Next Generation Access Networks in Luxembourg: Wholesale Competition and the Economic Impact of Public Investment in NGA Network Infrastructure*, Master Thesis Université Montpellier, Montepellier.

Zoenen, L. (2015), "Le Luxembourg fait son entrée dans le top 10", *Merkur*, Vol. 4 No. 65, available at: www.cc.lu/uploads/tx_userccmerkur/MERKUR_Merkur_2015_4.pdf

Appendix

Table AI Main strengths and weaknesses identified in the NRI from 2009 to 2015

Year	*Main strengths*	*Ranking*	*Main weaknesses*	*Ranking*
2016	Knowledge Intensive jobs	1	Tertiary education gross enrolment rate	97
	International internet bandwidth	1	Number of days to start a business	95
	Internet and telephony competition	1	Mobile network coverage	67
	Laws relating to ICT	1	Fixed broadband internet tariffs	65
	Intellectual property protection	2	Intensity of local competition	61
	Extent of staff training	2	Electricity production	60
	Software piracy rate	3	E-participation Index	54
	Secure internet servers	3	Number of procedures to start a business	54
	Effectiveness of law making bodies	4	Prepaid mobile tariffs	47
	Households with personal computer	4	Quality of management schools	34
2015	Knowledge intensive jobs	1	Tertiary education gross enrolment rate	95
	International internet bandwidth	1	Number of days to start a business	93
	Internet and telephony competition	1	Prepaid mobile tariffs	74
	Laws relating to ICT	2	Fixed broadband internet tariffs	66
	Intellectual property protection	3	Number of procedures to start a business	58
	Software piracy rate	3	E-participation Index	54
	Extent of staff training	3	Electricity production	45
	Government's success in ICT promotion	4	Quality of management schools	39
	Households with personal computer	4	Mobile network coverage	39
	Secure internet servers	4	Use of virtual social networks	33
2013	Laws relating to ICT	1	Tertiary education gross enrolment rate	112
	Internet and telephony competition	1	Number of days to start a business	81
	Software piracy rate	2	Fixed broadband internet tariffs	64
	Impact of ICT's on access to basic services	3	Quality of management schools	60
	Households with personal computer	3	Prepaid mobile tariffs	59
	Effectiveness of law making bodies	4	Intensity of local competition	58
	Extent of staff training	4	Number procedures to start a business	48
	Number of procedures to enforce a contract	5	Quality of math and science education	46
	Importance of ICT to government's vision	5	Business to consumer Internet usage	36
	Households with internet access	6	Quality of educational system	36
2012	Software piracy rate	1	Tertiary education gross enrolment rate	109
	Internet and telephony competition	1	Number of days to start a business	80
	Individuals using internet	4	Fixed broadband internet tariffs	61
	Households with personal computer	4	E-participation Index	60
	Households with internet access	4	Quality of management schools	58
	Effectiveness of law making bodies	5	Prepaid mobile tariffs	53
	Laws relating to ICT	5	Government online service index	51
	Efficiency of legal system in challenging regulations	5	Quality of math and science education	47
	Intellectual property protection	5	No. procedures to start a business	46
	Government prioritization of ICT	5	Intensity of local competition	41
2011	Financial market sophistication	1	Residential monthly phone subscription	111
	Internet and telephony competition	1	Tertiary education gross enrolment rate	108
	International internet bandwidth	1	Business monthly phone subscription	85
	Patent cooperation treaty application	1	Availability of scientists and engineers	81
	Software piracy rate	2	Number of days to start a business	72
	Efficiency of legal system in challenging regulations	3	Quality of management schools	66
	Households with personal computer	3	E-participation Index	66
	Government procurement of advanced technologies	4	Fixed broadband internet tariffs	58
	Buyer sophistication	4	Fixed phone tariffs	54
	Intellectual property protection	5	Government online service index	51
2010	Financial market sophistication	1	Tertiary education gross enrolment rate	104
	Level of competition index	1	Residential monthly phone subscription	97
	Internet bandwidth	1	Availability of scientists and engineers	79
	Efficiency of legal system in challenging regulations	2	Education expenditure	79
	Government procurement of advanced technologies	3	Number of days to start a business	75
	Venture capital availability	4	Quality of management schools	73
	Effectiveness of law making bodies	5	Business monthly phone subscription	68
	Buyer sophistication	5	Intensity of local competition	64

(*continued*)

Table AI

Year	Main strengths	Ranking	Main weaknesses	Ranking
	Extent of staff training	6	E-participation Index	64
	Internet users	7	Computer, communications import	60
2009	Internet bandwidth	3	Tertiary education gross enrolment rate	102
	Financial market sophistication	4	Local supplier quality	102
	Cost of mobile telephone call	4	Quality of management schools	86
	Business monthly phone subscription	6	Availability of scientists and engineers	82
	Internet users	6	Education expenditure	80
	Residential telephone connection charge	7	Number of days to start a business	71
	Number of procedures to enforce a contract	7	Intensity of local competition	64
	Business telephone connection charge	8	Government online service index	59
	High-speed monthly broadband subscription	8	Quality of math and science education	54
	Mobile telephone subscribers	9	Quality of scientific research organisations	53

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Luxembourg – A bastion of state-ownership in Europe?

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Abstract

Akin to many other European Union member states, over recent times the Luxembourgish telecommunications market is undergoing a process of market liberalisation, which is itself encapsulated by broader neoliberal tendencies. While many aspects of market liberalisation are similar to those in other European Union member states, there are others that appear to be highly distinctive. The government has simultaneously sought to liberalise the small telecommunications market while protecting the wholly state owned incumbent. Moreover, the state has created or participated in the creation of new companies, thereby deepening its presence within the telecommunications market, although the incumbent operator remains the predominant player. As a result, competition and market penetration ï especially by way of international investment ï has been curtailed and alternative fixed operators have found it difficult to gain access to public infrastructures while being unable to build out their own network infrastructure.

The current nature of the market raises four key questions that this paper will explore and seek to address. Firstly, how competitive (or óopenô) is the marketplace? Secondly, how has the extensive presence of the state in the market shaped its development? Thirdly, will Luxembourg be able to maintain its current international ICT competitiveness in the short and medium term? Fourthly, why have international operators invested (or not) in a market as small as Luxembourg? To answer these questions, we construct an extensive and detailed timeline of political, technological, regulatory and competitive developments within the Luxembourgish market. Contrary to prevailing international trends displaying the hegemony of neoliberalism, we reveal how the Luxembourgish telecommunications sector has benefitted from the deepening of state involvement over time. This leads us to conclude that Luxembourg is indeed a bastion of state ownership, as the government has not followed other European countries to reduce both its ownership and intervention in the telecommunications market.

Keywords: Luxembourg, state-ownership, market evolution, competition

1. Introduction

Akin to many other European Union member states, over recent times the Luxembourgish telecommunications market is undergoing a process of liberalisation, which is itself encapsulated by broader neoliberal tendencies. Neoliberalism is a complex, dynamic and mutable constellation of economic policies, political objectives and ideologies that have become widespread since the days of Reagan and Thatcher. Actually existing forms of neoliberalism are much more nuanced than the mantra of ‘freeing’ private enterprise suggests which tends to be associated with the market deregulation, privatization and the contraction of state services. While many aspects of market liberalisation are similar to those in other European Union member states, there are others that appear to be highly distinctive. The government had simultaneously sought to liberalise the country’s small telecommunications market while protecting a wholly state owned incumbent. The state has created or participated in the creation of new companies that provide high-speed fibre connectivity to international Internet peering hubs, and a commercially orientated local Internet exchange has been established. An alternative national high-speed network has also been developed, and several data centres built to stimulate competition.

The current nature of the market, that combines significant elements of state-ownership and entrenched operators with domestic and foreign investment and competition, raises several questions that will be addressed in this paper. Firstly, how competitive is the market? Secondly, how has the extensive presence of the state in the market shaped its development? Thirdly, will Luxembourg be able to maintain its current international ICT competitiveness in the short and medium term? Fourthly, why have international operators invested (or not) in a market as small as Luxembourg?

This paper tries to address these questions by investigating how the market has developed in Luxembourg. An overview of the current state of the market is provided that identifies the main operators as well as the relevant institutions. With this mind, the rest of this paper is divided into nine main sections. In the following section, relevant literature is recounted and the methodology adopted briefly outlined. Section 3 then provides an overview of Luxembourg. In Section 4 attention switches to describing the market contending with neoliberal processes before the role of government is outlined (Section 5). In Sections 6 and 7 the state of competition in fixed and mobile markets is respectively explored. The key issues that are identified are discussed in Section 8, and conclusions drawn in the final section.

2. Literature

With its green paper on telecommunications (European Commission, 1987), the European Union (EU) launched in 1987 the process of market liberalisation of telecommunications in Europe with the ultimate aim of creating a single European market. This involved market liberalisation of monopolies, the privatisation of state owned companies and the creation of the national regulatory authorities. As this has been extensively discussed, the literature that follows focuses on a range of issues that are relevant for our subsequent discussion of the process within Luxembourg.

Ungerer (2013) presents the history of the process and the different changes to the regulatory environment that happened over the last 25 years and examines the question whether the European telecommunications industry is ready for the Internet age. Cawley (2013), more specifically, looks into how this regulation has helped to develop both mobile and broadband communications. Levin & Schmidt (2010) discuss the establishment of national regulatory authorities and how they differ in competence and ability in different countries. They also discuss what co-ordinating role EU could or should play. Melody (2013) provides a critical discussion of current regulatory framework and questions whether this is really appropriate to create a single market. Lemstra & Van Gorp (2013) argue that further reforms are indeed necessary to achieve this ultimate goal, identifying the major barriers that prevent its realisation as well as the additional economic value that a single EU wide market would generate.

Bauer (2009) shows that countries also try to develop their respective markets through individual policies and direct investments and how this helps create different telecommunications markets across Europe in terms of the numbers of competitors, the degree to which fixed and mobile markets are competitive, the presence of inter-platform competition and so forth. Bortolotti et al. (2002) discuss how countries have divested themselves completely or partially from their national telecommunications and whether this has resulted in productivity improvements.

In the absence of a single market and the inherent complexity of telecommunication markets within individual member states, it is perhaps not surprising that many examples of country case studies can be found within the literature. Some of these have focuses on development countries like Germany (Elixmann, Schwab, & Stappen, 2003), Switzerland (Elixmann, Höckels, et al., 2003), The Netherlands (Grajek, 2010; Rood & te Velde, 2003) or the United Kingdom (Deshpande, 2013; Howick & Whalley, 2007; Tookey, Whalley, & Howick, 2006). Studies have also examined rural areas within development markets (see, for example, Galloway & Mochrie, 2005) as well as developing countries such as Peru (Yamakawa, Cadillo, & Tornero, 2012) or Nepal (Whalley, 2006).

The countries examined in these and many other case studies are substantially larger than Luxembourg, in terms of both its population and geography. One exception is the examination of the Cypriot telecommunications market by Symeou (2009). Cyprus is similar in population and geographical size to Luxembourg. Symeou (2009) argues that the success of market liberalisation might be affected by the smallness of a country and, therefore, the evaluation of success of market liberalisation based on industry concentration might be inappropriate. Moreover, market liberalisation might not even be necessary, with similar overall economic welfare being achieved by regulators if they allow a small number of market participants.

To review and evaluate the situation in Luxembourg we draw on a range of secondary sources such as the annual reviews published by the National Regulatory Authority. In addition, data have been extracted from the implementation reports and digital agenda scorecards of the European Union (for example, European Commission, 2013a). The annual reports and websites of the different operators in the Luxembourg market were incorporated into the analysis, as was information from the Luxembourgish statistical office (Statec) and Eurostat. Finally, information has been collected from the archives of several Luxembourgish newspapers and journals.

Prior studies of Luxembourgös economy have been included in the analysis. For example, studies about the importance of the ósservice industryô in Luxembourg and its evolution since 1960 (for example, Gargano, 2012), the size and activities of the financial sector (for example, Michaux, 2013) as well as a study about the use of ICT (for example, Airoldi, 2012) have been consulted. Finally, commercial sources of information detailing Luxembourg (for example, Datamonitor, 2010) as well as from several consultant reports (KPMG, 2012b; PWC, 2011) were included in the analysis.

3. Luxembourg

As shown in Figure 1 (below), Luxembourg is a land-locked country located between Belgium, Germany and France. It is also rather small, with a land area of only 2,586 km^2 and a population of 524,900 (Statec, 2012b). The official languages are Luxembourgish, French and German but many inhabitants also speak English. Luxembourg is a multicultural society, as reflected in the presence of people from across Europe living in the country. As of 2012, more than 43.8% of the total population is of foreign origin (Statec, 2012b). Consequently, Luxembourg is the European Union (EU) country with the highest number of foreign nationals as residents and the proportion of foreigners in the resident population is steadily growing. In addition, out of a total labour force of around 368,400, more than 143,400 are foreign cross-border workers that commute each day from primarily France, Belgium and Germany (Statec, 2012b)[1].

[Insert Figure 1 about here]

Luxembourg, or more formally the Grand Duchy, achieved full independence in 1867 and today is organised politically as a constitutional monarchy with a prime minister. The government has a strong reputation for efficiency due, in part, to a long tradition of cooperation between the largest two political parties motivated by the desire to achieve social cohesion and the creation of a business friendly environment[2]. The Grand Duchy is a full member of all major international institutions and a founding member of the EU. A number of major European institutions, including the European Investment Bank, the Court of Justice of the European Union and the European Court of Auditors have their headquarters in Luxembourg.

An economy dependent on financial services

Luxembourg is one of the wealthiest countries in the world with a GDP per capita in 2011 of just over US$ 90,000 (OECD, 2012)[3]. Luxembourgös industrialization began in the nineteenth century (Zahlen, 2008), driven by the steel industry[4]. Since the 1950ös a diverse array of international companies have located in the country (Zahlen, 2008), attracted by Luxembourgös stable economic environment and small and flexible state[5]. In addition, due to its geographic location, Luxembourg has also seen, more recently, logistic service providers invest in the country[6].

Overall, industrial activities generate around 13% of GDP and services the remainder (OECD, 2012). The services sector is dominated largely by finance, followed by real

[1] For more information see, for example Schmitz et al. (2012)
[2] The two main political parties in Luxembourg are the Socialist Party (www.lsap.lu) and the Christian Democrates (www.csv.lu).
[3] However, this figure should be treated with caution because of the high number of cross-border commuters.
[4] The steel industry continues to be important, albeit in a different way, as Arcelor Mittal, the worldös largest integrated steel and mining company, is headquartered in Luxembourg.
[5] For example, Delphi, DuPont de Nemours, Elcoteq SE, Electrolux, Ferrero, Goodyear, Guardian Industries, IEE, RTL Group and SES have all located in Luxembourg.
[6] Examples of such companies include Cargolux, DHL, Kühne & Nagel and Panalpina.

estate, leasing and consulting services (Gargano, 2012)[7]. Initially triggered by external factors, the banking industry took advantage of its highly experienced and skilled work force, its substantial international clientele and the favourable regulatory environment to dramatically expand the range of services and products that it offered (Zahlen, 2008). As of 2012, 143 banking institutions offering the entire spectrum of corporate and private banking services, could be found within Luxembourg (Statec, 2012a). It is worth noting that investment funds play a significant role within the financial sector, managing in July 2012 funds totalling almost ú 2.3 trillion (KPMG, 2012b). Successive EU directives that liberalized the marketing of investment funds contributed to the growth of the financial sector in Luxembourg, as did the attractive fiscal framework implemented by the government.

The countryôs large number of private banking clients also benefits the insurance sector. Insurance companies sell various products that are used by institutional clients as asset management tools. Approximately 244 reinsurance companies are licensed to operate in Luxembourg, with these companies managing about ú 50 billion of investments (KPMG, 2012a). Around 15% of the reinsurance companies are part of an insurance group, with the remaining 85% being part of industrial, financial or trading groups (KPMG, 2012b). Luxembourg is also emerging as a leading EU location for the cross border life insurance industry. One factor that has facilitated the development of this business is the regulatorôs constructive approach to new products, such as multi-currency life insurance contracts and unit linked life insurance contracts and, again, an attractive fiscal environment (KPMG, 2012b).

Being acutely aware of the countryôs dependency on the financial sector (Bourgain, Pieretti, & Høj, 2009), the government is increasing its efforts to diversify the economy (Schneider, 2012). The government has started several initiatives to attract companies that are active in the health and biotechnological industry. Over the last decade it has successfully attracted investments in logistics and e-commerce, and, more generally, it also tried to stimulate competition in telecommunications and ICT (PWC, 2011). In addition, new legislation was enacted in 2009 that provides for additional incentives relating to research and development (R&D)[8]. The country, however, spends just 1.6% of its GDP on R&D related activities[9].

Information and communication technologies

Information and communication technologies (ICTs) are arguably well developed in Luxembourg. As shown in Table 1 (below), in 2013 almost everyone in the country owned a personal computer and had access to the Internet. The proportion of households accessing the Internet via dial-up is declining, while both broadband and DSL seem to have peaked. Interestingly, according to Airoldi (2012), just over 60% of the population use mobile Internet access.

[Insert Table 1 about here]

In 2012, among the enterprises with 10 or more employees, practically all (98%) have access to the Internet. Almost all of these connections occur through broadband access (95%), and many enterprises (54%) also have a mobile connection (Statec,

[7] The services sector accounts for 28% of GDP, compared to 22.5% for real estate, leasing and consulting services (Gargano, 2012).
[8] For more information see www.fnr.lu
[9] For more information see www.luxinnovation.lu

2012a). Three quarters of the enterprises have their own website, and almost half an Intranet (Statec, 2012a).

Information technologies and e-commerce are growth areas for Luxembourg. Luxembourg was the first European country to create a specific, clearly defined and secure legal framework for e-commerce (PWC, 2011) and it also has the lowest standard rate of VAT at 15% on such services within the EU. The VAT rate levied on e-books is just 3% [10]. Theses attractive rates of taxation, together with good communication infrastructure, has led several players in the gaming and gambling sector to set up their headquarters in Luxembourg or even build their European technology centres in Luxembourg[11]. This has, is turn, encouraged low-latency Internet providers to expand their ICTs operations to include Luxembourg (PWC, 2011). Although global media and Internet brands like Amazon and PayPal, as well as large telecommunications companies like Vodafone have all invested in Luxembourg, the fiscal advantages noted above are due to disappear in 2015 as new EU regulations come into force (Fayot & Funck, 2012).

This has, however, not stopped the government promoting Luxembourg to the ICT industry. The government has sought to encourage the creation of new businesses - through, for example, initiatives like ôLuxembourg for Business ï Proud to Promote ICT[12] - and has stated its eagerness to further develop the ICTs sector in line with the major industry trends (Service des Médias et des Communications, 2013). Efforts are also being made to develop ICTs research with a focus on the security, reliability and trustworthiness of ICTs systems and services.

ICTs market size

Unfortunately there are no officially published figures regarding the size of the ICTs market in Luxembourg. Table 2 (below) draws on a variety of sources to provide an overview of the ICT[13], highlighting in the process the main trends that have occurred. The table clearly demonstrates the important role that the ICT sector plays in Luxembourgôs economy, and, despite the financial crisis that began in 2008, it has continued to grow over the last 5 years. The sector has also regularly created several hundreds of additional new jobs each year.

[Insert Table 2 about here]

It should, however, be noted that Table 2 does not include the turnover generated by international e-commerce operators located in Luxembourg. This turnover is largely generated outside of Luxembourg and mainly linked to a specific EU VAT regulation. Again these figures are not completely known, but some estimates indicate that for VAT revenues alone about ú2,000 million is generated by the different players.

4. Liberalisation and the ICT market

Starting in 2003 the regulator[14] has published an annual statistical report of the telecommunications market in Luxembourg. Using these reports and other documents

[10] See http://www.guichet.public.lu/entreprises/en/fiscalite/tva/notions/e-commerce/index.html
[11] Examples here include OnLive Inc. (which implemented a cloud gaming platform and chose Luxembourg to locate all its servers for the European distribution of its services), Big Fish Games, Agapier, Bigpoint, Kabam-Europe, Nexon Europe Sàrl and Innova.
[12] See http://ict.investinluxembourg.lu/
[13] As the sources used do not always present the data in the same way, the table has been discussed with some government officials and representatives from other stakeholders.
[14] See www.ilr.public.lu accessed 31.5.2014

such as the Digital Agenda scoreboards published by the European Commission, Table 3 has been compiled to provide an overview of the major events that have occurred since the start of 1990s.

[Insert Table 3 about here]

Revenues and fixed vs. mobile

As Figure 2 shows, the size of the market has grown considerably since 1999. This is largely due to several consecutive technological changes such as GSM and UMTS as well as the widespread adoption of the Internet and broadband Internet access just after the turn of the millennium. From 2007 onwards the overall size of the market has stagnated, though with a slight drop in 2009 and 2010 due to the economic crisis encountered by the Eurozone.

[Insert Figure 2 about here]

Three mobile operators are active in the country: LuxGSM, Tango and Orange. LuxGSM is the mobile arm of the incumbent operator, while Tango and Orange are wholly owned subsidiaries of Belgacom and Orange/France Télécom respectively. Due to the small (geographical) size of the country and a large number of daily cross-border commuters, there is also substantial competition from German, French and Belgium network operators who rely on what is termed ócross-border technical unavoidable spill-overô to serve customers. However, this spill-over does not reach into the main business areas in either the south or centre of Luxembourg.

Mobile revenues grew quickly between 2000 to 2003 until the market was saturated when penetration reached 140% of the population (ILR, 2014). Due the small size of the country and the high number of foreign workers, roaming charges constitute a substantial part of mobile revenues (ILR, 2014). These revenues, however, have stagnated or even begun to decline because of the price reductions imposed by the EU (Luxemburger Wort, 2013). Since 2010 mobile market revenues have exceeded those of the fixed telecommunications market, primarily due to the growth in mobile (broadband) Internet access (ILR, 2014). Fixed telecommunication revenues have remained flat over the period under study. However, a closer examination reveals that revenues from fixed voice telephony services have decreased while those from leased lines and broadband Internet access have grown. As a consequence, the latter is offsetting the decline of the former.

[Insert Figure 3 about here]

Entreprise des Postes et Télécommunications – the incumbent

Established in 1842 as a public administrator of post and telecommunications, EPT was converted into a 100% state owned enterprise in 1992. Table 4 (below) identifies the major milestones in the development of EPT. However, over 150 years of existence as a public administration have arguably left a deep impact in terms of structure and culture of the organisation. The company is controlled by the Ministry of Economy, with a board composed primarily of government and union representatives.

[Insert Table 4 about here]

The company is organised into 3 divisions: postal, financial and telecommunication services. Although the proportion of total revenues generated by telecommunication services is declining, almost 60% of EPTôs total revenues are generated by ICT related activities. This decline reflects the increasing competitive nature of Luxembourgôs ICT market, a development that has encouraged the company to search for new opportunities. One aspect of this has been the desire of EPT to diversify its own operations, while another has been its willingness to acquire companies to broaden the portfolio of services that it offers. Altogether the EPT group employs about 3800 people which makes it the fifth largest employer in Luxembourg (Statec, 2012b). Table 5 below shows the group as of beginning 2013.

[Insert Table 5 about here]

Some of these subsidiaries have been successful and contribute substantial sums to EPTôs ICT related revenues: ebrc, for example, has revenues of approximately ú30 million and Netcore around ú25 million (Gaudron & Ducat, 2013). The contribution of these companies helps explain the substantial increase in telecommunication revenues that has occurred in recent years.

In an interview in 2010, the then CEO identified the main strategic priorities of the group as the following: the functional separation between telecommunication services and networks[15], the full market liberalisation of the postal sector in 2013 and the roll-out of a country wide Fibre-to-the-Home (FttH) network (Gaudron, 2010a). More recently, the new CEO, in the context of the presentation of a new brand, added the importance of a new and unified company culture for EPT and its subsidiaries (Gaudron, 2013). He also emphasised the social role of an entity that is 100% state-owned and the importance of the three different activities (Zeitung, 2013). Perhaps surprisingly, the CEO also announced that EPT would look for new opportunities outside of Luxembourg (Müller, 2013).

5. Institutions and policy initiatives

The government is a key player within Luxembourgôs ICT market. In this section, the different institutions that play a role in shaping policies and regulating the market will be outlined. This will then be followed by an overview of some of the major initiatives that have been taken.

Institut Luxembourgeois de Régulation

Initially set-up in 1997 as ñInstitut Luxembourgeois des Télécommunicationsò (ILR, 2008) with 2 employees drawn from EPT and an externally recruited director, it developed by 2008 into a 50 person administrative body regulating utility sectors - telecommunications, electricity, gas, railways and post ï as well as coordinating the use of radio frequency resources and protecting customers. ILR is not involved in developing telecommunications policies; instead, its mission is to implement these as well as to implement the different EU directives related to the so-called ótelecom packagesô.

Its first major task was a licence application process in 1998 for the second mobile operator[16], which was organised with the help of Arthur D. Little as a óbeauty contestô based on coverage, service offering and quality (ILR, 2008). This approach was repeated for all subsequent major licence application processes as it was felt that it would not be appropriate to jeopardize the business cases of the applicants by requiring (large) up-front payments.

[15] A initial project proposed by EPT has not yet been accepted by ILR (Gaudron, 2012)

[16] This was won by Millicom SA and operated under the brand name Tango. Its licence fee was linked to annual turnover.

ILR then focussed on the market liberalisation of the fixed networks. Initially it defined different categories of licences[17], and subsequently through requesting EPT to publish reference interconnection and later reference unbundling offers at increasingly competitive prices (ILR, 2012a). Following EU regulations (Sutherland, 2008), number portability for fixed (ILR, 2000) and mobile numbers (ILR, 2005) were introduced in 2000 and 2005 respectively.

In 2002 ILR launched a first call for applications for four 3G UMTS network licences (ILR, 2009a), which were allocated initially to the two existing 2G mobile operators plus Orange. There was no candidate for the fourth licence. In 2003 this fourth licence was advertised again, divided into two and awarded to Luxembourg Online and Astralis. In 2004, Orange returned its licence and this was awarded to Luxcommuncations SA who started 3G operations under the name of VoxMobile soon after. In 2006, ILR launched an additional call for applications for 2G Edge and 3G spectrum, which was also awarded to Voxmobile (ILR, 2007). In 2007 ILR launched two calls for applications for a broadband wireless access network(ILR, 2009a), with a licence being awarded to Luxembourg Online and its partner. They never launched their services with the result that the licence was taken back by ILR in 2009 (ILR, 2009b).

A considerable amount of effort has been spent on coordinating radio frequencies (Dard, 2013, Paperjam, 2013b). This activity is particularly difficult due to the small size of the country and the need for international satellite communication frequencies to be used by SES and, to a lesser extent, RTL Group.

As ILR has never been a very óaggressiveô regulator (Waverman & Koutroumpis, 2011, Zenhäusern et al., 2012) it is no surprise that it has rarely imposed its decisions. Instead it has opted to negotiate compromise solutions that are acceptable to all of the stakeholders involved. It has also sought to avoid making ómistakesô as well. Unlike some EU member states, ILR has not auctioned spectrum but instead preferred to allocate spectrum through a series of beauty contests. By adopting such an approach, ILR avoided the start-up problems and high consumer prices that occurred in those countries that auctioned, for example, their 3G licences.

Service des Médias et des Communications

The Service des Médias et des Communications[18] (SMC) is associated with the Minister of Communications, but in contrast to ILR it is the body responsible for defining and promoting the policies decided by the government in the areas of electronic communications, e-commerce, electronic security and media. As a result, its main activities consist in promoting Luxembourg internationally, advising the Minister of Communications[19], supervising the local media sector and representing the government in different national companies and international organisations.

In 2001 an action plan - eLuxembourg - was implemented to promote the use of the Internet and to move the public sector towards solely communicating with the public electronically. The result was the so-called œSpaceô as a means of interacting with most, but not all, of the public sector. However, no specific budget was allocated to the initiative and no single government department was in charge. It is no surprise,

[17] Licenses have subsequently been replaced by declarations.
[18] See http://www.mediacom.public.lu/ for more information.
[19] Currently, the Prime Minister is also in charge of Communications

therefore, that this initiative gradually faded away without much success being achieved.

In 2004, prompted by the EUôs i2020 initiative, SMC presented a national action plan for broadband internet access (SMC, 2009). The objective was straightforward: to reach 95% of population. This goal was quickly achieved, with Luxembourg becoming one of the first OECD countries to achieve 100% DSL-based broadband coverage.

In 2005 the Government, together with several local banks and EPT, set up Luxtrust, a local electronic signature system. Luxtrust plays the role of the ócertification authorityô and delivers certificates on USB sticks or SIM cards[20]. This technology is extensively used in Luxembourg for e-commerce and e-banking as well as for communications between the state and public.

In 2006 SMC was the driving force, together with the then Minister of Communications, behind the creation of LuxConnect (LuxConnect, 2013). Also during 2006 SMC was actively involved in Luxembourg becoming the first EU member state to transpose the directive regarding e-commerce and electronic signatures into the local context. Two years later, a specific legal framework was created to facilitate the management of intellectual property and internet domain names (SMC, 2010b). In 2009, SMC was involved in the creation of Lu-CIX (Henry, 2014a), a commercial Internet peering point to which all of the local operators quickly connected.

LuxConnect

Over the course of 2004 and 2005, ILR assessed the fixed network market, focussing on the international and national high-bandwidth connectivity for commercial users. National operators were complaining that they were experiencing difficulties obtaining access órights of waysô and accessing existing trenches to install their own fibre optical cables. International operators were often stopped at the national boarder and forced to use expensive leased lines in order to reach the main business areas in Luxembourg City. During international economic missions, the government promoted Luxembourgôs tax advantages in order to attract foreign investors. In particular, e-commerce providers, who were required by the European Commission to have a base somewhere in the EU, were targeted (SMC, 2010b). However, most of these initiatives failed because of technical reasons linked to missing international connectivity.

After some discussions between the Ministry of Economy and EPT, it was decided to set up a second 100% state owned operator. This new company would:

- Build a national dark fibre network. This would be made available to telecommunications operators so that they can build and enhance their own footprint in Luxembourg.
- Operate a network that connects Luxembourg to the Internet exchanges in Amsterdam, Brussels, Frankfurt and Paris. Distances would be minimised while route and fibre diversity maximised.
- Support the national ICT, media and e-business sectors by providing carrier neutral, state-of-the-art data centre facilities (LuxConnect, 2013).

[20] See www.luxtrust.lu for more information.

The project was allocated an initial budget of ú30 million. By the end of 2012, LuxConnect employed 23 staff, had capital of ú75 million and had invested over ú92 million developing its business.

Interestingly LuxConnect does not define itself as a telecommunications operator and is probably best described as a ócarrierøs carrierö. As the company provides its services only on a business-to-business wholesale basis. Its customer base is made up exclusively of telecommunications operators, system integrators, hosting and software-as-a-service companies. The services are offered on a strictly neutral and non-discriminatory way: identical pricing and support are provided to customers accessing the same product or service under matching conditions. It provides raw datacentre capacity as well as dark fibre or high bandwidth connectivity using a cost-plus pricing scheme(LuxConnect, 2013).

Operations commenced in 2009 with a first data centre and an international fibre optical network. Since then, the company has arguably been very successful (Journal, 2013). LuxConnect has contributed to the development of a second and commercial national Internet peering point (Lu-CIX) and facilitated the establishment of a wholesale cloud service, namely Luxcloud (Bova, Plummer, Petri, Malinverno, & Govekar, 2014).

Ultra-High Broadband Strategy

In 2010, ILR, together with the Ministry of Economy and the Minister of Communications, published a report outlining Luxembourgøs future broadband strategy (SMC, 2010a). They claimed that both productivity and GDP growth requires ultra-high bandwidth connectivity for all households. Broadband connectivity was viewed by the government as being part of the incumbentøs universal service obligations that stated that by 2020 every household should have access to a connection with speeds of 1 Gbit/s upstream and 500 Mbit/s downstream (SMC, 2010a). The following rollout targets were set:

- 25% of population by 2013
- 50% of population by 2015
- 100% of population by 2020

In addition, an intermediate objective of every household having at least 100 Mbit/s download and 50 Mbit/s upload by 2015 was set. Ultra-high bandwidth business zones would also be established[21], connected by two independent networks in order to guarantee full redundancy. The government also announced two other, somewhat vague, objectives: to become a óworld leaderö in terms of broadband connectivity penetration and to achieve competitive pricing in line with the EU average (European Commission, 2013b).

The Government, as their sole shareholder, asked EPT to invest about ú180 million until 2015 to fund the initial rollout. It was agreed that EPT would install at least 4 fibres into each home and grant access to alternative carriers to one or more of these on a non-discriminatory basis (SMC, 2010a). Cable TV operators were encouraged to develop their own networks as an alternative, with its independency of the incumbentøs infrastructure ensuring that redundant access to 95% of households in Luxembourg was possible (SMC, 2010a).

[21] It was not specified how many of these zones exist, and where they are located.

Several additional measures were agreed. A centralised database detailing network infrastructure across the country would be established[22], as would a second database focusing on civil works projects. In-house cabling would be made mandatory for all new buildings. LuxConnect also was asked to push the development of their national networks and in particular to connect to the main ‘business zones’ while ILR was ‘invited’[23] by the government to proceed as quickly as possible with the frequency planning and licensing process for 4G LTE services. For its part, the government promised to transpose the 2009 EU telecom package immediately into national law.

In April 2012, SMC and the Ministry of Economy commissioned a study to review the broadband strategy announced in 2010 (BooZ&Co, 2012). This new study proposed a closer collaboration between EPT and cable-TV operators with the aim to use the latter's existing networks to offer broadband connectivity in the less densely populated areas in the north of the country.

In May 2013 the Ministry of Economy and Foreign Trade announced that additional funds would be made available to speed up the rollout of the broadband infrastructure (Minstère de l'Economie, 2013). Through doing so, it was hoped that the country's economic recovery would hastened. Overall EPT and LuxConnect are now expected to invest over €1000 million over the period from 2013 to 2017 (Minstère de l'Economie, 2013).

6. Competition in fixed networks

ILR, in their official list of operators within Luxembourg, identified 88 different operators, 37 networks and 240 service providers at the end of 2012 (ILR, 2012b). EPT is, by far, the largest of these – although Figure 8 (below) shows that the market share of EPT is declining, the company still generates almost 80% of the sector's fixed revenues. Notably, revenues from other operators began to grow in 2007, the year in which LuxConnect launched its operations. Through the use of its infrastructure, other operators were able to provide services to enterprise customers and thus increase their market share and revenues over time.

[Insert Figure 8 about here]

In common with many other countries, revenue from the fixed line sector has been falling steadily in recent years. Since 2005 the revenue generated by mobile telecommunications has by far exceeded that from fixed. Having said this, the decline in voice telephony communications revenues has been partially offset by the growth of broadband revenues. However, as can be seen from Figure 9 (below), broadband revenues have begun to fall after several years where they were stable.

[Insert Figure 9 about here]

Telindus Telecom

Telindus was initially established as an ICT integrator by a private investor in cooperation with Arcelor-Mittal[24]in the 1980s. Over time it became the country's largest ICT integrator, with more than 350 employees and a turnover of about €70 million (Paperjam, 2013a).

[22] Which at the moment (May 2014) does still not exist.
[23] This is the actual term used in the presentation of the plan.
[24] The world's largest steel producer, which was then ‘ARBED’.

At the end of 2005, after the death of the private investor, Belgacom acquired Telindus Belgium and Luxembourg (Lightreading, 2005). Through this acquisition, Belgacom extended their product range to be able to offer enterprise customers not only traditional connectivity and leased lines, but also LAN, voice and IT services as well.

In 2011, using the infrastructures offered by LuxConnect, the Luxembourgish branch of the company changed its name into Telindus Telecom and became Belgacomôs ICT full range ICT service provider for Luxembourg. The company focuses solely on commercial customers, offering services such as connectivity and software. It is the main competitor to EPT in the lucrative enterprise market.

This successful business model has been copied by several smaller operators or ICT integrators like Telecom Luxembourg, BCE, Datacentre Luxembourg and Orange Business Services. They individually play a minor role in the market when compared to either EPT or Telindus Telecom. Nevertheless, most of these operators would not exist without the creation of LuxConnect and in that respect the governmentôs intention to stimulate competition appears to have been successful.

Artelis

Artelis was initially set up in 1999 under the brand name of Cegecom (Cegecom, 2013) by Cegedel[25], the local electricity company. The intention was to use the fibre optical cables inside the high-tension electricity lines to offer services to enterprise customers. However, it quickly became clear that these lines were not close enough to the end customers and certainly would not cover the main business centres. Thus, Artelis tried to develop their own local access network and tested several technologies over time - Powerline, Wireless Local Loop (WLL) and Microwaves ï before acquiring the countryôs only WLL operator Firstmark[26]. They also relied on EPTôs reference unbundling offer as well as continuing to develop their own national fibre back-bone infrastructure (Gaudron, 2010b).

Around the time of its launch, Artelis considered itself as the main national competitor to EPT and even tried to enter the residential market with Internet access and fixed voice services under the brand name ñBambooò (Cegecom, 2002). They also stated their intention of applying for mobile licences, but gave up twice at the last minute[27].

In 2006, the company merged with VSEnet[28], a similar organisation based in the German state of Sarre that they had already cooperated with for some time. At this point company was rebranded as Artelis (Artelis, 2013). The merger changed the shareholder structure so that it became VSE AG (53.05%), Enovos International S.A. (36.95%), and Saar LB (10%).

Since the merger Artelis has sought to provide high-speed data connectivity and act as a carrierôs carrier for the main business centres and small and medium sized enterprises. Significantly, its geographical focus is now on greater Luxembourg region and the surrounding areas of Germany. It is on this basis that Artelis claims to be the only óinternationalô operator based in Luxembourg.

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[25] This company is now called Enovos.
[26] See http://archiv.ringpfeil.net/firstmark/_purehtml/markets/en_luxembourg.htm for further details.
[27] Authorôs interview with former CTO of Artelis
[28] See www.vsenet.de for further details.

Luxembourg Online

Founded by two private investors in 1995 as an Internet service provider, this company gradually emerged as the only independent local operator that is fully owned by private local investors. In 1997 Luxembourg Online (Luxembourg Online, 2014) launched one of the first e-commerce platforms in Luxembourg and in 1999 it began offering free Internet dial-up access that is based on call-termination revenues from in-bound calls (Luxembourg Online, 2013). In 2001 the company applied for a full voice licence and became the first operator to offer both free Internet and free voice based on a flat-fee local loop bought in from EPT and Cegecom (Luxembourg Online, 2014).

In 2003 Luxembourg Online launched its broadband Internet access, again based on local access from EPT as well as an Internet access product via cable TV networks as it had no infrastructure of its own. In 2004 it started to offer alternative voice products to the residential market, though these met with limited success (Luxembourg Online, 2014). As a consequence, it moved to VOIP and became the country’s first operator to offer such a service to its broadband Internet access customers.

In 2006 Luxembourg Online applied for the fourth UMTS licence, but failed with the licence being awarded to Astralis. It appealed and was awarded ‘a half-licence’ in 2008 (ILR, 2009b). ILR, in order to avoid deciding in favour of one party over the other, simply split the available wireless spectrum into two equal halves. However, to date, Luxembourg Online has never used its licence. Instead Luxembourg Online established a mobile virtual operator based on the resale of services provided by Orange, branding the service as ‘LOL mobile’. In 2007, it also applied, together with Broadcasting Center Europe, for a 3,5 GHz WiMax licence (ILR, 2009a). Once again, although it was successful in its application, the licence has not been utilised.

In 2011 Luxembourg Online launched its own IPTV service. It was partnered in the venture by several cable TV operators, Tango and EPT. In the following year, it created a joint venture with Eltrona, the country’s largest CATV operator, to offer triple play services over cable TV networks[29].

7. Mobile competition

As highlighted above in Figure 2, the size of the mobile market when measured by revenues has exceeded that of the fixed telecommunications market since 2005. Although revenues were stable between 2005 and 2011, they have begun to grow once more. According to ILR, LuxGSM controls just over 53% of the market, with the remainder being split between the two other operators (ILR, 2014). This split has been very stable over time; there was a slight decrease when the third mobile operator launched its service in 2005, but the subsequent introduction of mobile number portability has not led to any noticeable change.

[Insert Figure 10 about here]

Due to unique characteristics of the Luxembourgish labour market and the small size of the country, roaming revenues are very important. The recent decision of the EU to impose price caps on voice and data roaming (Cuvelliez & Dricot, 2013; Luxemburger Wort, 2013) will, therefore, lead to considerable reductions in the roaming revenues of operators. Given the revenue split highlighted in Figure 11 for

[29] Further details can be found at http://www.eltrona.lu/offres_trio.htm.

2012, this decline is likely to have a far-reaching impact on Luxembourgôs mobile operators.

[Insert Figure 11 about here]

This together, with a substantial reduction in average revenue per user around 2009 that is evident in Figure 12 (below) due to the economic crisis (ILR, 2011) resulted in a fairly flat evolution of mobile revenues between 2005 and 2010. The decline in national voice revenues that is evident in Figure 11 has partially been offset by the increase in smartphones and the associated revenues.

Tango

Tango has been active in the Luxembourgish telecommunications market, initially in the fixed (voice) market and, more recently, in the mobile since 1989. During its first decade, when it was known as 3C Communications Luxembourg, the company attracted the interest of a number of investors such as Bank Invik, Millicom International Cellular, Mach, Transcom, Transac and Tele2 Europe (Tango, 2013a).

A group of investors with Millicom and Bank Invik at its core won the beauty contest, which was based mainly on speed of rollout and coverage, in 1997 (Tango, 2013a). The company started operations in 1998 under the brand name of Tango. Success was more or less immediate: the companyôs services and products attracted substantial numbers of subscribers during the launch phase. The company now claims a market share of over 40% and around 270,000 subscribers (Tango, 2013b). GSM network coverage was extended and a fixed-line network set up in parallel using EPTôs access network and Tangoôs voice switching system. This service was commercialised in 2005 under the brand name of Tele2 Luxembourg (Tango, 2013a).

In the early 2000s Tango achieved a series of firsts: it was the first company to launch WAP services, a data (GPRS) network and UMTS-based services. In 2005 the company launched the first bundled offers[30], followed in 2007 by the first HSPA óMobile ADSLô network supporting speeds of up to 7.2 Mbit/s (Tango, 2013a).

In December 2008 Belgacom Group bought Tango from Tele2 Europe for a reported ú210 million (Tango, 2013a). This was the first major commitment by a larger international operator in Luxembourg[31]. Since the sale to Belgacom, Tango has continued to invest into its network infrastructure and was the first operator in October 2012 to launch a commercial LTE data service (Tango, 2012a). They also launched, around the same time, an IP-TV service using EPTôs and Artelisô unbundled DSL packages (Tango, 2012b).

The company claims to have over 40% market share with about 270.000 mobile subscribers (Tango, 2013a). Being part of the Belgacom group, it co-operates actively with Telindus Telecom[32] to offer specific fixed/mobile bundles to corporate customers.

Orange

In 2003 the two CEOs of Tango, together with several local investors, decided to set-up a third mobile UMTS only operator called VoxMobile (Orange, 2013). The licence was quickly awarded. Interestingly they also convinced EPT to act as an MVNO host

[30] These combined fixed services with DSL-based Internet access and mobile provision.
[31] The Millicom Group has a history of acquiring and developing mobile operations, often in Africa, before divesting them.
[32] See the Telindus website, www.telindus.lu, for more information.

so that they could swiftly start providing 2G operations. Again, the success was more or less immediate, mainly because of a strong marketing campaign and the offer of a free life-long subscription. However, the company experienced problems with the availability of 3G devices with the consequence that of their customers used 2G instead. As such, significant revenues accrued to EPT as their MVNO host.

As a consequence, in 2005 the company took the decision to launch its own 2G network. This had a significant negative impact on their operations that resulted in additional financing being sought ï a reputed extra ú10 million was sought from the companyôs shareholders[33]. In 2007 additional financing was provided by Orange/France Télécom through Mobistar, its Belgium mobile operations, and resulted in the company increasing its stake in VoxMobile to 90%. In the following year Orange/France Télécom acquired the remaining 10% and, beginning from the start of 2009, changed the companyôs brand to Orange (Orange, 2013).

A 4G network was launched in the autumn of 2012. Notwithstanding the expansion of the company and the use of a well-known brand name, the company is the smallest of the three mobile operators with a claimed subscriber base of about 100,000 subscribers (Raizer, 2013).

8. Discussion

The previous sections have described various aspects of the liberalisation of ICT markets in Luxembourg. The country has not been at the forefront of neoliberal trends in Europe, but instead has adopted an approach that could be best described as being an óinformed followerô. This may be partially due to the small size of Luxembourg and its telecommunications market that leads to limited competitive pressures and the relatively low interest among larger operators to establish operations[34]. It could, however, also be a consequence of a political desire to protect the incumbent, who, with over 3800 employees, is one of the largest employers in the country, representing an important reservoir of óvotersô and contributes a considerable amount of tax revenue. In addition, the regulatory body without the benefit of any form of institutional antecedents, and it also had to grapple with limited resources and little experience, at least initially.

EPT still dominates most market segments and, in that sense, market liberalisation does not appear to have pervaded the operating environment as is the case in many other countries. EPT still controls around half of the mobile market, and almost all of the fixed, Internet and broadband Internet access markets. Having said this, the ICT revenues of EPT are stable while those of competitors are steadily growing but are still far lower than those of the incumbents.

EPT has not necessarily been at the forefront of innovation, new technologies or service developments. They tended to follow the developments of neighbouring countries and their incumbent operators and ómimicô, that is, copy, their behaviour. It is, therefore, no surprise to note that a range of services ï mobile data, broadband, LTE, cloud services ï were introduced between 12 and 18 months after their introduction in surrounding countries. It is also fair to state that the small size of the local market and their limited experience also prevented them from swiftly introducing new services.

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[33] Authorôs interview with former CEO of VOX

[34] For a broader discussion of smallness see, among others, (Symeou, 2009).

Prior to 2000 some national organisations like utilities and media companies diversified into the telecommunication market while remaining nationally focused. Two factors, however, negatively affected the development of the telecommunications market. The dot.com bust forced some of the operators to focus their activities on their core lines of business and geographical markets[35]. Thus, their diversification plans were not implemented. Secondly, many of the alternative operators faced day-to-day problems that prevented them from gaining access to public infrastructures that would enable them to build their own infrastructures. Several of the administrations (roads, railways, local communes) were not aware and not accepting the fact that the market had been liberalised and quite naturally continued to inform only their former colleagues in EPT about planned civil and infrastructural works. While the situation gradually improved, it was only with the creation of LuxConnect that this barrier was overcome.

Since 2004 the development of the ICT sector in Luxembourg has attracted considerable attention from the government in general and the Minister of Communications in particular. International consultants were hired to assess the óstate of playô across the sector, discussing with a wide array of stakeholders. These discussions showed that, whilst the mobile market was operating competitively, the fixed market was still largely dominated by the incumbent (ILR, 2004). In particular, international broadband connectivity and access to the main Internet peering points found to be problematic (ILR, 2004). The government initially increased pressure on EPT but soon took the completely unexpected decision to create a second ñstate-ownedò operator to stimulate competition - LuxConnect was created in 2006 to address, at least partially, the problems that were being experienced (LuxConnect, 2013). The creation of LuxConnect has stimulated competition in terms of network infrastructures and datacentre capacity and has allowed several national and international players to offer services to enterprises. It has also attracted many international e-commerce and game providers to establish technical infrastructures in Luxembourg. The impact of this should not be underestimated: substantial tax revenues and employment in the ICT that now accounts for 7% of the countryôs GDP. In 2010 Luxembourg defined ambitious goals for developing its óultra-high bandwidth[36] infrastructure, (SMC, 2009), and asked EPT to build a nationwide FTTH network. However, during the course of 2012 it became clear that the given objectives could not be achieved and an alternative plan was sought. The current suggestion is to use the network infrastructure of cable TV operators in the north of the country where population densities are lower.

According to a OECD study (Greenstein & Mcdevitt, 2012), which tried to measure the effects of broadband connectivity, Luxembourg appears to have done relatively well in offering high broadband connectivity at attractive prices. In addition, the market has grown considerably since 1997 in terms of both absolute value and in terms of the number of market participants. Luxembourg is well connected to the main international Internet hubs, and is able to offer broadband access to all of its population. The country also contains high quality data centre capacity and is about to rollout next generation networks (LTE and FTTH).

Some of the larger international or global operators have been interested in Luxembourg because of their home customers often have a subsidiary or a local

[35] See, among others, (Fransman, 2002) for a discussion of the dot.com bust.
[36] 100 Mbit/s to every household

operation located within the country. Even before telecommunications market liberalisation commenced, British Telecom, for example, was present in Luxembourg through a small local sales office relying on the infrastructure provided by EPT. During the initial phase of market liberalisation, that is, from 1998 to 2001, many international players showed some interest in developing their activities in Luxembourg and about 20 licences for fixed network services were awarded in 1999 alone(ILR, 1999). Thus, operators like Global One, WorldCom and KPN established operations in Luxembourg. Unfortunately, the ñdot.com bustò (Fransman, 2004) at the turn of the millennium forced most operators to focus on their home markets and thus abandon their presence in Luxembourg.

Only WorldCom, which later became Verizon Communications, remained with a datacentre offering hosting and disaster recovery services to mainly financial institutions. When LuxConnect started its operations in 2009, some of the operators that had left around the turn of the millennium returned so that currently KPN, Level3, Verizon, BT, AT&T, Colt' Cable&Wireless, Cogent, Interoute, Telefonica, T-Systems have sales offices in Luxembourg. Having said this, only Verizon has its own datacentre and own fibre connectivity to and from Luxembourg.

In 2006 Belgacom expressed an interest in Luxembourg and started to invest in Telindus. They later acquired Tango, the countryôs second mobile operator, and in 2011 transformed Telindus into Telindus Telecom to become a major alternative operator for professional customers. Tango, like Belgacom, cooperates with Vodafone as a network partner[37]. France Télécom flirted with investing Luxembourg before finally doing so in 2010 when it acquired a mobile operator. Rebranded as Orange in 2011, they are a key player within the market offering a range of products and services[38]. Although Telindus Telecom and Orange have deployed their own mobile network infrastructure they are also reliant on access to the infrastructures operated by LuxConnect and EPT.

How competitive ICT markets are is often measured through composite indices. One such index is the óGlobal Information Technology Reportô that is published by the World Economic Forum and which, to a lesser or greater extent, focuses on how ICT enhance competitiveness (Bilbao-Osorio, Dutta, & Lavin, 2013). If we examine these indices then we find that in recent years Luxembourg has performed well, thereby suggesting that the evolution of the market described above has increased the countryôs international ICT competitiveness. However, this has been achieved through mass state intervention, especially on the supply side, with LuxConnect playing a central role. This inevitably raises the question as to whether this intervention will continue in the future, especially given the budgetary pressures being faced by the government. The rollout of the FTTH infrastructure is not yet complete, and has attracted a relatively small number of subscribers in the south of the country[39]. These developments cast doubt on the future development of this infrastructure.

[37] Vodafone has extended its geographical coverage through signing óNetwork Partner Agreementsô with a range of operators. Operators agree to collaborate with Vodafone in terms of international roaming and often co-brand their operations to include the name óVodafoneô.

[38] See www.orange-business.com for further information.

[39] End of 2013, only 12000 subscribers have opted to use the FTTH infrastructure that is being rolled out.

The focus on high quality, highly reliable, Tier IV, datacentres has also created its own problems. Quite simply, there is over capacity to the extent that some of the recently constructed datacentres are not being fully used (Henry, 2014b). Moreover, the emergence of cloud services has changed the market, with customers increasingly demanding simpler services that are not tied to a single underpinning infrastructure. In other words, customers are demanding services that are available wherever they are not just where the physical infrastructure is located.

9. Conclusion

This paper has sought to chart and then explore the degree and forms of actually existing market liberalisation that has occurred within the Luxembourgish telecommunications market. We have demonstrated how the state has continued to play a key role within this market. If we return to the four questions that we asked at the start of the paper, what conclusions can we draw?

The first question asked whether the market in Luxembourg displays the features of a competitive marketplace. Looking at the above it can be concluded that the market has witnessed only a limited degree of market liberalisation. EPT is still the dominant player across much of the market. Having said this, the overall size of the market has grown substantially during this period of neoliberal experimentation.

The second question asked how the intervention of the government has shaped the market? The government has undertaken substantial supply side intervention and made significant investments that have resulted in a network duopoly where the state competes with itself. Given this, it can be argued that Luxembourg is indeed a bastion of state ownership, as the government has not followed other European countries to reduce both its ownership and intervention in the telecommunications market.

The third question asked whether Luxembourg would be able to keep its current competitiveness in the international ICT environment? Luxembourg has a good ICT infrastructure and international connectivity as well as substantial datacentre capacity. Local customers are presented with attractive triple and quadruple play offers, nationwide xDSL and 3G availability. Luxembourg is well positioned on many of the international ICT indices and enjoys a good international ICT competitiveness. In that sense, the Luxembourgish situation seems to confirm previous findings from countries like Cyprus in that liberalisation is not necessarily the right answer for small economies. However, further research is required to establish the importance of non-infrastructure related factors like, for example, access to finance, access to ICT skills, the impact of research and development and how it may be encouraged and so forth.

The final question asked whether international operators have invested in the local market? So far, Luxembourg has not been able to attract much in the way of foreign investment and when investment has occurred it can be argued that it was mainly for tax reasons. This raises a significant question, namely, what will happen once these fiscal incentives are reduced in 2015? Will the government seek to compensate for their removal by extending its commitment to the sector through, for instance, continued investment or will the investment in infrastructure that has occurred begin to attract (foreign) investment and thus generate economic activity?

References

Airoldi, M.-J. (2012). *Le comportement des Luxembourgeois face aux nouvelles technologies de l'information et la communication depuis le début des années 60*. Luxembourg.

Artelis. (2013). Artelis - Overview. *web site*. Retrieved August 15, 2013, from http://www.artelis.lu/index_en.html

Bauer, J. M. (2009). Regulation, public policy, and investment in communications infrastructure. *Telecommunications Policy*, *34*(1-2), 49. doi:10.1016/j.telpol.2009.11.011

Bilbao-Osorio, B., Dutta, S., & Lavin, B. (Eds.). (2013). *The Global Information Technology Report 2013 Growth and Jobs in a Hyperconnected World* (2013th ed.). Geneva: World Economic Forum.

BooZ&Co. (2012). *National Strategy for Very High Speed Networks*. Luxembourg.

Bortolotti, B., DôSouza, J., Fantini, M., & Megginson, W. L. (2002). Privatization and the sources of performance improvement in the global telecommunications industry. *Telecommunicartions Policy*, *26*(5-6), 243ï 268. doi:10.1016/S0308-5961(02)00013-7

Bourgain, A., Pieretti, P., & Høj, J. (2009). *Can the Financial Sector continue to be the Main Growth Engine in Luxembourg ?* (No. 660). Paris.

Bova, T., Plummer, D. C., Petri, G., Malinverno, P., & Govekar, M. (2014). *Cool Vendors in Cloud Services Brokerage Enablers , 2013* (pp. 1ï 7).

Cawley, R. a. (2013). EU regulation and the development of mobile and broadband services. *Info*, *15*(2), 39ï 61. doi:10.1108/14636691311305416

Cegecom. (2002, December 11). Nouvelle extension du réseau de Bamboo - powered by Cegecomȷ *Paperjam*. Luxembourg.

Cegecom. (2013). CEGECOM: Home. *Web site*. Retrieved August 15, 2013, from http://www.cegecom.lu/?id=50&L=1

Cuvelliez, C., & Dricot, J.-M. (2013, August 10). Roaming: Chronique dôune mort annocée, souhaitée et postposée. *L'Echo*, p. 17.

Dard, D. (2013, July 20). LôILR n'a pas chômée en 2012. *Le Quotidien*, p. 5. Luxembourg.

Datamonitor. (2010). *Luxembourg Country Analysis Report - In-Depth PESTLE Insights* (pp. 11ï 27). Luxembourg.

Deshpande, A. (2013). Broadband deployment and the bandwagon effect in the UK, *15*(1), 34ï 47. doi:10.1108/14636691311296192

Elixmann, D., Höckels, A., Kiesewetter, W., Neumann, K.-H., Schimmel, U., Schwab, R., é Stumpf, U. (2003). *Stand des Schweizer Telekommunikationsmarktes im internationalen Vergleich*. Biel.

Elixmann, D., Schwab, R., & Stappen, C. (2003). Development of the telecommunications market in Germany since liberalisation. *Info*, *5*(1), 41ï 51. doi:10.1108/14636690310473881

European Commission. (1987). *Towards a dynamic European Economy Green Paper on the Development of the Common Market for Telecommunications Services and Equipment* (p. 256). Brussels.

European Commission. (2013a). *Broadband coverage in Europe in 2012*. Brussels.

European Commission. (2013b). *Digital Agenda Scoreboard 2013 Electronic communications market indicators : Definitions , methodology and footnotes on Member States*. Brussels.

Fayot, F., & Funck, L. (2012). Luxembourgôs TMT Sector. In J. P. Panka (Ed.), *The Technology Media and Telecommunications Review* (3rd ed.). Law Business Research Ltd.

Fransman, M. (2002). *Telecoms and the internet age - from Boom to Bust to...* (1st ed.). Oxford: Oxford University Press.

Fransman, M. (2004). The telecoms boom and bust 1996-2003 and the role of financial markets. *Journal of Evolutionary Economics*, *14*(4), 369ï 406. doi:10.1007/s00191-004-0196-x

Galloway, L., & Mochrie, R. (2005). The use of ICT in rural firms: a policy-orientated literature review. *Info*, *7*(3), 33ï 46. doi:10.1108/14636690510596784

Gargano, L. (2012). *L'essor du sector tertiaire au Luxembourg* (p. 4). Luxembourg.

Gaudron, J.-M. (2010a, May 28). « Nous vivons une période de changements critique et capitale ». *Paperjam*. Luxembourg.

Gaudron, J.-M. (2010b, May 28). Sous haute surveillance. *Paperjam*. Luxembourg.

Gaudron, J.-M. (2012, September 25). Télécoms ; les P & T doivent revoir leur copie. *Paperjam*. Luxembourg.

Gaudron, J.-M. (2013, June 15). LôEPT devient Post Luxembourg. *Paperjam*, pp. 1ï 2. Luxembourg.

Gaudron, J.-M., & Ducat, A. (2013, July 4). P&T: les filiales dopent le chiffre dôaffaires. *Paperjam*. Luxembourg.

Grajek, M. (2010). Estimating network effects and compatibility: Evidence from the Polish mobile market. *Information Economics and Policy*, *22*(2), 130ï 143. doi:10.1016/j.infoecopol.2009.07.002

Greenstein, S., & Mcdevitt, R. (2012). *Measuring the Broadband Bonus in Thirty OECD Countries* (No. 197). *OECD Digital Economy Papers*. Paris.

Henry, R. (2014a, March 3). A wonderful 5th anniversary for LU-CIX. *IT Nation*. Luxembourg.

Henry, R. (2014b, April 10). La cartographie complète des datacentres en France et au Luxembourg. *It Nation*. Luxembourg.

Howick, S., & Whalley, J. (2007). Understanding the drivers of broadband adoption: the case of rural and remote Scotland. *Journal of the Operational Research Society*, *59*(10), 1299ï 1311. doi:10.1057/palgrave.jors.2602486

ILR. (1999). *Rapport annuel de l'Institut Luxembourgeois des Télécommunications 1999*. Luxembourg.

ILR. (2000). *Rapport Annuel de l'Institut Luxembourgeois de Régulation 2000*. Luxembourg.

ILR. (2004). *Rapport statistique succinct Année 2004*. Luxembourg.

ILR. (2005). *Rapport statistique des télécommunications au Luxembourg pour l'année 2005*. Luxembourg.

ILR. (2007). *Rapport statistique des télécommunications au Luxembourg pour l'année 2007*. Luxembourg.

ILR. (2008). *10 Years Institut Luxembourgeois de Régulation*. Luxembourg.

ILR. (2009a). Institut Luxembourgeois de Régulation - Appels de candidatures. *ILR web site*. Retrieved August 11, 2013, from http://www.ilr.public.lu/services_frequences/appelscandidatures/index.html?highlight=3g

ILR. (2009b). *Rapport statistique des télécommunications Luxembourg pour l'année 2009*. Luxembourg.

ILR. (2011). *Rapport statistique des télécommunications du Luxembourg de l'année 2011*. Luxembourg.

ILR. (2012a). Institut Luxembourgeois de Régulation - Interconnexion et accès. *ILR web site*. Retrieved August 11, 2013, from http://www.ilr.public.lu/communications_electroniques/interconnexionetacces/index.html

ILR. (2012b). *Registre public des entreprises notifiées fournissant des services aux consommateurs*. Luxembourg.

ILR. (2014). *Rapport statistique des télécommunications du Luxembourg de l'année 2013*. Luxembourg.

Journal. (2013, October 9). LuxConnect - et de quatre. *Journal*, p. 28. Luxembourg.

KPMG. (2012a). *Luxembourg Business Compass October 2012*. Luxembourg.

KPMG. (2012b). *Luxembourg Platform for Business*. Luxembourg.

Lemstra, W., & Van Gorp, N. (2013). Telecommunications reform and the internal market in Europe. *Info*, *15*(2), 73ï 90. doi:10.1108/14636691311305434

Levin, S., & Schmidt, S. (2010). Telecommunications after competition: challenges, institutions, regulation. *Info*, *12*(2), 28ï 40. doi:10.1108/14636691011027166

Lightreading. (2005). Belgacom Buys Telindus | Light Reading. *Website*. Retrieved August 15, 2013, from http://www.lightreading.com/document.asp?doc_id=621497

LuxConnect. (2013). Welcome to LuxConnect | LuxConnect. *LuxConnect Web site*. Retrieved August 11, 2013, from http://www.luxconnect.lu/

Luxembourg Online. (2013). Luxembourg Online Internet libre. *Web site*. Retrieved August 15, 2013, from http://www.internet.lu/cal_home/Internet_gratuit.htm

Luxembourg Online. (2014). Luxembourg Online. *Web site*. Retrieved May 31, 2014, from http://www.internet.lu/

Luxemburger Wort. (2013, September 12). Roaming: Die EU macht ernst. *Luxemburger Wort*, p. 51. Luxembourg.

Melody, W. H. (2013). Moving beyond liberalization: stumbling toward a new European ICT policy framework. *Info*, *15*(2), 25ï 38. doi:10.1108/14636691311305407

Michaux, R. (2013). *Le secteur bancaire au Luxembourg* (p. 5). Luxembourg.

Minstère de lôEconomie. (2013). « Plan Marshall » pour le Luxembourg. *web site*. Retrieved August 11, 2013, from http://www.eco.public.lu/salle_de_presse/com_presse_et_art_actu/2013/05/Marshall/index.html

Müller, C. (2013, April 24). Luxemburger Post blickt in die Zukunft. *Tageblatt*. Luxembourg.

OECD. (2012). *OECD Economic Surveys: Luxembourg 2012*. Paris: OECD Publishing.

Orange. (2013). Orange Luxembourg | à propos de nous. *Website*. Luxembourg. Retrieved August 15, 2013, from http://www.orange.lu/a-propos-de-nous/index.html

Paperjam. (2013a, April 10). Croissance continue confirmée pour Telindus Telecom. *Paperjam*. Luxembourg.

Paperjam. (2013b, July 19). Publication du rapport dôactivité ILR pour l' année 2012. *Paperjam*. Luxembourg.

PWC. (2011). *Luxembourg: an e-hub for Europe Opportunities and actions on the horizon 2015* (p. 36). Luxembourg.

Raizer, T. (2013, February 6). Orange reste dans le vert. *Paperjam*. Luxembourg.

Rood, H., & te Velde, R. a. (2003). Investment strategies in the Netherlands. *Telecommunications Policy*, *27*(10-11), 701ï 715. doi:10.1016/j.telpol.2003.08.001

Schmitz, F., Drevon, G., & Gerber, P. (2012). *La mobilité des frontaliers du Luxembourg : dynamiques et perspectives*. *LES CAHIERS DU CEPS / INSTEAD*. Luxembourg.

Schneider, E. (2012). Top 10ز Luxembourg ICT assets. *Eurocloud Congress 2012*. Luxembourg: Eurocloud.

Service des Médias et des Communications. (2013). *Luxembourg & ICT - a snapshot*. Luxembourg.

SMC. (2009). *Plan d'action national en matière de TIC et de haut-débit*. Luxembourg.

SMC. (2010a). *Stratégie nationale pour les réseaux à « ultra-haut » débit*. Luxembourg.

SMC. (2010b). *Why Luxembourg ? A Comprehensive Overview of the Regulatory, Economic and Lifestyle Advantges for ICT and Media Companies*. Luxembourg.

Statec. (2012a). *Annuaire statistique*. (STATEC, Ed.) (2013th ed.). Luxembourg.

Statec. (2012b). *Luxembourg in Figures*. Luxembourg.

Sutherland, E. (2008). European telephony numbering space. *Info*, *10*(2), 24ï 33. doi:10.1108/14636690810862785

Symeou, P. C. (2009). Does smallness affect the liberalisation of telecommunications? The case of Cyprus. *Telecommunications Policy*, *33*(3-4), 215ï 229. doi:10.1016/j.telpol.2008.12.006

Tango. (2012a, October 2). Tangoôs 4G services are finally released. *Press Release*. Luxembourg.

Tango. (2012b, October 14). The new generation in entertainment arrives in Luxembourg. *Press Release*. Luxembourg.

Tango. (2013a). History Tango. *Website*. Retrieved August 15, 2013, from http://www.tango.lu/page.php?url=tangocompany/tangocompany/history

Tango. (2013b, July 26). Half-year resultsز Tango still on an upward trend. *Press Release*. Luxembourg.

Tookey, A., Whalley, J., & Howick, S. (2006). Broadband diffusion in remote and rural Scotland. *Telecommunications Policy*, *30*(8-9), 481ï 495. doi:10.1016/j.telpol.2006.06.001

Ungerer, H. (2013). Back to the roots: the 1987 telecom green paper 25 years after ï has European telecom liberalization fulfilled its promise for Europe in the internet age? *Info*, *15*(2), 14ï 24. doi:10.1108/14636691311305399

Waverman, L., & Koutroumpis, P. (2011). Benchmarking telecoms regulation ï The Telecommunications Regulatory Governance Index (TRGI). *Telecommunications Policy*, *35*(5), 450ï 468. doi:10.1016/j.telpol.2011.03.006

Whalley, J. (2006). Recent developments in the telecommunications industry of Nepal. *Info*, *8*(1), 57ï 71. doi:10.1108/14636690610643285

Yamakawa, P., Cadillo, G., & Tornero, R. (2012). Critical factors for the expansion of broadband in developing countries: The case of Peru. *Telecommunications Policy*, *36*(7), 560ï 570. doi:10.1016/j.telpol.2012.03.004

Zahlen, P. (2008). *L'économie luxembourgeoise - une histoire mouvementée*. Luxembourg.

Zeitung. (2013, April 24). Zukunft der Post sichern in allen 3 Bereichen. *Zeitung*, p. 3. Luxembourg.

Zenhäusern, P., Schneider, Y., Berner, S., & Vaterlaus, S. (2012). *Polynomics Regulation Index 2012*. Olten (CH).

Figure 1: Luxembourg

Table 1: Households with PC and Internet access (%)

Year	2005	2006	2007	2008	2009	2010	2011	2012
Households with PC	75	77	80	83	88	90	92	92
Households with Internet access	65	70	75	80	87	90	91	93
Broadband (DSL, fibre, CATV)	52	63	77	76	82[1]	78	75	73
Analogue/ISDN dial-up	51	36	26	24	20	30	27	22
DSL line	49	59	76	74	79	70	63	61

Note

1. The regulator adopted its approach to counting CATV customers to ´active users onlyâ. This change explains the decrease in the penetration of broadband access.

Source: Statec, ILR

Table 2 - Size of the ICT Ecosystem - main indicators

Main indicators	2001[40]	2008	2009	2010	2011	2012	2013
Companies	1797	1517	1594	1680	1750	1825	1920
Employment	11308	13626	13651	14269	14760	15200	16000
Share of total employment		3,9%	3,8%	3,5%	3,7%	4,0%	4,2%
Turnover (in million Euro)	5785	6537	6745	8771	N/A	9500	N/A
Added value (in million Euro)	1846	2264	2196	2600	N/A	2840	N/A
Added value (% of GDP)		6,87%	N/A	7,3%	N/A	6,6%[41]	N/A

Sources: Eurostat, EU, Statec, authorsô calculations, paperjam

[40] Based on Nace 1.0 classification

[41] EU -27 mean value 4.6%

Table 3: Major milestones since liberalisation

Year	Development	Comment
1987	European Commission publishes its Green Paper to initiate liberalisation reforms all over Europe	Initial goal was the creation of a common market for services and equipment
1990	EC Directive 90/388 requesting member states to open up telecommunications services for competition	Separation of operator and regulator became necessary
1992	Entreprise des Postes et Télécommunications (EPT) is created[1]	Change from public administration to a 100% state owned company
1992	Ministry of Communications is created	Takes over regulatory activities from former P&T administration
1992	Luxembourg gets connected to the internet	Internet access for schools, teachers and some government agencies[2]
1993	Launch of LUXGSM, EPTôs mobile 2G network	Replacement of existing BENELUX analogue network
1995	Launch of ñdial-upò internet services by EPT	Internet access becomes available to the general public
1997	Luxembourgish law on liberalisation of telecommunications	Defines universal service, rules of competition and interconnection, creates independent regulator
1997	Creation of ñInstitut Luxembourgeois des Télécommunicationsò later ñInstitut Luxembourgeois de Régulation (ILR)ò	Takes over regulatory work from ñMinistry of Communicationsò ï which is disbanded[3]
1997	Second mobile licence awarded to Millicom SA[4]	Beauty contest approach
May 1998	Second mobile operator starts operations under the brand name of ñTangoò	
July 1998	Fixed network market officially ñliberalisedò	All procedures in place in December only
1999	ñDot.comò boom ï 19 licences awarded to alternative operators	
2000	Introduction of new numbering plan, first Reference Unbundling offer, trials with Wireless Local Loop and ñPowerlineò technologies[5]	
2001	ñDot.comò bust ï consolidation and drop-outs	No new operators, year of stagnation
2002	3 Mobile licences for 3G networks awarded to EPT, Tango and Orange Fir	No candidate for the 4th available licence
2003	4th Mobile 3G licence awarded to Luxcommunications SA Broadband Internet access via ADSL by EPT became saw great success First ñofficialò statistics about the local telecommunications market became available	Later called Voxmobile
2004	Orange returns its 3G licence, VoxMobile was awarded a 2G licence, many specific service providers appeared	
2005	New regulatory framework was put in place transposing the new EU set of directives	
2006	Second state owned operator ñLuxConnectò[6] was created	It was hoped that this would stimulate competition, major investments in international

	EPT started to build Teralink[7] its own international backbone network EPT acquires 100% of European Business Recovery Center The fourth 3G licence was split into two and awarded to Luxembourg Online[8] and Astralis a joint venture between SES and Artelis[9] The city of Luxembourg and EPT launched a city-wide WLAN network[10] Belgacom enters Luxembourg market by acquiring the countryθs largest ICT integrator Telindus[11]	connectivity and data centres were made None of the two licensees went into operation
2007	Mobistar, the Belgium arm of Orange acquired Voxmobile Luxembourg Online and Broadcasting Centre Europe were awarded a WiMax licence in the 3.5 GHz range	First time that a global operator committed to major investments in Luxembourg Has not gone into operations so far
2008	Belgacom acquires Tango (2nd Mobile Operator) EPT invests into ICT integration business and acquires Netcore	Belgacom now present in fixed and mobile market
2009	LuxConnect opens its first datacentre and international back-bone network LU-CIX, a privately owned internet peering point established[12]	 Soon to be merged with Restena
	EPT started to invest into Next Generation Network (NGN) and fibre to the home (FTTH) technologies	
2010	Ultra-high broadband access strategy published	EPT is charged with execution
	LuxConnect opened second data centre and developed LuxCloud to start offering cloud services EPT opened its 3rd and 4th datacentre	
2011	New EU ñtelecom packageò transposed into Luxembourgish law EPT started to commercialise ñLuxFibreò up to 100 Mbit/s FTTH service Telindus (Belgacom) converted into a telecommunications operator ï Telindus Telecom	
2012	Orange and Tango start offering LTE 4G services Ministry announces its intention to build a TETRA network and publishes a call for a public-private partnership. EPT opens its 5th datacentre LuxConnect opens its 3rd datacentre	
2013	Telindus Telecom and EPT respond to the call of PPP for the Tetra Network Ultra High Broadband Strategy is revised and potentially adapted EPT announces rebranding and major restructuring in June Minister of Economy announces a ñMarshallò plan claiming to invest over 1.000 mio Euro in Telecommunications infrastructures in the next 5 years EPT announces LTE lunch for the end of the year	Won by EPT in December 2013 CATV operators are asked to participate EPT gets the major part of these investments Commercial roll-out starts in December 2013

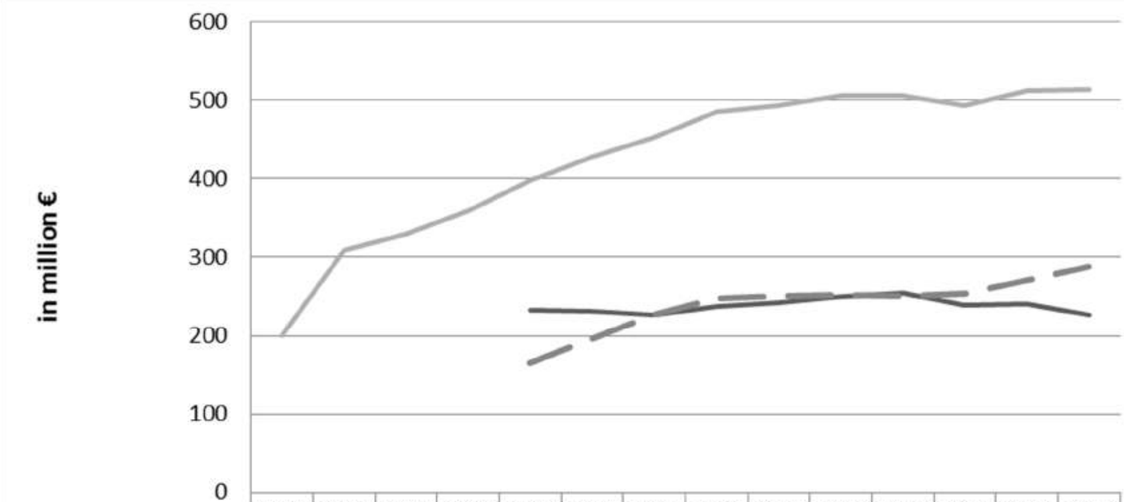
	The 4th LTE/UMTS licence is awarded to Blue Communication who announced the creation of Join Experience ï an MVNO on EPTôs mobile network[13]	EPT holds a 50% share of this venture

Notes

1. For additional information regarding EPT see www.pt.lu, accessed 16.2.2013
2. See www.restena.lu, accessed 16.2.2013
3. There remains, however, a ôMinister in charge of communicationsô and a Service des Médias et de la Communication.
4. See www.millicom.lu, accessed 16.2.2013
5. For a comparison of the technologies see, for example, Fornefeld, Delaunay Elixmann (2008).
6. For details of the company see www.luxconnext.lu, accessed 16.2.2013
7. For details of the company see www.teralink.lu, accessed 16.2.2013
8. For details of the company see www.internet.lu, accessed 16.2.2013
9. For details of the company see www.artelis.lu, accessed 16.2.2013
10. See www.hotcity.lu for more details, accessed 16.2.2013
11. See www.telindus.lu for more details, accessed 16.2.2013
12. See www.lu-cix.lu, accessed 16.2.2013
13. See www.joinexperience.com accessed on 14.12.2013

Sources: ILR, EC, SMC and authorsô interviews

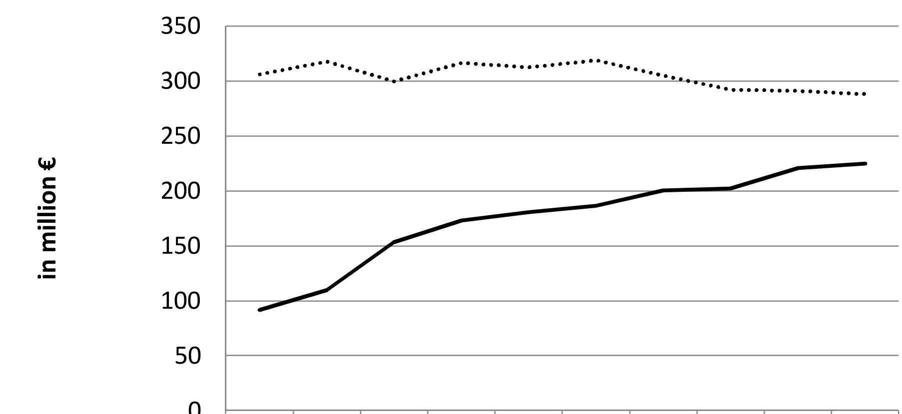
Figure 2: Market size (in ú million) and revenue split between fixed and mobile



	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Market Size	200	310	330	360	398	427	454	485	493	506	506	494	511	513
Fixed					233	231	226	238	242	251	255	240	241	227
Mobile					165	196	228	248	251	252	251	255	270	288,3

Source: compiled by the authors from the annual statistical reports of Institut Luxembourgeois de Régulation

Figure 3: Market share ï incumbent versus other operators



	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
EPT	306	318	300	317	313	319	305	292	291	288
Alt. Ops.	92	110	153	173	180	187	201	202	221	225

Source: compiled by the authors from the annual statistical reports of Institut Luxembourgeois de Régulation

Table 4: Major developments of EPT

Year	Development	Comments
1842	Creation of Public Post and Telecommunications Administration	
1992	Creation of ñEntreprise des Postes et Télécommunicationsò	A 100% state owned enterprise
1993	Launch of LuxGSM ï the first 2G mobile network	Replacing the old ñBeneluxò wide analogue system
1994	Launch of ñintegrated services digital networkò	Migration of analogue fixed line to digital fixed line
1995	Launch of ñDial-upò internet access	
2001	Commercial launch of broadband internet access	LuxDSL
	Launch of General Packet Radio Services	Mobile data access
2003	Launch of 3G UMTS network	
2005	Launch of ñintegralò first ñtriple-playò offer	
	Launch of Blackberry services Launch of Public WIFI hotspots	In cooperation with Vodafone In major hotels and public places
2006	Teralink	International high speed fibre connectivity
2007	Inauguration of EBRC second data centre	
	Pilot Project for IP-TV	
2008	Commercial launch of IP-TV services	
2009	Participation in Lu-CIX	Commercial internet peering point
2010	Fourth Data centre opened	
	3D and HD TV services offered	
2011	Launch of Ultra-high bandwidth Internet access	Luxfibre
2012	5th Datacentre opened First Cloud services Full liberalisation of postal services on the 1.1.2013	

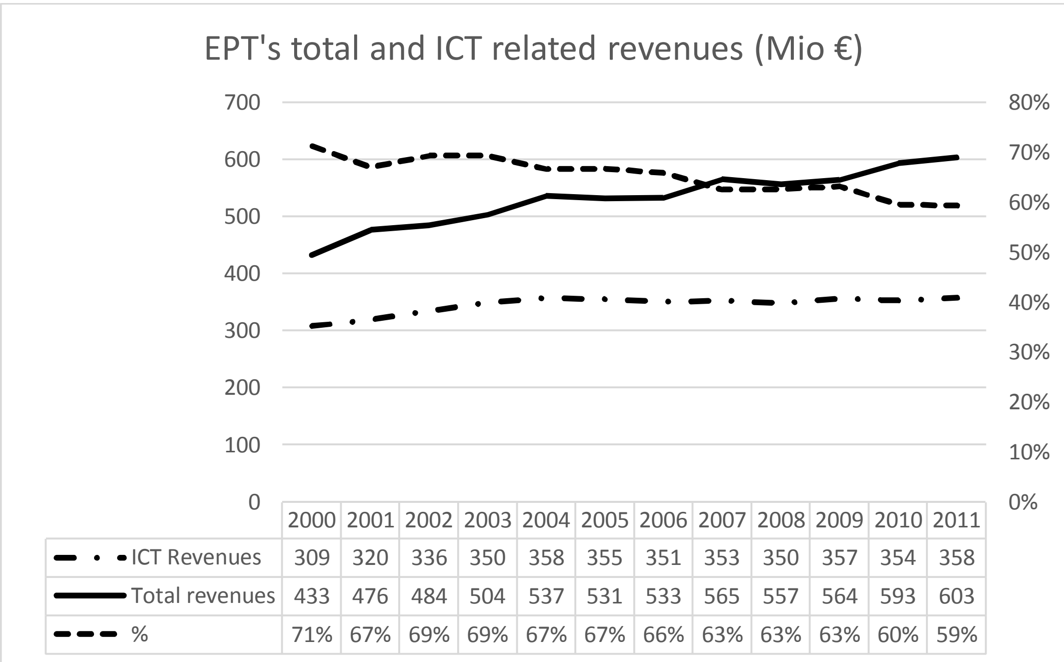
Sources: compiled by the authors from EPTôs web site and a variety of sources

Table 5: Subsidiaries of EPT

Company	Activities	Stake
Ebrc	Datacenter and Business Resilience Services	100%
P&T LUXGSM	Sales of Mobile and Fixed Communications	100%
P&T Consulting	Software Development	100%
Netcore	ICT Integrator	100%
Luxembourg e-archiving	Electronic archiving services	100%
Victor Buck Services	Printing and Financial reporting	90%
Editus	White and yellow pages and databases	89.92%
Michel Greco	Express delivery of mail and small parcels	60%
Infomail	Distribution of advertising material	55%
Visual Online	Internet Service provider	51%
TNT Express	International express and courier services	50%
Hotcity	Public WLAN in major cities	49%
Eltrona	The countryôs largest CATV operator	34%
Regify	Secured Email	11%

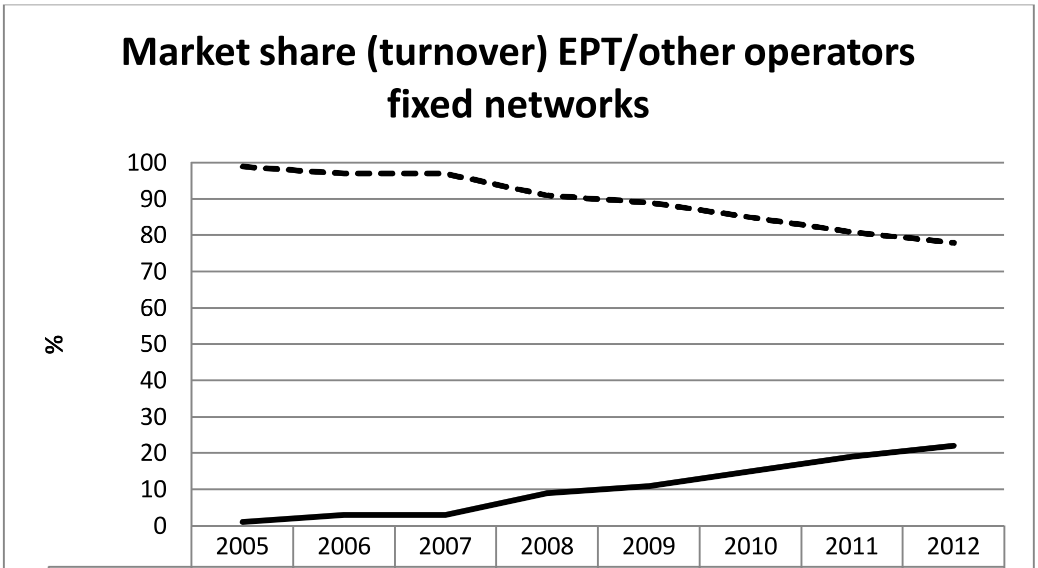
Source: compiled by the authors from the annual reports of EPT and a variety of websites

Figure 5: ICT versus total revenues for EPT



Source: compiled by the authors from EPTôs annual reports

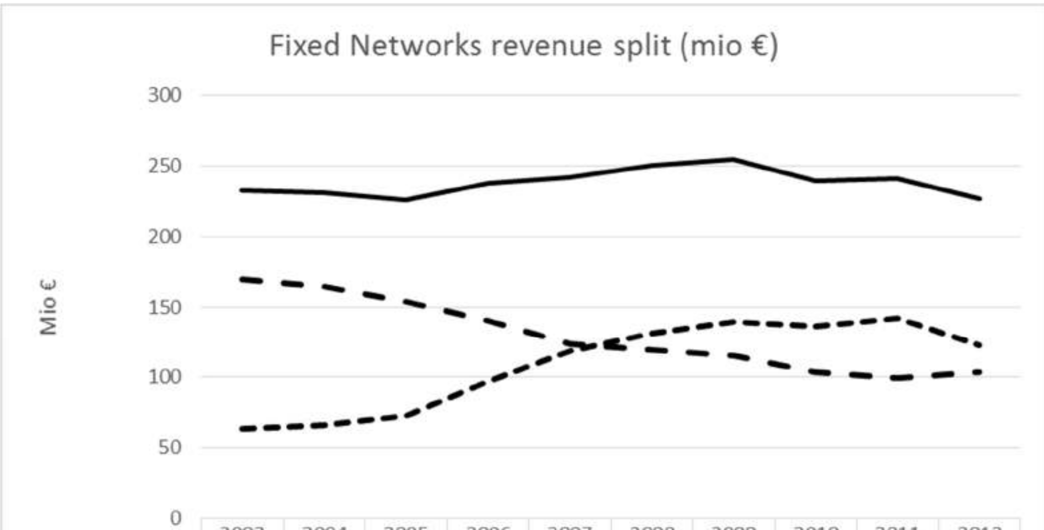
Figure 8: Market share of EPT and other operators



	2005	2006	2007	2008	2009	2010	2011	2012
EPT	99	97	97	91	89	85	81	78
OAO	1	3	3	9	11	15	19	22

Source: compiled by the authors from the annual statistical reports of Institut Luxembourgeois de Régulation

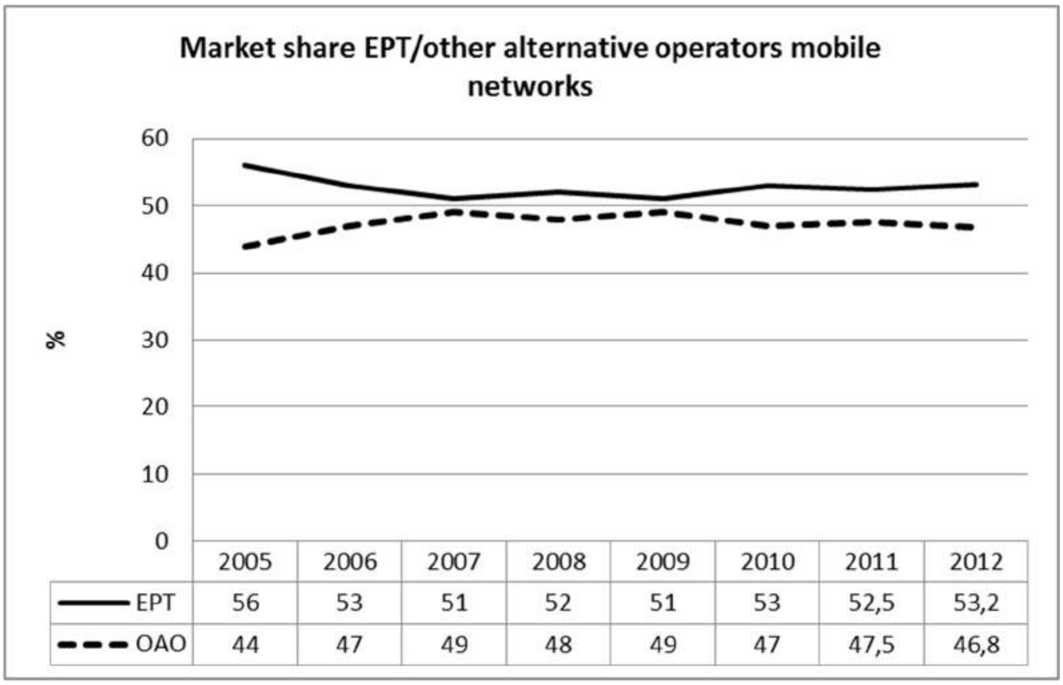
Figure 9: Changing nature of fixed network revenues



	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Voice	169,4	165	153,7	140,2	124	119,5	115,5	103,7	99,3	103,9
Internet	63,4	66,3	72,4	97,3	118,4	130,9	139,3	135,9	141,7	123,2
Total	233	231	226	238	242	251	255	240	241	227

Source: compiled by the authors from the annual statistical reports of Institut Luxembourgeois de Régulation

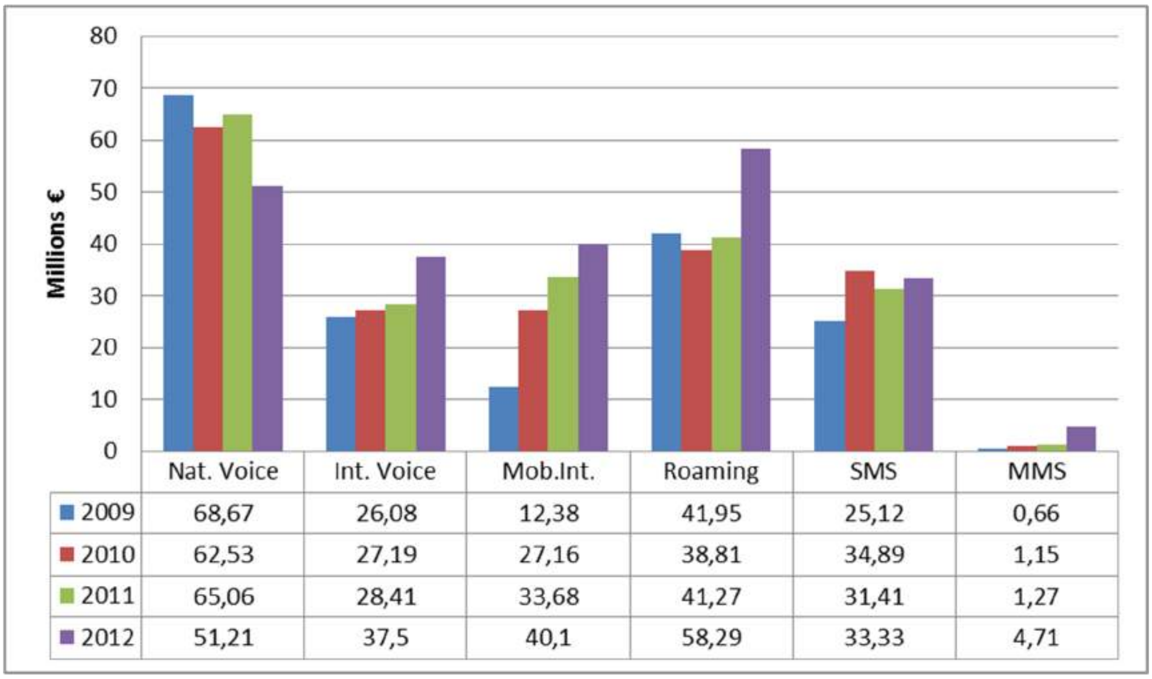
Figure 10: Competition in mobile networks



	2005	2006	2007	2008	2009	2010	2011	2012
EPT	56	53	51	52	51	53	52,5	53,2
OAO	44	47	49	48	49	47	47,5	46,8

Source: compiled by the authors from the annual statistical reports of Institut Luxembourgeois de Régulation

Figure 11: Mobile revenue split



	Nat. Voice	Int. Voice	Mob.Int.	Roaming	SMS	MMS
2009	68,67	26,08	12,38	41,95	25,12	0,66
2010	62,53	27,19	27,16	38,81	34,89	1,15
2011	65,06	28,41	33,68	41,27	31,41	1,27
2012	51,21	37,5	40,1	58,29	33,33	4,71

Source: compiled by the authors from the annual statistical reports of Institut Luxembourgeois de Régulation

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ICT ecosystems in small countries: an analysis of Luxembourg.

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Conference Paper

ICT ecosystems in small countries: an analysis of Luxembourg

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Provided in Cooperation with:
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ICT ecosystems in small countries: an analysis of Luxembourg

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Abstract

Purpose: Information and communication technologies (ICT) are increasingly becoming an important component of economic development. 'Ecosystems' are one way of understanding complex interactions and relationships. Luxembourg's ICT sector is usually characterised as performing admirably - it is often at the top-end of different indices and international league tables. Nevertheless, headline statistics and high-level assessments often disguise the complexities of dynamic relations. It is in this respect that this paper deploys the concept of ecosystems to investigate Luxembourg's ICT sector.

Design/methodology/approach: The layered ecosystem model, devised by Martin Fransman, is utilised to map key actors that comprise Luxembourg's ICT ecosystem, following which a programme of semi-structured interviews were conducted. This empirically produced material, combined with documentary analysis, provides the basis for an analysis of the interrelated elements that are shaping the development of Luxembourg's ICT ecosystem.

Findings: The study has identified the main forces that affect the ICT ecosystem and concluded that Luxembourg's strengths are related to its well-developed ICT infrastructures such as international fibre and national ultra-high broadband connectivity and high quality datacentres and its political vision for ICT that has led to a supportive policy environment. Its main weaknesses are related to an inappropriate educational system in which technical and scientific training is less developed, missing e-skills such as coding, application development, technical IT know-how as well a non-entrepreneurial mind-set and a risk averse culture.

Social implications: The paper highlights the importance of the different socio-economic, political, strategic and technological forces that shape the ICT ecosystem of a small country in order to provide a comprehensive basis for its policy makers.

Originality/value: An empirical focus on a small country helps to redress the research imbalance, whereby small countries are often overlooked by scholars. Nevertheless, we contend that such "smallness" engenders a unique opportunity for research engagement with a majority of primary actors in ecosystems, which might be unfeasible in larger countries.

Keywords: ICT ecosystems, Luxembourg, qualitative analysis

1. Introduction

Luxembourg has one of the most developed telecommunications infrastructures within the European Union (European Commission, 2013a). Broadband and Next Generation Networks (NGN) are available to 100% of the population. The latest mobile networks technologies are present almost everywhere and the country operates about 20% of the world's high resilience datacenter capacity (Luxembourg for Business, 2013). According to the Ookla netindex[1], Luxembourg is positioned 9th out 113 countries with mobile download speed of 23 Mbits/s, and 19th out of 202 countries with about 40 Mbits/s download speed in fixed networks.

This paper builds on the definition of the Information and Communications Technologies (ICT) sector and the underlying classification put forward by OECD (2011) for "measuring the information society". This definition of ICT includes IT goods and services, Information content as well as Telecommunications goods and services including manufacturing and production of these. Information technologies and e-commerce are seen as growth areas for Luxembourg (PWC, 2011). ICT technologies are widely used by households and businesses, about 17.000 people work directly in ICT and many more in the related financial industry. Over the last 15 years, governments have supported the development of the ICT sector as a policy maker, as a regulator but also as ICT service provider as the Government is a 100% owner of two telecommunications operators and has invested directly or indirectly in many ICT related activities. These activities have helped to create a dynamic ICT ecosystem (Rafique, Yuan, Tareen, Saeed, & Hafeez, 2012). In addition, Luxembourg has improved in the last 15 years its relative ratings in international indices, such as, for example, the networked readiness index produced by the World Economic Forum (Dutta, Geiger, & Lanvin, 2015) in which Luxembourg is now placed among the top 10 most "network ready" countries in the world. Nevertheless, Luxembourg's ICT ecosystem also exhibits some frailties not always captured or transparent in international league tables.

This paper deploys the layered ecosystem model approach as proposed by Fransman (2010) as a means to identify the main actors in Luxembourg's ICT ecosystem. Fransman's model has been widely cited and used by many scholars. By applying this model, the authors aim to map the different actors in the ICT sector, analyse the relationships between the actors within the ecosystem in order to better understand how the ICT ecosystem in Luxembourg has developed over the last 15 years and more generally what are the internal and external factors that have helped to shape it over this period in time.

The remainder of the paper is structured as follows. Section 2 presents different approaches to analyse an ICT economy and introduces a specific ecosystem model. Section 3 gives a brief overview of the ICT ecosystem, its size and its main players and presents some of its major developments over the last 15 years. Section 4 argues the case to developing a better understand of the situation by conducting a qualitative exploratory analysis and presents the methodology used. Section 5 presents the initial[2]

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[1] See http://explorer.netindex.com/maps?country=Luxembourg accessed 15.5.2015

[2] Work in progress as part of the lead author's DBA thesis

outcomes of this analysis and the final section discusses this outcome and draws some initial conclusions and suggests potential areas for further work.

2. From Value chains to Ecosystems

In order to establish a competitive and sustainable ICT industry it is important to understand its structure, its underlying business relationships as well as the external forces that help to shape it.

There is a wide range of models available to make sense of the structure of the ICT industry. Many of these apply or develop the Porter's value chain to the ICT environment or parts of it (Maitland et al., 2002) or have extended this model to a so-called value net (Li & Whalley, 2002, Peppard & Rylander, 2006, Rafique et al., 2012). This idea which has also been taken up and developed further by for example Hallikas et al. (2008) and Oestreicher et al (2012). Similarly, Porter's model about competitive forces (Porter, 1990) has been adapted to the ICT environment (Karagiannopoulos, Georgopoulos, & Nikolopoulos, 2005). Along the same lines, Briglauer (2004) has developed a generic reference model in order to asses from a regulatory viewpoint competition in different communications markets. Additional work has been done in characterising the ICT Ecosystem as a network (Garcia & Vicente, 2012), as well as looking into how such networks are built and maintained (Partanen & Möller, 2011).

These models are essentially linear ones, but today's business environment is complex and dynamic and presents multiple relationships where companies are interacting to deliver their products and services. As a consequence, the ICT sector is increasingly characterized as a socio-technological system facing asymmetric and delayed feedback structures, which lead to turbulent changes (instability/existence of multiple equilibria) and high uncertainty. Koslowski, Longstaff, Vidal & Grob (2012) see strong indications that ICT ecosystems represent complex adaptive systems as they exhibit several generic properties, for example, emergence, self-organization and non-linearity. They see the ICT sector as an ecosystem as many heterogeneous organisations that are woven into a web of links and respond interactively to forces in the environments. The understanding of the dynamics of one domain in isolation from the other is impossible and demands both, a systemic and evolutionary view.

According to Kim, Lee, & Han (2010) an ecosystem can be defined as an economic community involving many companies working together to gain comparative advantages as a result of their symbiotic relationships. The authors also argued that ecosystems permit companies to create new values that no company could achieve alone. Likewise, they identified symbiotic relationships that can provide some benefits for related parties such as consumers and partners

Hence it is important to examine ICT ecosystems in order to understand the co-evolution between technological and economic as well as regulatory forces and developments and to provide a comprehensive basis for policy makers, For the purpose of understanding the structure of the ICT ecosystem in Luxembourg, it is suggested here to use a layer model described by Martin Fransman (Fransman, 2001, 2002a, 2002b, 2004, 2006, 2014). This model allows a clear identification of the different categories of actors within the system as well as the "interfaces" and relationships between those actors and thus provides a simple yet effective way to gain a good understanding of the different types of actors, their respective roles and importance to the sector as well the interrelations between them

Building on a technical network model[3], Fransman proposed a 4 layer model to describe and analyse the ICT ecosystem. He deliberately used the term ecosystem (borrowed from biology) to stress the importance of the links between the various ICT actors. When looking at the supply side of the ICT ecosystem, fourtypes of actors can be distinguished (see figure 1):

- Layer I: Network element providers (eg Cisco, Samsung, Alcatel-Lucent, Ericsson, Nokio Networks)
- Layer II: Network operators (fixed and mobile) (eg BT, Deutsche Telekom, Vodafone)
- Layer III: Content & application providers (eg Google, Apple, YouTube)
- Layer IV: Final consumers

In the new ICT ecosystem (ie post-internet), users are gaining presence on the supply side of the system by co-creating with suppliers.

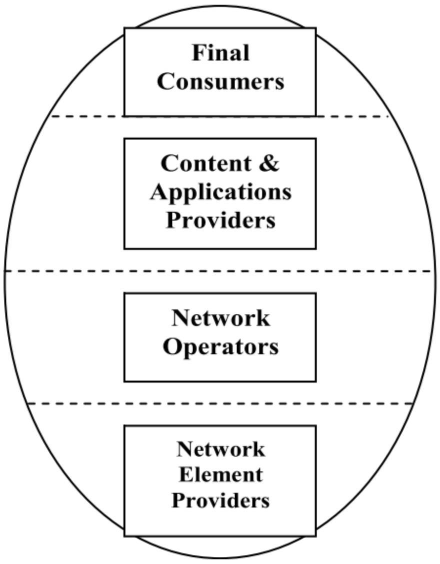

Figure 1 - the 4 layer model

In contrast to the so-called "old ICT ecosystem" (ie pre- internet), which could be described as a closed innovation system with the most important links being between network operators and network suppliers (Layers I and II), the new ICT ecosystem is more open. In recent years, the focus has shifted to the interaction between platform, content and application providers (Layer III).

In his more recent work, Fransman (Fransman 2007, 2010, 2011) has commented on the "necessarily" static picture that such a model provides and has focussed on the role of the dynamic or as Fransman calls them "symbiotic" relationships between the different layers and their role for innovation (Fransman, 2014). These relationships can be described as multi-dimensional representing financial and material flows as well as information and input flows into the innovation processes within the ecosystem.

[3] See http://www.itu.int/ITU-T/recommendations/rec.aspx?rec=2820 accessed 15.6.2013

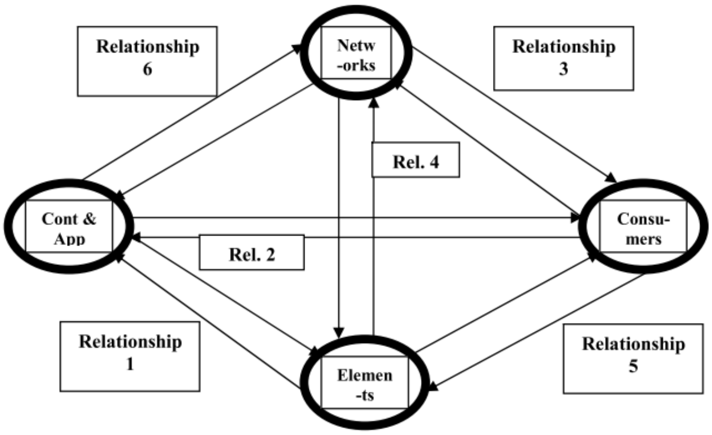

Figure 2 - Relationships within the layer model

An application of how this model can be used to understand the interactions between different actors is provided by, for example, Arlandis & Ciriani (2010). It also includes a detailed database of players in the different layers and focussed but takes a high level view by looking at different economic cluster such as the EU, the US and Asia.

Another application of the Fransman model can be found in Veugelers (2012). Here the model is used to understand why Europe's ICT companies are lagging behind the US and in particular with regard to the "leading platform providers who are capturing most of the value in the ICT ecosystem". It is argued that a very fragmented EU market, lack of entrepreneurial mind-set as well as lack of risk capital are identified as being the main blocking points.

3. Luxembourg's ICT sector

Following the OECD definition of ICT, 7% of the country's Gross Value added is generated within the sector. This share is considerably above the EU-27 average which is around 4.6% of the total GVA and is the highest among the 27 EU member states (European Commission, 2013b). The country has not only a high proportion of highly skilled workers, but has also one of the highest shares of ICT-using occupations among OECD countries. The Luxembourg labour market is characterised by one of the largest shares of knowledge-intensive activities[4] in Europe, with 56% of all the jobs in 2011 falling into this category (Service des Médias et des Communications, 2013).

In terms of computer skills, an European survey on ICT usage in households and by individuals showed that Luxembourg, together with the Nordic countries, features the highest shares of highly skilled computer users in Europe (Service des Médias et des Communications, 2013). Concerning features like Internet skills, participating in social or professional networks, Internet banking, online shopping, ordering goods or services over the Internet, a similar picture of Luxembourg as being part of the leading European nations arises. It shows that e-skills are acquired by individuals to 35% through formal education, 26% through training courses upon demand of their employer, 27% through self-study, 66% through learning by doing, 69% through informal assistance from

[4] An activity is defined as being knowledge-intensive if the tertiary-educated persons employed represent more than 33% of the total employment in that activity (REF NEEDED).

colleagues or friends. Again Luxembourg lies in first or second place of all EU member States.

ICT infrastructure and connectivity

With regard to ICT infrastructure and connectivity (Fransman's layers 1 and 2) Luxembourg has invested considerable efforts to build and efficiently operate multiple state-of-the-art high capacity fibre networks. This is to ensure national and international connectivity, connecting Luxembourg to major hubs in Europe, thereby positioning Luxembourg as a major player in the middle of the so-called 'Golden Ring', which shapes the major Internet hubs of Europe: London, Amsterdam, Frankfurt and Paris (Service des Médias et des Communications, 2013). Also, in terms of communication access paths, Luxembourg occupies one of the strongest positions within OECD countries (OECD, 2013).

By 2009 100% of Luxembourg's population was covered with 3G mobile networks, whereas in 2012 64% of the population were covered by the 4G network. Similar considerations apply to broadband connectivity and will be even further developed, as in its national strategy for very high-speed networks, issued in April 2010 (SMC, 2010a), the Government intends to increase the speeds of the existing networks, and provide, in the medium term, access to optical fibre in the entire territory. It is the Government's intention to transform Luxembourg into the first "fibred" country of the EU, if not in the world. Luxembourg has also grown into the premium location for data centre parks in Europe, with more than 19 data centres are operational, presenting generally the highest securities standards (SMC, 2010b).

With regard to the ICT equipment in enterprises, the aforementioned study, using figures provided by STATEC for 2012, states that among enterprises with 10 or more employees, practically all (98%) have Internet access, virtually all (95%) through a broadband access and many (54%) also through a mobile connection. Three quarters of the enterprises have their own website, 48% an Intranet, 32% an extranet, 16% videoconferencing facilities and among the enterprises using computers 100% worked with a wired local area network (LAN) and 43% had also a wireless local area network (WLAN). It can be assumed that these numbers have since then improved.

ICT usage in private households

The 2015 STATEC bulletin on ICT in households and among individuals in 2014 (Bodson & Frising, 2015), highlights the recent expansion of social networks and cloud activities, especially among young people. In 2014, 60% of residents aged 16 to 74 participated in social networks, of which Facebook was the most popular as 57% of residents were present there, with only 8 and 9% for LinkedIn, Google+ and Twitter combined. Generally customers only consult one social network (64%), with only 36% of users consulting several networks. Not surprisingly, young people are very active: 91% are present in at least one social network against 26% of the 65-74 years category. Social networks are used primarily to maintain existing relationships (82%), to renew past relationships (74%) and share photos and videos (57%). As for the absentees from social networks, they often justify this with their desire to keep their private life to themselves (74%).

The "cloud" also marks a great success as the country moves with 37% of users to the third position of EU28. The cloud is mainly a case for youth with 50% of users and is linked to the level of education: post-secondary graduates are 44% against 26% for lower secondary graduates and non-graduates.

In comparison to previous studies, this STATEC bulletin states that in 2014 96% of household residents had access to the Internet, an increase of six points compared with 2010 and 26 percentage points compared to 2006. Luxembourg is now positioned at the top of all European countries. The computer remains the number one device for accessing the Internet (87%), followed by the smartphone (70%). Similarly, with regard to online commerce, in 2014 74% of residents made purchases of goods and services on the Internet. This proportion has doubled in 10 years, from 39% in 2005. Among the most common purchases are those related to holidays (vacation dwellings (45%) and transport rental tickets, 39%). Purchases of books and magazines are also common (44%). At a European level, Luxembourg is in fourth position with regard to purchases over the Internet.

Government initiatives

The Luxembourg ICT-stakeholders have recognized the important role that ICT plays in national economic development. Luxembourg has, in recent years, experienced a major advancement with the accelerated development of the country's innovative technology companies, whether in the media sector, e-commerce, digital content, cloud computing, big data or electronic payments (Kitchell, 2010).

A considerable investment has been realised to transform Luxembourg into a highly connected country, while providing the necessary support structures, such as communications infrastructure (connectivity, data centres, security-related services), research and innovation institutions (university, research centres, support to innovative companies, etc.), or adapting the legislative framework for a dematerialized digital society. It was thus possible to create an attractive setting for companies that wish to develop their activities in the country, as well as to provide new employment perspective for highly specialised workers, thereby increasing the competitive as a nation on the whole (SMC, 2010b).

As a consequence, the ICT sector becomes an economic player in its own right and is not merely limited to its function as a services provider to other economic sectors. In both ways, as an economic sector by itself and as a vector of competitiveness for all other socio-economic sectors, the ICT sector will play an important part in the modernisation, performance, competitiveness and efficiency of the country.

In order to strengthen and consolidate the country's position in the field of ICT and to transform its ICT sector into a 'high tech' centre of excellence, the Luxembourg government, in conjunction with its stakeholders, a digital strategy, encompassing subjects as diverse as the computerization of government services, e-skills, the adaptation of financial support instruments, the development of new niche markets for new markets (big data, health technologies, innovation in services to the financial sector ("FinTech"), virtual currency, creative industries, etc.), and the Government accepts this strategy of horizontal and consistently across all its policies that may be relevant (Gouvernment du Luxembourg, 2014b).

4. Methodology

Whilst all of the above mentioned facts and figures tend to show that ICT has developed over the course of the last 15 years, it is it not clear what have been the main reasons for this relative success and whether this will continue in the future. Therefore, we propose to apply the Fransman model to explore the ICT ecosystem and to identify the different forces and relationships at hand.

In a first step the main categories of actors have been identified in the different layers as well as institutions that shape and influence the relationship between the different layers using a focus group of 9 experts. The outcome of this work resulted in the overview of the ICT sector in Luxembourg that is presented in Figure 3 (below).

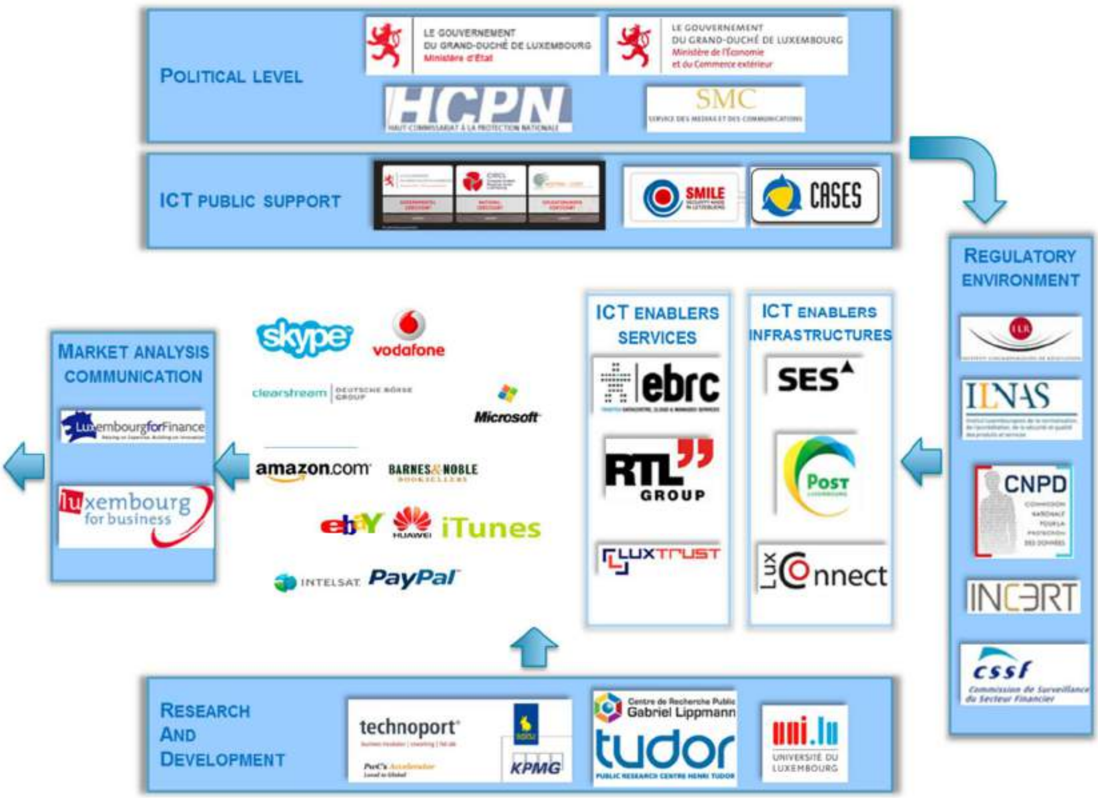

Figure 3: Luxembourg's ICT Ecosystem

This model was discussed with different stakeholders and developed by the lead author in an interactive and iterative manner. Focussing on the above mentioned relationships within the ecosystem, it starts by identifying actors at government and political level that shape the regulatory and policy environment for ICT within the framework of the regulatory packages set by EU (European Commission, 2014a). It then identifies the different state-owned agencies and institutions that provide support to the ICT sector in terms of public funding, awareness raising and training (upper box in the model).

The next level identified concerns regulation in the broadest sense, including the National Regulatory Authority, the National Standards Agency, the Data protection commission as well as regulatory authorities for the financial sectors (right box). The ICT ecosystem is also supported by R&D activities and organisations such as

University of Luxembourg, public research centres but also venture capitalists and incubators (lower box).

Looking closer into the system itself, it is possible to identify ICT enablers that provide the underlying infrastructures; this includes network element providers and network operators corresponding to the layers 1 and 2 of Fransman's model. Building on this, one can find the ICT service enablers that would fit within Fransman's third layer and the customers or users of ICT of which some have been identified in the diagram above. Customers are Fransman's fourth layer. These include most of the actors in Luxembourg's well developed financial sector (KPMG, 2013). Finally we can also identify several institutions or organisations, private and public that are active in promoting the sector both nationally and internationally

Building on the figure above, we have chosen to conduct a qualitative exploratory analysis (Cresswell, 2014; Easterby-Smith, Thorpe, & Jackson, 2012) building on extensive unstructured and face-to-face interviews (Schultze & Avital, 2011) with major stakeholders within the ICT ecosystem. The objective was to study the forces that shape the ICT ecosystem, to understand their interactions and to identify its strengths and weaknesses. A two stage approach was adopted, using a focus group consisting of major industry and institutional players in order to establish an initial template through a SWOT analysis (Anderson, 2010; King, 1998). This SWOT analysis was the used to design open-ended questions to start the interviews and to assist in the later coding process of the outcome of these.

Potential interviewees were then identified based on the lead authors' contacts – about 60 people have been identified. Care was taken to have a reasonable sample of actors across all of the different "Fransman layers" as well as institutions and outside "influencers". Only senior decision makers were interviewed, all with many years of experience in ICT and more particular the Luxembourgish situation.

Table 1 below identifies the companies or institutions that have been interviewed, categorised by the different layers identified by Fransman. Requests were made by email and generated a positive response rate of higher than 80%, with additional people contacting the lead author to volunteer to be interviewed. A total of 51 interviews were conducted over a period of 9 months during 2014, roughly one or two per week. Starting usually with "what do you find good or bad about the ICT ecosystem in Luxembourg?" No clear definition of the ICT ecosystem was made but participants often gave their own definition. Interviews took place in a location chosen by the interviewee (mainly their offices) and were recorded. In order to guarantee confidentiality a "non-disclosure agreement" was signed. Initially the interviews were completely unstructured, however, after a first analysis and in order to avoid too much duplication of the same topics, subsequent interviews were semi-structured in order to identify the widest possible range of different views. During the interviews, participants were asked to identify what they considered to be the main strengths and weaknesses of Luxembourg's ICT ecosystem, what according to them has led to the current state of its development and how they thought that the ecosystem was likely to evolve in the future. They were also asked to come up with suggestions for future actions.

The recordings of the interviews, which generally lasted around 1 hour, were then imported into NVIVO, a computer aided qualitative data analysis software to be processed (Bazeley & Jackson, 2007; Beekhuyzen, 2010; Neill, 2013; Welsh, 2002; Wong, Medicine, & Lumpur, 2008). As NVIVO is able to code data directly in either text, pdf, audio or video files, it was decided to code directly on the audio content, transcribing and translating however the main ideas and topics into text as well. Due to the multilingual workforce of Luxembourg, interviews have been conducted in four languages - Luxembourgish, French, German and English - and were then partially translated. An advantage of NVIVO is that is allows almost instant access to any of the underlying data so that everything that has been said can be traced back directly from coded outcomes.

Fransman's layer	Interviewed Organisations and Institutions	Individuals
I – network element providers	Alcatel-Lucent, Cisco, HP, Unify	4
II – converged communication and content distribution providers	Broadcasting Center Europe, British Telecom, Cegecom/Artelis (2), Eltrona,(2) Fédération des Opérateurs Alternatifs Luxembourg, HotCity, Join Wireless, Post (2), Société Européenne des Satellites,Telecom Luxembourg,	13
III – platforms, content and applications	Association des professionels du secteur financier, Association des professionels du secteur de l'information, CTTL, Data4, Datacentre Luxembourg, Ebrc, Itrust, Luxconnect (3), Luxcloud, Netcore, Systemat, Telindus (2),	15
IV – consumers	Appolo Strategies, Association des Banques et Banquiers, Exxus (2), Gartner , Ikano, Fédération des Artisants,,Luxembourg Business Federation, ProNewTech, PwC	10
Outside influencers – finance, regulation, standardisation	Interdisciplinary Centre for Security Networking and Trust (2), Institut Luxembourgeois de Regulation, Luxinnovation, Luxembourg Institute of Technology, Ministère de l'Economie, Moskito, Service des Médias et des Communications	8

Table 1: Companies and institutions interviewed

Coding started with the initial template from the aforementioned SWOT analysis but evolved over time. Additional interviews have been conducted until no further new codes or topics arose. Translation, partial transcription and coding took about 3-4 hours per interview. The use of NVIVO gives a lot of facilities, for example it allows immediate display all the codes per interviewee, it allow basic statistical analysis for example on frequency of codes, time spent, how often a certain code or indeed expression has been used. It also allows for a graphical representation of interviews, the topics covered as well as the relationships between codes. Instant access to underlying text, audio, or video files is possible and all raw data are always available.

On the other hand, understanding and setting up the tool can be cumbersome, the raw data generate large files that are difficult to handle, the coding takes a lot of time and is necessarily somewhat subjective. As a consequence, based on some samples – coding verification has been done independently. The tool, however, also has an "autocoding" function that could unfortunately not be used because of the respondents' use of different languages.

5. Main forces shaping the Ecosystem

The following section presents the outcomes of the interviews with the different stakeholders identified in Table 4 (above). It appeared that a majority of interviewees made a difference between factors that Luxembourg and the actors in the ecosystem have some control over (endogenous factors) and those that were “outside” of the system and driven mainly by the wider EU regulatory and geopolitical competitive environment (exogenous factors). Figure 4 (below) presents the different categories of topics that were mentioned as well as the different individual items and their relative importance, whereas Tables 3 and 4 also indicate how often a certain topic was mentioned.

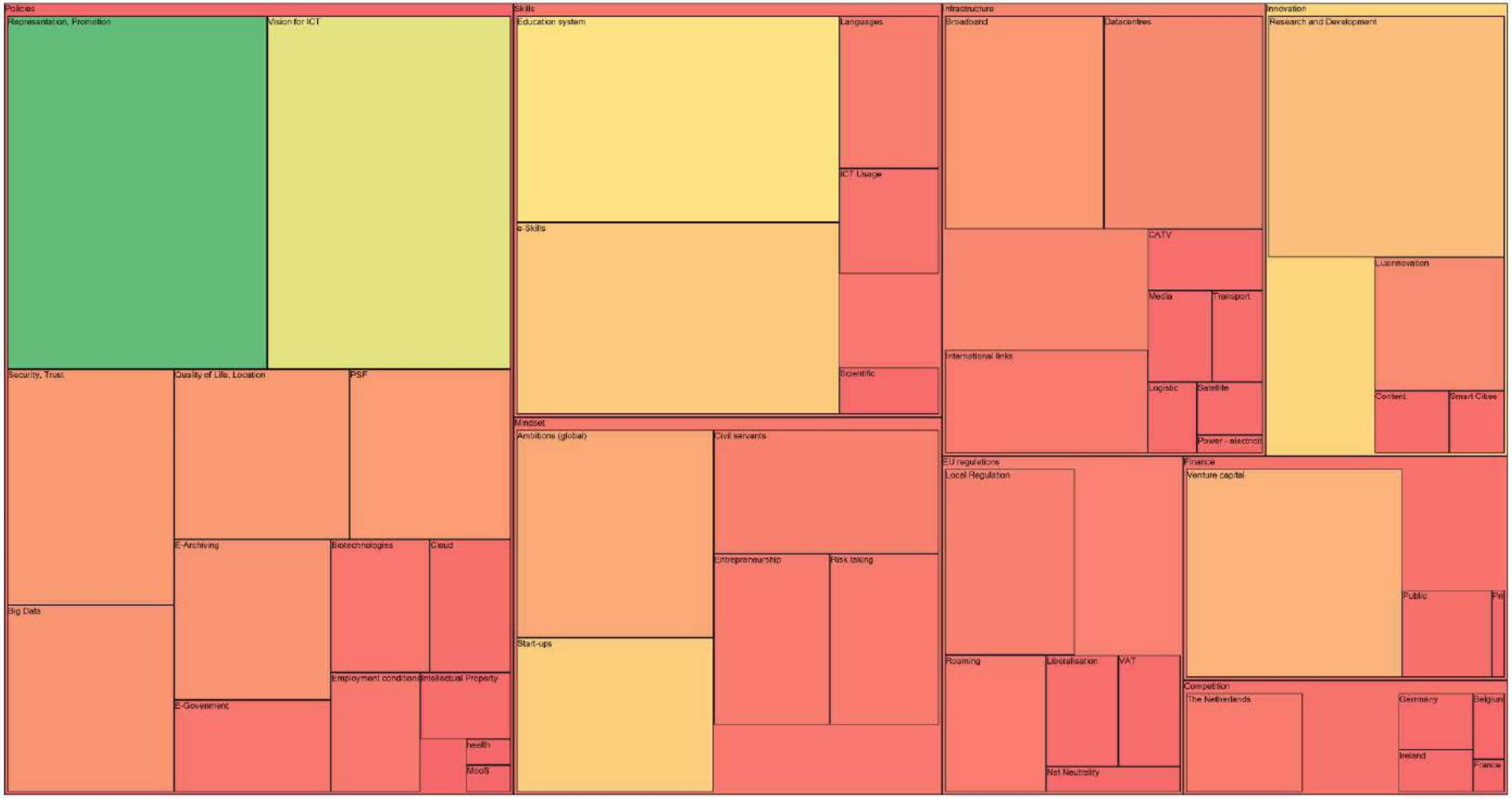

Figure 4 –Forces and specific topics identified by stakeholders

5.1. Exogenous Factors

The table below shows the exogenous factors that were mentioned as well as the frequency that they occurred in the interviews.

Exogenous Factors	Identified by stakeholders
Competition	**30**
Belgium	2
France	1
Germany	3
Ireland	3
The Netherlands	11
Regulations (EU)	**66**
Liberalisation	7
Local Regulation	21
Net Neutrality	3
Roaming	12
VAT	6

Table 2: Exogenous Factors influencing the ICT Ecosystem in Luxembourg

The importance of EU regulations

A large majority of the stakeholders are well aware that the local ICT ecosystem is heavily influenced and evolves within the framework of the different EU regulatory packages (see, for example, European Commission, 1987, or European Commission, 2013b) and programmes that have been put in place mainly in order to stimulate competition and the move towards a digital single market (European Commission, 2010). It was felt that often these EU regulations are not working in favour of the ICT ecosystems of small countries and the pressure towards a single EU wide market favours large or indeed global players. In this context, the discussion about reducing or abolishing roaming charges was often mentioned as an example (De Fooz, 2014a; Henry, 2014b) as well as the fact that there exist many restrictions with regards to access to on-line content and geo-blocking applied by major content owners. This prevents local consumer from legally accessing such content (Boston Consultancy Group, 2013).

On the other hand, some stakeholders also mentioned the effect of the different VAT regimes on electronic commerce. This has had, so far, a major positive influence on the development of the industry (PWC, 2011). These stakeholders were also aware, however, that this effect is currently about to disappear in line with EU rules (Post Telecom, 2014).

Many stakeholders also identified issues related to the local implementation of the EU regulations and it amongst others it was felt that national regulatory authority did not actively enough intervene in the market and did not have the necessary resources.

Growing international competition

In addition international competition from different EU member states both to attract ICT activities and on the export level have also identified to be increasingly important. In this context, the main competitors identified were the Netherlands, Ireland as well as Luxembourg's immediate neighbouring countries. It was felt that competition was generally becoming more intense and that recent events around "Luxleaks" (Paperjam, 2014b; Raizer, 2014b) as well as Luxembourg's image as a "tax heaven" were negatively affecting Luxembourg's position (Guardian, 2014). It also becomes increasingly difficult to identify and communicate Luxembourg's unique selling points, with some actors commenting that a new marketing and communication strategy might be needed (Bervard, 2015; Fondation Idea, 2014; Gouvernement du Luxembourg, 2014).

Overall, participants felt that both of these sets of external factors had a major influence on the ecosystem and suggested that Luxembourg, due to its small size, might be more vulnerable or exposed to the these forces that the Fransman model gives less emphasis to.

5.2. Endogenous Factors

Table 4 below shows some details of the endogenous factors that were mentioned by the different stakeholders as well as their frequency. The list of these factors is much longer and it will not be possible to address then in depth here. Thus, only a broad overview will be provided below (by order of the importance expressed by the number of times a certain topic was mentioned).

Government Policies

A wide range of different policy initiatives have been identified and commented on. There was a large and general agreement that successive governments had taken ICT seriously and developed, as expressed by the World Economic Forum (Dutta et al., 2015), a "vision for ICT" and launched a wide range of initiatives that have helped the sector to develop. It was felt, however, that more could have been done in terms of marketing and promotion of Luxembourg to the outside world and that the sector also needed a more coherent approach in terms of its representative bodies. Indeed, too many associations, forums, federations, clusters and agencies are claiming to represent their individual members' interests, but there is a lack of overall representation of the sector, both nationally as an interface to policy makers and internationally. In that respect, participants welcomed the recent creation of an overarching federation called ICT Luxembourg (Gaudron, 2014) as well as a new government strategic plan called Digital Lëtzebuerg (De Fooz, 2014b; Land, 2014) and expressed their hopes (and fears) that these initiatives might improve the situation.

Many participants, and in particular foreigners working and living in Luxembourg, identified its smallness as a major factor. This smallness leads to a very high quality of life (low pollution, safety, nature, high standard of living) and, most importantly, to easy access to political decision makers implying the potential to react flexibly and quickly. On the other hand, many stakeholders also mentioned that this high standard of living also leads to very high living costs and consequently of employment. In particular, housing has become extremely expensive making it difficult for young entrepreneurs to move to Luxembourg (Sorlut, 2014). Several individual government initiatives were positively commented on. These included the creation a specific status and certification for services providers to the financial sector (Deloitte, 2013), the focus on security, trust and data protection (Trân, 2013), initiatives around the usage and exploitation of big data (KMPG, 2014) and the legal framework on intellectual property rights (Raizer, 2014a).

Endogenous Factors	Identified by stakeholders
Finance	**59**
Private	1
Public	7
Venture capital	40
Innovation	**89**
Content	4
Luxinnovation	15
Research and Development	49
Smart Cities	3
Mind-set	**131**
Ambitions (global)	35
Civil servants	24
Entrepreneurship	17
Risk taking	16
Start-ups	26
Policies	**326**
Big Data	25
Biotechnologies	11
Cloud	9
E-Archiving	21
E-Government	12
Employment conditions	9
Health	5
Intellectual Property	5
Mini One Stop Shop for VAT	1
Professional of Financial Sector	23
Quality of Life, Location	25
Representation, Promotion	77
Security, Trust	33
Vision for ICT	72
Skills	**144**
Education system	57
e-Skills	53
ICT Usage	9
Languages	13
Scientific	4
Infrastructure	**118**
Broadband	29
CATV	6
Datacentres	29
International links	18
Logistic	3
Media	5
Power – electricity	1
Satellite	2
Transport	4

Table 4: Endogenous factors identified by stakeholders

However, some people commented negatively on the fact the Luxembourg had still not managed to create a legal framework for "e-archiving" (Cencetti, 2014a; Ministère de l'Economie et du Commerce Exterieur, 2013). Some participants also felt that more could have been achieved in terms of "e-government" (Gouvernement du Luxembourg, 2005) and "e-health" (Henry, 2014a; PWC Luxembourg, 2013). It was also suggested that too much effort was focused on biotechnologies (Gouvernement du Luxembourg, 2013). A handful of participants suggested initiatives to fill these gaps.

Education and e-skills

The interviewees also insisted on the importance of relevant skills, both on a technical and scientific level but more generally the e-skills necessary to make the best use of ICT. It was found that Luxembourg has performed particularly badly on these "softer" elements. Participants actually complained about the fact that it became increasingly difficult to recruit the necessary employees on the local and even regional market, and that substantial effort was needed to attract such employees to Luxembourg. One or two actually identified missing e-skills as a major hindrance to their further development. Several national studies are available to confirm this situation (Fedil, ABBL, & CLC, 2014; Gouvernement du Luxembourg, 2011) but this is also a major issue in surrounding countries and generally in Europe (European Commission, 2014b; Gareis et al., 2014).

On the other hand, participants mentioned the lack of appropriate training and education within Luxembourg both in terms of software programming but also more generally in terms of technical and scientific education (European Schoolnet, 2012). Some also commented more generally on the efficiency and effectiveness of Luxembourg's educational system, a system that is based on "tri-language" education and which needs some adaptations in the light of the quickly evolving social and technological environment (Gouvernment du Luxembourg, 2014a; OECD, 2014). Many of the participants highlighted the urgency of this issue and hoped that the government's new strategic plan would help to ease the situation (De Fooz, 2014c).

Mind-set

Stimulating entrepreneurship and facilitating the creation of start-ups are also important element of success. It was found that Luxembourg lacks both the necessary processes and procedures but, more importantly, an entrepreneurial mind-set. Participants also identified a general mind-set issue in terms of the risk awareness particularly of the local population. Indeed a lot of young people prefer a job as a civil servant in an administration or local community to – sometimes less well paid – jobs in private sector.

Infrastructures

Developing ICT infrastructures has been confirmed as an important building block for a successful ICT ecosystem. Participants agreed that Luxembourg has been doing very well on these elements, with extensive high-quality, high-resilience data centre capacity (Service des Médias et des Communications, 2013), low-latency international connectivity and broadband internet access are in place and used both by private individuals and professionals. These need to be supported, however, by investments in complementary infrastructures such as transportation (Antzorn, 2014a) and energy distribution networks (ILR, 2013).

Some participants made critical comments about unused capacity, both in terms of international communication links and data centres and mentioned the lack of space for larger data centres of a lower quality standard (Labro, 2015). Some also suggested that perhaps too much focus had been given to providing fibre connectivity to each household as part of the government's broadband strategy (SMC, 2010a). A more focussed approach, making more use of the already existing CATV networks, might have been more effective (Henry, 2013; OPAL, 2013).

Innovation
Luxembourg's university, which is only 10 years old, was felt by many participants not yet to be fully aligned with the requirements of Luxembourg's economy (Paperjam, 2014a). It was also suggested that the same was true for the country's public research centres (Lambotte, 2014b). Technical, and in particular ICT education programmes, are missing or very narrowly focused. There is also no business school attached to these programmes.

There also have only very limited creations of spin-offs or start-ups through these institutions. It was also felt that organisations facilitating these processes were not working efficiently (Cencetti, 2014b; Luxinnovation, 2013; Machuron, 2014) and that better coordination between them was needed. Many of the statements made have been recently confirmed in an OECD study about innovation policies in Luxembourg (OECD, 2015).

Access to financing
Luxembourg's financial centre is very well developed (Bourgain, Pieretti, & Høj, 2009; Merker, 2013) and this may explain that access to finance was not generally found to be major issue (IT One, 2014). Access to initial, high risk, venture capital was identified as being of some importance but overall the main problems seems to be the lack of initiatives and ideas for new start-ups rather than their financing (Antzorn, 2014b; Lambotte, 2014a; Machuron, 2014)

Industry structure
Participants were also asked how they saw the structure of the market following several years of liberalisation and privatisation efforts. It was felt by the participants to be very important to have an adequate mix of public and private investments, but that the incumbent operator after years of liberalisation of the market was still very dominant. This could prevent both local investments as well as foreign direct investment par major ICT or telecommunications actors.

Figure 5 (below) summarises the main findings of the analysis. These have been derived using an inductive approach from the statements made by the interviewees. Interviewees have identified the different underlying internal and external forces. For some factors (green) the participants felt, overall, that Luxembourg was performing well and that the ICT infrastructure as well the governments' "vision for ICT" were considered to be particular strengths of Luxembourg. Educational topics, e-skills and the missing "entrepreneurial mindset" were identified as major weaknesses. Growing international competition was identified as the main external threat that the ecosystem is currently facing.

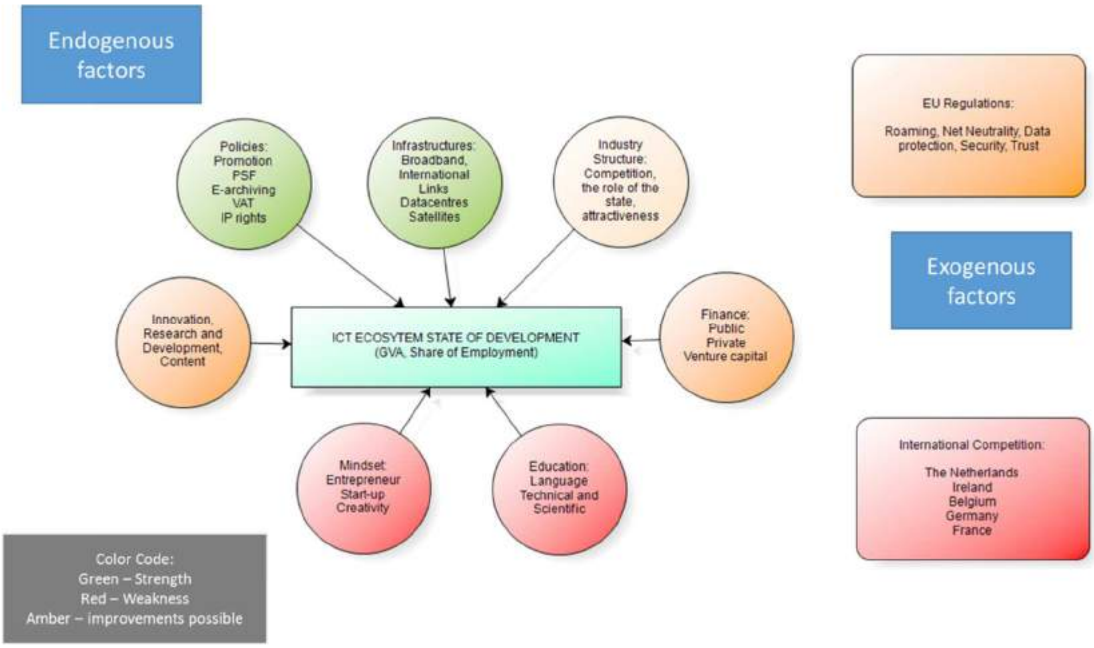

Figure 5: Overview of factors influencing Luxembourg's ICT Ecosystem

6. Discussions and conclusions

In this paper we have employed the layered model of Fransman to identify major industry participants within the different layers. An exploratory qualitative analysis building on interviews with over 50 participants in the ICT ecosystem in Luxembourg were undertaken.

These participants confirmed that, according to them, Luxembourg has been successful in developing its ICT sector over the past 15 years, which is reinforced by international rankings and comparisons, and 'official' reports. The government's initiatives have contributed to developing the underlying ICT infrastructures in terms of international connectivity, broadband and ultra-high broadband access as well as datacentre infrastructures. They also confirmed that the industry structure has changed over time and that competition in several segments of the sector has increased. This competition has resulted in innovative products and services being offered at appropriate pricing levels, and these services have been adopted by both private users and enterprises. This, in turn, has led to the creation of jobs and added value for Luxembourg's economy.

On the other hand, participants acknowledged that new challenges have appeared over time and that past policy initiatives may not be enough to sustain present competitive advantages. Clearly, Luxembourg is impacted by changes in EU rules and regulations which make it increasingly difficult to offer financial or tax advantages to companies investing in Luxembourg, and the government has faced some strong international pressures recently in that respect (Lecadre, 2014; Paperjam, 2014b; Raizer, 2014b, 2014c, 2014d). Consequently, it becomes more difficult to position Luxembourg successfully in the context of increased EU and even global competition and Luxembourg needs to make changes to its ICT ecosystem.

Many factors could potentially contribute to the creation of 'unique selling points' for Luxembourg, but participants expressed concern that Luxembourg has been over reliant on developing its ICT infrastructures in terms national and international fibre connectivity and datacentres. Derived from interviews, we have identified many additional factors that also need to be further developed and that Luxembourg has been unable, to date, to institutionalise an educational framework equipped to "produce" the necessary IT skills on a local basis due to a natural inertia in adapting the curriculums. Instead it has relied on "import of knowledge" from neighbouring countries, whilst focussing on its language skills and legal, financial and humanities education. Different initiatives are now under discussion both on the supply side (new training programmes, private schools, professional development) and on the demand side (promotion of Luxembourg as an attractive place to live and work) but all of these will take time to become embedded.

On the other hand, innovation, entrepreneurship, the willingness to take risk and to start new ventures also appears to be underdeveloped. This might necessitate changes to innovation policies and R&D orientation, as well as a re-engineering of the legal and regulatory environment to help better facilitate the creation of start-ups.

Overall, the case of Luxembourg illustrates that it is important to examine the exogenous and endogenous dynamics of ICT ecosystems, which can reveal some nuances erased from international indices and high-level analyses, which could aide policymakers. The above analysis provides a first step and part of a wider effort to better understand the ICT ecosystem in Luxembourg, or in other small economies, albeit the analytical formulations remain provisional as research is on-going. Indeed, there is a need for deeper analysis of interview material.

The paper has benefitted from applying Fransman's model, which proved useful in identifying key stakeholders. Nevertheless, it does not allow the identification of all of the different subcategories in the different layers that might have substantially different views and requirements. It is, by its nature static and does not adequately cope with the dynamics of the ecosystem and recursive interrelationships that are manifold even during the short period covered by the study. Moreover, stakeholders can be – and are often – main players in one, two or even more of the different layers and adopt a different position depending on the layer concerned. The model does not in itself give sufficient importance to external factors such as regulations or international competition. It does not, therefore, allow for the positioning of any supporting institutions and supporting agencies, such as for example, "Luxembourg for Business" or the different regulatory bodies as shown earlier in Figure 3.

Limitations notwithstanding, to the best of our knowledge, this is the first time that an in-depth analysis of Luxembourg's ICT ecosystem has been performed. This helps to redress the research imbalance, whereby small countries are often overlooked by scholars. Nevertheless, we contend that such "smallness" engenders a unique opportunity for research engagement with a majority of primary actors in ecosystems, which might be unfeasible in larger countries. Comparative analysis of the ICT ecosystems of small countries might be an interesting avenue of further research.

References

Anderson, C. (2010). Presenting and evaluating qualitative research. *American Journal of Pharmaceutical Education*, *74*(8), 141.

Antzorn, F. (2014a, March 4). 31 heures de temps perdu dans les bouchons. *Paperjam*. Luxembourg.

Antzorn, F. (2014b, June 24). L ' écosystème des start-up en à peine 300 clics. *Paperjam*. Luxembourg.

Arlandis, A., & Ciriani, S. (2010). How Firms Interact and Perform in the ICT Ecosystem? *Communications & Strategies*, *79*(3), 121–141.

Bazeley, P., & Jackson, K. (2007). *Qualitative Data Analysis with NVivo*. *Sage Publications* (Vol. 2nd).

Beekhuyzen, J. (2010). The Nvivo Looking Glass : Seeing the Data Through the Analysis. *Qualitative Research*, 1–12.

Bervard, L. (2015, May 9). Es gibt kein Wundermittel mehr. *Luxemburger Wort*, p. 24. Luxembourg.

Bodson, L., & Frising, A. (2015). *Les TIC dans les ménages et chez les particuliers en 2014*. Luxembourg.

Boston Consultancy Group. (2013). *Reforming Europe's Telecoms Regulation to Enable the Digital Single Market*. Brussels.

Bourgain, A., Pieretti, P., & Høj, J. (2009). *Can the Financial Sector continue to be the Main Growth Engine in Luxembourg ?* (No. 660). Paris.

Briglauer, W. (2004). Generic reference model for the analysis of relevant communications markets: fundamental competition concepts. *Info*, *6*(2), 93–104.

Cencetti, J. (2014a, July 21). L ' archivage électronique, une nouvelle source économique. *IT Nation*. Luxembourg.

Cencetti, J. (2014b, September 24). Pour une meilleure coopération FNR et Luxinnovation. *IT Nation*. Luxembourg.

Cresswell, J. W. (2014). *Research Design* (4th ed.). London: Sage Publications.

De Fooz, A. (2014a, October 6). La fin du roaming, vraiment? *Soluxions*, pp. 14–15. Luxembourg.

De Fooz, A. (2014b, October 21). Digital Lëtzbuerg, en avant! *Soluxions*. Luxembourg.

De Fooz, A. (2014c, October 22). "e-jobs", manque de "soft skills"! *Soluxions*. Luxembourg.

Deloitte. (2013, November 27). PSF en 2013 : panorama et perspectives d ’ un secteur en résilience. *Paperjam*. Luxembourg.

Dutta, S., Geiger, T., & Lanvin, B. (2015). *The Global Information Technology Report 2015*. Geneva.

Easterby-Smith, M., Thorpe, R., & Jackson, P. (2012). *Management Research* (4th ed.). London, UK: Sage Publications.

European Commission. (1987). *Towards a dynamic European Economy Green Paper on the Development of the Common Market for Telecommunications Services and Equipment*. Brussels.

European Commission. (2010). *A Digital Agenda for Europe*. EU.

European Commission. (2013a). *Digital Agenda Scoreboard 2013 Electronic communications market indicators : Definitions , methodology and footnotes on Member States*. Brussels.

European Commission. (2013b). Digital Agenda Scoreboard key indicators. Retrieved from http://digital-agenda-data.eu/datasets/digital_agenda_scoreboard_key_indicators/indicators

European Commission. (2013c, September 11). Commission adopts regulatory proposals for a Connected Continent. *Memo*. Brussels.

European Commission. (2014a). *Digital Agenda Scoreboard 2014 – Digital Performance of Luxembourg*. Brussels.

European Commission. (2014b). *e-SKILLS IN EUROPE Luxembourg Country report*.

European Schoolnet. (2012). *Survey of Schools: ICT in Education Country Profile Luxembourg*.

Fedil, ABBL, & CLC. (2014). *Les TIC, ton job d’avenir*.

Fondation Idea. (2014, July 2). “Nation Branding” - nouveau positionnement du Luxembourg. *Idée Du Mois 3*, pp. 1–16. Luxembourg.

Fransman, M. (2001). Evolution of the Telecommunications Industry into the Internet Age. *Communications & Strategies*, (43), 57–113.

Fransman, M. (2002a). Mapping the evolving telecoms industry: the uses and shortcomings of the layer model. *Telecommunications Policy*, *26*(9-10), 473–483.

Fransman, M. (2002b). *Telecoms and the internet age - from Boom to Bust to...* (1st ed.). Oxford: Oxford University Press.

Fransman, M. (2004). The telecoms boom and bust 1996-2003 and the role of financial markets. *Journal of Evolutionary Economics*, *14*(4), 369–406.

Fransman, M. (2006). *Global Broadband Battles*. (M. Fransman, Ed.) (1st ed.). Stanford: Stanford University Press.

Fransman, M. (2007). Innovation in the New ICT Ecosystem. *International Journal of Digital Economics*, (68).

Fransman, M. (2010a). The New ICT Ecosystem. In *The New ICT Ecosystem: Implications for Policy and Relation*.

Fransman, M. (2010b). *The New ICT Ecosystem - Implications for Policy and Regulation* (New and re.). Cambridge: Cambridge University Press.

Fransman, M. (2011). The evolving ICT industry in Asia and the implications for Europe. *JRC Technical Notes*, *63986*, 78.

Fransman, M. (2014). *Models of Innovation in Global ICT Firms : The Emerging Global Innovation Ecosystems* (No. EUR 26774 EN). (M. Bodganowicz, Ed.). Luxembourg: European Commission.

Garcia, A. S., & Vicente, M. R. (2012). *ICT Technologies in Europe : A Study of Technological Diffusion and Economic Growth under Network Theory* (No. WP-AD 2012.21).

Gareis, K., Hüsing, T., Birov, S., Budlova, I., Schulz, C., & Korte, W. B. (2014). *E-skills for jobs in Europe: Measuring progress and moving ahead.*

Gaudron, J.-M. (2014, July 15). ICTluxembourg : « Une contrepartie homogène ». *Paperjam*. Luxembourg.

Gouvernement du Luxembourg. (2005). *Plan directeur de la gouvernance électronique*. Luxembourg.

Gouvernement du Luxembourg. (2011). Luxembourg e-skills 2011 repertory. Luxembourg: Gouvernement du Luxembourg.

Gouvernement du Luxembourg. (2013, October 10). Inauguration de LuxFold, société de biotechnologie, première start-up financée par le fonds Advent Life Science. *Press Release*. Luxembourg.

Gouvernement du Luxembourg. (2014, June 24). Francine Closener au sujet du " Nation branding ." *Gouvernement Du Luxembourg*. Luxembourg.

Gouvernment du Luxembourg. (2014a, February 10). Claude Meisch : " Dem Bildungskrich en Enn setzen ." *Gouvernement Du Luxembourg*.

Gouvernment du Luxembourg. (2014b, June 5). Lancement de la stratégie " Digital Lëtzebuerg " par le Conseil de gouvernement des 3 et 4 juin 2014. *Gouvernement Du Luxembourg*. Luxembourg.

Guardian, T. (2014, November 5). Luxembourg tax files: how tiny state rubberstamped tax avoidance on in industrial scale. *The Guardian*. London.

Hallikas, J., Varis, J., Sissonen, H., & Virolainen, V. M. (2008). The evolution of the network structure in the ICT sector. *International Journal of Production Economics*, *115*, 296–304.

Henry, R. (2013, November 28). L'OPAL mitigiée sur le déploiement du ultra-haut débit. *IT Nation*.

Henry, R. (2014a, March 25). L'adoption de services e-santé progresse trop lentement en Europe. *IT Nation*.

Henry, R. (2014b, April 3). Le Parlement européen met fin au roaming. *IT Nation*. Luxembourg.

ILR. (2013, September 26). ILR: un comparateur du marché de l'électricité. *Paperjam*. Luxembourg.

IT One. (2014, April 15). Luxembourg, un environnement propice pour les start-ups. *IT One*. Luxembourg.

Karagiannopoulos, G. D., Georgopoulos, N., & Nikolopoulos, K. (2005). Fathoming Porter's five forces model in the internet era. *Info*, *7*(6), 66–76.

Kim, H., Lee, J.-N., & Han, J. (2010). The role of IT in business ecosystems. *Communications of the ACM*, *53*(5), 151.

King, N. (1998). Template analysis. In *Qualitative methods and analysis in organizational research A practical guide* (pp. 118–134).

Kitchell, M. (2010). *Luxembourg as a Center for Online and ICT Business*. Luxembourg.

KMPG. (2014, January 31). If Big Data is the new gold, could Luxembourg be the perfect safe? *KPMG Blog*.

Koslowski, T. G., Longstaff, P. H., Vidal, M., & Grob, T. (2012). Resilience Analysis of the ICT Ecosystem. In *23rd European Regional International Telecommunication Society conference; Vienna* (pp. 1–18).

KPMG. (2013). *Luxembourg Banks Insights 2013*. Luxembourg.

Labro, T. (2015, March 18). Les datacenters à l'épreuve. *Luxemburger Wort*, p. 1+12,13. Luxembourg.

Lambotte, S. (2014a, April 8). Start-up : forces et faiblesses du Luxembourg. *Paperjam*. Luxembourg.

Lambotte, S. (2014b, December 18). En tête de LIST. *Paperjam*. Luxembourg.

Land. (2014, June 6). Digital Letzebuerg. *Land*, p. 9. Luxembourg.

Lecadre, R. (2014, December). Luxleaks: J'ai agi par conviction, la cohérence était d'assumer. *Liberation*. Paris.

Li, F., & Whalley, J. (2002). Deconstruction Of The Telecommunications Industry : From Value Chains to Value Networks. *Telecommunications Policy*, *44*(9-10), 451–472.

Luxembourg for Business. (2013). *LUXEMBOURG and ICT : a snapshot*. Luxembourg.

Luxinnovation. (2013, October 16). Luxinnovation: plus qu'une nouvelle image. *Paperjam*. Luxembourg.

Machuron, C.-L. (2014, March 6). Luxinnovation : la boutique des start-up. *Silicon Luxembourg*, pp. 1–6.

Maitland, C. F., Bauer, J. M., & Westerveld, R. (2002). The European market for mobile data: evolving value chains and industry structures. *Telecommunications Policy*, *26*(9-10), 485–504.

Merker, J. (2013). A sectoral approach to the Luxembourg economy The financial sector. In *Exploring the social. political and business environment of Luxembourg*. Luxembourg: AMCHAM, Luxembourg School of Commerce.

Ministère de l'Economie et du Commerce Exterieur. (2013, January 22). Archivage électronique : Étienne Schneider présente le projet de loi. *Paperjam*. Luxembourg.

Neill, M. O. (2013). *The NVivo Toolkit*.

OECD. (2011). *OECD Guide to Measuring the Information Society 2011*. OECD Publishing.

OECD. (2013). *Communications Outlook 2013*. OECD Publishing.

OECD. (2014, September 9). Regards sur l'éducation 2014: le Luxembourg dans la comparaison internationale. *Gouvernement Du Luxembourg*. Luxembourg.

OECD. (2015). *OECD Reviews of Innovation Policy Luxembourg 2015*. Paris.

Oestreicher, K., Walton, N., & Grove, H. (2012). *New Internet-Based Technology Ecosystems*. Worcester.

OPAL. (2013, November 28). Opérateurs alternatifs: «Ne nous oubliez pas!». *Paperjam*.

Paperjam. (2014a, June 10). Uni.lu: un déménagement sur fond de polémique. *Paperjam*. Luxembourg.

Paperjam. (2014b, November 6). LuxLeaks: le moment des ripostes. *Paperjam*. Luxembourg.

Partanen, J., & Möller, K. (2011). How to build a strategic network: A practitioner-oriented process model for the ICT sector. *Industrial Marketing Management*, *In Press,* 1–14.

Peppard, J., & Rylander, A. (2006). From Value Chain to Value Network : Insights for Mobile Operators From Value Chain to Value Network : Insights for Mobile Operators. *European Management Journal*, *24*(2).

Porter, M. E. (1990). Competitiveness: Challenging the Conventional Wisdom. *Harvard Business Review*, *68*(3), 190–192.

Post Telecom. (2014, July 20). Cutting through EU VAT Complexity. *Post Telecom Blog*. Luxembourg.

PWC. (2011). *Luxembourg: an e-hub for Europe Opportunities and actions on the horizon 2015*. Luxembourg.

PWC Luxembourg. (2013, December 23). L'e-santé , bien plus qu'un projet informatique, un véritable enjeu de société. *Communiqué de Presse*. Luxembourg.

Quatraro, F. (2009). Martin Fransman: the new ICT ecosystem. Implications for Europe. *Journal of Evolutionary Economics*, *20*(2), 321–328.

Rafique, K., Yuan, C., Tareen, A. W., Saeed, M., & Hafeez, A. (2012). Emerging ICT Ecosystem - from Value Chain to Value Ecosystem. In *8th International Conference on Computing Technology and Information Management (ICCM),* (pp. 95–100).

Raizer, T. (2014a, August 22). Propriété intellectuelle : l'union fera la force. *Paperjam*. Luxembourg.

Raizer, T. (2014b, November 7). LuxLeaks: la deuxième lame du gouvernement. *Paperjam*. Luxembourg.

Raizer, T. (2014c, December 3). Corruption: Luxembourg progresse, avant LuxLeaks. *Paperjam*. Luxembourg.

Raizer, T. (2014d, December 14). LuxLeaks: l'inculpé s'explique. *Paperjam*. Luxembourg.

Schultze, U., & Avital, M. (2011). Designing interviews to generate rich data for information systems research. *Information and Organization*, *21*(1), 1–16.

Service des Médias et des Communications. (2013). *Luxembourg & ICT - a snapshot*. Luxembourg.

SMC. (2010a). *Stratégie nationale pour les réseaux à « ultra-haut » débit*. Luxembourg.

SMC. (2010b). *Why Luxembourg ? A Comprehensive Overview of the Regulatory, Economic and Lifestyle Advantges for ICT and Media Companies*. Luxembourg.

Sorlut, P. (2014, January 23). «Les coûts, le défi au Luxembourg». *Paperjam*.

Trân, A. (2013, June 10). Security as an infrastructure. *IT Nation*. Luxembourg.

Veugelers, R. (2012). *New ICT sectors: Platforms for European Growth?*

Welsh, E. (2002). Dealing with Data: Using NVivo in the Qualitative Data Analysis Process. *Forum Qualitative Sozialforschung / Forum: Qualitative Social Research*, *3*.

Wong, L. P., Medicine, F., & Lumpur, K. (2008). Data Analysis in Qualitative Research: A Brief Guide to Using NVivo. *Malaysian Family Physician*, *3*, 14–20.

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Competing through e-skills: Luxembourg and its second level digital divide

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Abstract

There is growing awareness amongst policy makers, scholars and practitioners that the Information and Communication Technology (ICT) sector plays an important role in a country's economy and welfare. The ICT sector relies on highly performing technical infrastructures but also needs skilled people who are able to understand its complexities and are fully capable of making the best use of its potential.

In this article we present and discuss this tension for the case of Luxembourg, one of the smallest countries in the world whose economy is open and largely service driven. Although a lot of improvements have been made in recent years regarding its ICT infrastructure, Luxembourg performs poorly in international league tables with regards to e-skills or digital competences showing a tendency to a "second level digital divide" in terms of its ICT professionals.

Drawing on a prior study which mapped Luxembourg's ICT ecosystem, we conducted qualitative interviews with human resources managers that allowed us to identify the need for relevant ICT professional skills. By applying an e-competences framework, we have identified six different families of ICT jobs that are most demanded in Luxembourg as well as their underlying competences. We then present several policy initiatives that could address the challenges faced by Luxembourg. By doing so we provide a contribution in order to better understand the issues related to e-skills and digital competences in a small country. To the best of our knowledge this is the first study of this kind looking specifically into the e-skills situation in Luxembourg

Keywords: e-skills, digital divide, competences frameworks, Luxembourg, ICT

1. Introduction

There is an on-going debate amongst scholars, practitioners and policy makers about the importance of Information and Communications Technologies (ICT) for the sustainable development of Europe and its role in terms of competing with the US or Asia (Bughin et al., 2016). A crucial element in this discussion is the growing lack of ICT skills throughout almost all EU member states (European Schoolnet, 2015). Many, if not most, EU member states are facing a growing lack of e-skills and it is predicted that there will be an overall shortage of supply of about 800,000 ICT professionals in the EU by the year 2020 (European Schoolnet, 2015; Gareis et al., 2014; Hüsing, Korte, & Dashja, 2015).

In this paper, we examine this situation looking at the case of Luxembourg, one of the smallest EU member states. The ICT sector generates about 7% of Luxembourg's GDP and directly employs about 17,000 people (Luxembourg for Business, 2013a) distributed across nearly 1,800 companies. Successive governments have supported the development of the sector by stimulating investments in communication infrastructures and data centres (Binsfeld, Whalley, & Pugalis, 2015). This has allowed Luxembourg to improve its position in international league tables like, for example, the networked readiness index produced by the World Economic Forum (World Economic Forum, 2015). However, when looking into the details of such assessments it appears that not all of the underlying contributing factors have developed positively in recent years. Whereas Luxembourg is amongst the top performers in terms of telecommunications infrastructures and datacentres (Luxembourg for Business, 2014), it does not score very well in terms of e-skills. In particular, Luxembourg lacks ICT professionals and their associated digital competences. Luxembourg's country profile (European Commission, 2015b, 2015c) within the Digital Economy and Society Index (Mateus, 2015), shows that, whilst there are widespread basic digital skills available, there is a shortage of qualified ICT experts in Luxembourg. Thus "in 2014, 58.5% of enterprises which recruited or tried to recruit staff for jobs requiring ICT specialist skills reported problems in filling these positions, up from 52.8% in 2012. This is the second-highest figure in the EU" (European Commission, 2015c).

Furthermore, Luxembourg shows the lowest percentage of graduates in STEM (science, technology, engineering and mathematics) graduates with only 3.6 graduates in STEM per 1000 individuals compared to an average of 17 graduates per 1000 individuals across the EU level. Having said this, there is high demand as about 5.1 % of the working population are considered to be ICT specialists, which is amongst the highest demands within the EU (European Commission, 2015c). As can be expected, the lack of ICT specialists, combined with a high demand, leads to significant competition between different employers and to comparatively high salary levels for those possessing the required skills. Thus, for example, an experienced CIOs can earn as much as €250,000 per year - similar to salaries paid to CEOs - according to a recent study by recruitment specialists (Hays, 2016). However, this obviously has a negative impact on Luxembourg's productivity and international competitiveness (Thelen, 2014).

When looking at the Networked Readiness Index (NRI) (Baller, Dutta, & Lanvin, 2016; World Economic Forum, 2015), it can be seen that Luxembourg is performing particularly badly on aspects such as "quality of management and scientific education" where it ranks 39 of 143 countries , "tertiary education enrolment" (93rd), "E-participation" (54th) and "quality of maths and science education" (28th)[1]. Similarly, the International Telecommunications Union looks

[1] The authors are also working on an article which discusses the lessons to be learned from NRI for Luxembourg in greater details.

at skills related aspects as part of its ICT Development Index (IDI), which is unfortunately only updated every 5 years (International Telecommunications Union, 2015). In 2015, Luxembourg ranked first worldwide in the "access" sub-index and 5th in the "use" sub-index, whilst it ranked only 80th in the "skills" sub-index, a position even worse than in 2010 when it was 73rd.

On the other hand, the EU commission (European Commission, 2014) confirms a growing demand for ICT professional skills but also finds that the country's digital strategy (Gouvernment du Luxembourg, 2014) makes little reference to e-leadership skills and/or digital entrepreneurship. Several other prior studies have looked into the potential for e-jobs in Luxembourg (Fedil, ABBL, & CLC, 2014; FEDIL, 2012; Gareis, Markus, Dashja, & Stabenow, 2015; Gouvernement du Luxembourg, 2011). These studies developed predictions about expected jobs in terms of numbers and, by doing so, confirmed a high and growing demand for ICT professionals. None of these studies identified current and future specific e-skills or e-competences needs for ICT professionals, and none of them proposed initiatives to develop or acquire these skills. Moreover, many of the above studies relied on secondary statistical data,[2] which is often collected for a different purpose and carries the risk of being outdated.

Looking at all of the above, it appears that in the particular context of ICT professionals Luxembourg shows signs of a "second level digital divide" (Min, 2010; van Deursen & van Dijk, 2015; van Dijk, 2006). Therefore, in this paper, we address the question about what specific e-skills and ICT job profiles are needed today and in the foreseeable future in order to support the economic growth of Luxembourg's ICT sector. To explore this question, we adopt a qualitative approach. Building on our initial study about the strengths and weaknesses of the ICT sector in Luxembourg (Binsfeld, Pugalis, & Whalley, 2015), we conducted a second explorative qualitative study focussing on e-skills for ICT professionals and collected new empirical evidence through direct engagement with actors in charge of human resources from a sample of companies. The outcomes of this second study are presented here. We identify, using the conceptual framework of the e-competences model developed by the EU commission (European Committee for Standardization (CEN), 2014b, 2014c), different e-skills and families of jobs which interviewees perceived to be particularly important. To the best of our knowledge this is the first time such a study has been performed in the context of Luxembourg. We intend to provide a contribution to stimulate the debate about the second level digital divide amongst policy makers, education and training providers and companies not just in Luxembourg but also in similar economical or geographical contexts.

The rest of this paper is divided into 4 sections. Section 2 presents and discusses some of the general frameworks in terms of e-skills, e-competences and digital jobs and presents the growing demand for e-skills at international level. Section 3 introduces the methodology applied and then presents the outcome of our empirical work in terms of job families, ICT competences and training offer in Luxembourg. Section 4 summarises the outcome of this empirical research and suggests policy initiatives which could help to address the situation. Section 5 provides some overall conclusions and suggestions for further actions and research.

[2] See for example the list page 15 in (Gareis et al., 2015)

2. Digital Competences, e-skills and ICT professionals

There is some uncertainty in literature about what actually constitutes an e-skill or e-competence and what is meant by digital competences (Ant, Goetzinger, & Binsfeld, 2016). Consequently, definitions remain fluid and contested, and there is no widely accepted notion ‘e-skills’. The purpose of this section is to present different definitions and to introduce the conceptual framework which has been used to analyse the data.

According to Ilomäki, Paavola, Lakkala, & Kantosalo (2014), e-skills encompass a wide range of ICT related elements such as knowledge, skills, abilities, attitudes, performances and must be seen in a wider perspective of social and managerial skills. They systematically reviewed at a total of 76 different studies and suggested that digital competence can be defined as consisting of four components:

(1) technical competence;
(2) the ability to use digital technologies in a meaningful way for working, studying and in everyday life;
(3) the ability to evaluate digital technologies critically; and
(4) the motivation to participate and commit in the digital culture.

Along similar lines, the European Commission proposes a comprehensive model for a definition and hierarchy of e-skills according to three different proficiency levels (Mclaughlin et al., 2014):

- ICT user skills/digital literacy - skills that are fundamentally necessary for the effective use and application of common ICT systems, devices and software tools in support of their own work and their personal interests. Broadly speaking, these cover the term ‘digital literacy’, which refers to the confident and reflected use of ICT for work, leisure, learning and communication.
- ICT practitioner skills - skills that are necessary for researching, designing, developing, planning strategically, managing, producing, consulting, marketing, selling, integrating, installing, administering, maintaining, supporting and servicing ICT systems.
- E-business/E-leadership skills - these refer to the abilities needed to exploit strategic opportunities by using ICT technology (especially the Internet), to assure stronger performance of organizations and to research capabilities for new ways of improving or implementing business, administrative and organizational processes. E-business skills are linked to strategy and innovation, and contain in addition a significant part of generic, i.e. non-sector and non-ICT specific skills.

This paper will focus exclusively on ICT professionals, which can broadly be located in the ICT practitioners and E-leaders categories identified above. Again there is some uncertainty what is actually meant by an ICT professional – see, for example, Thompson (2008) who argues that the profile and the role of an ICT professional has evolved dramatically over time and is likely to further evolve in the future. Agresti (2008), therefore, argued that a “body of knowledge” would be required to come up with a more precise definition of the ICT profession.

Building on this idea, the EU commission proposed such a “foundational body of knowledge” (Veling, Murnane, O’Brien, & Mclaughlin, 2013) in order to establish “a common language” and “a shared understanding”, at least at the EU level, of what constitutes an ICT professional. As part of this initiative, they also developed a “European e-competence framework”, which suggests 36 ICT competences and five proficiency levels with the aim of providing more transparency regarding ICT competences across organisations and countries (see Figure 1 below).

A wide range of similar frameworks have been developed such as, for example, the skills framework for the information age (SFIA)[3], the information security skills framework (IISP)[4], the "référentiel de competences TIC du collectif genèvois (Collectif genevois pour la formation de base des adultes, 2015), the conceptual framework for digital competences (Ferrari, Punie, & Brečko, 2013) or the framework developed by Canada's Association of IT Professionals (Information and Communications Technology Council, 2014). All of these models identify broadly similar job roles than the ones mentioned in Figure 1. In parallel, Ferrari, Punie, & Brečko, (2013) have also developed a model for digital literacy and digital competences which are increasingly required by the general public a part of their day-to-day lives. This model covers the following five areas: information processing, communication, content-creation, problem-solving and safety. It is, however, less suitable for ICT professionals because it focusses on the usage of ICT by the general public.

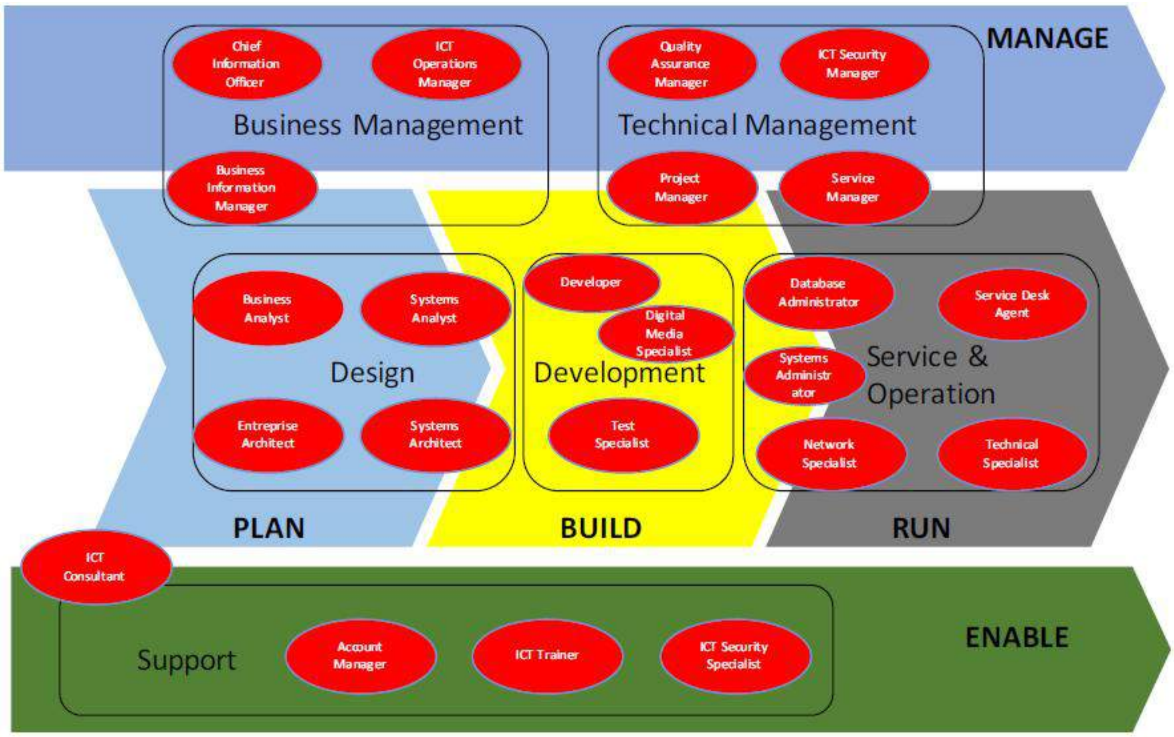

FIGURE 1 - STRUCTURE OF EUROPEAN ICT PROFILES (SOURCE: CEN)

Generally speaking these models tend to be very similar and given the specific context of Luxembourg, we have focussed in the following on the use of the EU e-competences framework[5]. Based on the European ICT Professional Profiles, the e-Competence Framework provides a reference of competences for ICT professionals, using a common language for competences, skills and proficiency levels that can be understood across Europe. It was created for application by ICT service, user and supply companies, for managers and human resource (HR) departments, for education institutions and training bodies including higher education, for market watchers and policy makers, and other organisations in public and private sectors.

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[3] See http://www.sfia-online.org/en accessed 2.7.2016
[4] See www.iisp.org accessed 2.7.20216
[5] This framework has also be used by the authors to analyze the qualitative data collected during their research process

It has been widely documented, there is a wide range of material available to explain how it can be applied and it has been standardised by the European Committee for Standardization, (2014a, 2014b, 2014c)[6].

3. What specific e-skills are needed for Luxembourg's ICT ecosystem now and in the foreseeable future?

3.1. Methodology

As mentioned above, we collected in a first step primary data by conducting a set of 51 interviews with stakeholders active in the local ecosystem, obtaining in the process their views about the strengths and weaknesses of the ICT Ecosystem in Luxembourg (Binsfeld et al., 2015). This initial study did confirm the findings from previous research as many interviewees complained about the missing "entrepreneurial mind-set", the lack of professional e-skills and a growing second level digital divide. It was not possible, however, to identify in detail what specific e-skills were needed as we talked at this stage to CxO level stakeholders rather than to heads of human resources or officers in charge of recruitment. Therefore, we carried out a second qualitative and explorative analysis building on semi-structured interviews with mainly Heads of Human Resources in order to collect their views about the different job profiles that might be relevant for Luxembourg.

According to Luxembourg's statistical office (Statec, 2012), there are nearly 1,800 companies active in the ICT sector in Luxembourg. About 91% of these are very small with less than 10 employees and 62% are one man businesses. About 150 companies employ between 10 and 20 employees and another 130 between 20 and 250 employees whereas only 4 companies employ more than 250 people (of which the publicly owned telecommunications incumbent operator represents the biggest one)[7]. Taking this industry structure into account, we identified a sample of 20 interviewees with representatives from the 4 biggest players but also including representatives from the one man companies in order conduct the interviews.

The main objectives of our interviews was to collect opinions and views about the following issues: what are the most relevant technological trends that affect e-skills, what are the perceived most relevant and job profiles, what levels of qualification, certification, education and training are most looked for, is previous experience important, why is there not more local supply of workforce, which are the countries of residence of existing workforce and what are the perceived future needs in terms of jobs and qualifications. All interviewees were briefed by telephone and received a written list of questions (interview guide) before the interview so that they were able to prepare themselves and collect the necessary information within their organisations.

In terms of introduction and before actually discussing the specifics of e-skills and job roles, interviewees were asked what they perceived as the technological trends that could have a major influence on their respective organisations and indeed the whole ICT ecosystem in the short and medium term. The following trends were identified by the interviewees:

- mobility and mobile application technologies
- growing importance of social media for both private and business purposes.
- cloud computing
- big data analytics

[6] More information on e-CF and alternative competences models and their application can be found for example in Ant et al., (2016)

[7] More information about the structure of the ICT ecosystem can be found for example in Krylova, (2015) or in (Service des Médias et des Communications, 2013)

- the Internet of things (IoT)
- IT security

This is very much in line with many recent studies identifying and examining technological trends. Indeed, the same topics are mentioned in, for example, Accenture, (2015); Deloitte, (2015); European Schoolnet, (2015), IDC (2014) and Robinson, Hendricks, Hanny, Korte, & Hüsing (2015).

Interviews generally lasted around 40 minutes and the responses were noted down directly into the interview guide and their correctness of these notes validated with interviewees. The outcome of the interviews was analysed using the e-competences framework mentioned – see Figure 1.

To conclude the process and develop a deeper understanding of the results, three prospective workshops were organised with a subset of the interviewees mentioned above. The objective of these workshops was to identify potential initiatives and specific actions that might help to improve the situation. Workshop participants were asked to brainstorm and discuss what according to them should and/or could be done[8]. The outcomes were then discussed with a wider range of stakeholders in order to draw general conclusions towards identifying what specific e-jobs and digital competences would actually be required. In addition, we also conducted a summary of the ICT training offer in Luxembourg in order to establish a high-level inventory of local initial and vocational training offers for the ICT sector with the objective examine whether the current training offer actually corresponds with the skills sets required.

3.2. Empirical findings from the interviews

The outcomes presented here should be considered taking into account the fact that the specific situations of the different companies interviewed could vary substantially. A one-man company has different recruitment needs than one with say nearly 1,000 highly qualified and specialised ICT professionals. The opinions expressed in terms of job profiles have been related to the e-competences framework in Figure 1. They have then been cross-checked with the findings of the recent study by the local business federation mentioned above[9], which builds on a much larger and different sample size (Fedil, ABBL, & CLC, 2016). This process allowed to identify six families of e-jobs which are considered as being the most relevant for the Luxembourgish ICT sector. These are:

- Jobs related to marketing, communication and business intelligence
- Jobs related to IT management, quality, testing and security, technical oriented profiles related to infrastructure and network management
- Jobs related to IT governance and IT project management
- Jobs related to user assistance and support
- Jobs related to design, development and maintenance of software and applications.

As shown in Table 1 these families of jobs were felt relevant by many of the participants, although their activities and sizes show a great variation. Considering the technological trends mentioned above, most interviewees agreed that demand for the identified job profiles was likely to further increase in the coming years. This observation was verified by two local recruitment agencies specialising in ICT jobs in Luxembourg

[8] A summary overview of some potential initiatives is provided in appendix
[9] The lead participated in this study as a representative of his organisation

Compar	Employees in Luxembou	Main activity	Marketing, Communication and Business Intelligenc	IT Management, quality, testing and security	Infrastructures and networks	IT Governance and Project Managemen	User Assistance and Support	Software development and maintenance
1	1500	E-commerce	X	X	X			X
2	200	Research and Development	X					
3	30	Web and Online Marketing	X					X
4	30	SAP integrator	X		X		X	
5	5	Cybersecurity		X	X	X	X	
6	5	Web design			X			X
7	5	Cybersecurity		X			X	
8	5	Digital Marketing	X					X
9	5	Software Development		X				X
10	15	IT maintenance services	X		X		X	
11	15	IT infrastructure and cloud services		X	X	X	X	X
12	3000	Telecom incumbent	X	X	X			
13	50	IT Consulting	X		X	X	X	X
14	500	International media company	X		X	X		X
15	500	Satellite operator		X	X		X	
16	30	IT Project Management		X			X	
17	300	Software Development	X	X	X	X	X	X
18	30	IT Consulting		X	X	X	X	X
19	300	ICT Integrator		X	X		X	
20	20	VoIP equipment provide	X	X	X		X	X

TABLE 1 - JOB PROFILES MENTIONED IN INTERVIEWS

Interviewees reported that many of their employees had followed, in terms of their formal education, a technically oriented curriculum in computer science and nearly all of them have acquired their qualifications outside of Luxembourg. Qualifications were obtained either within the greater region (France, Belgium, Germany) or further afield (Switzerland, UK or USA). In terms of the required formal qualification levels, it was reported that only a low number of job roles can be fulfilled with a qualification level below at least two years of university studies. A clear majority said that for them, Bachelor of Science and Master of Science level qualifications would be the most relevant.

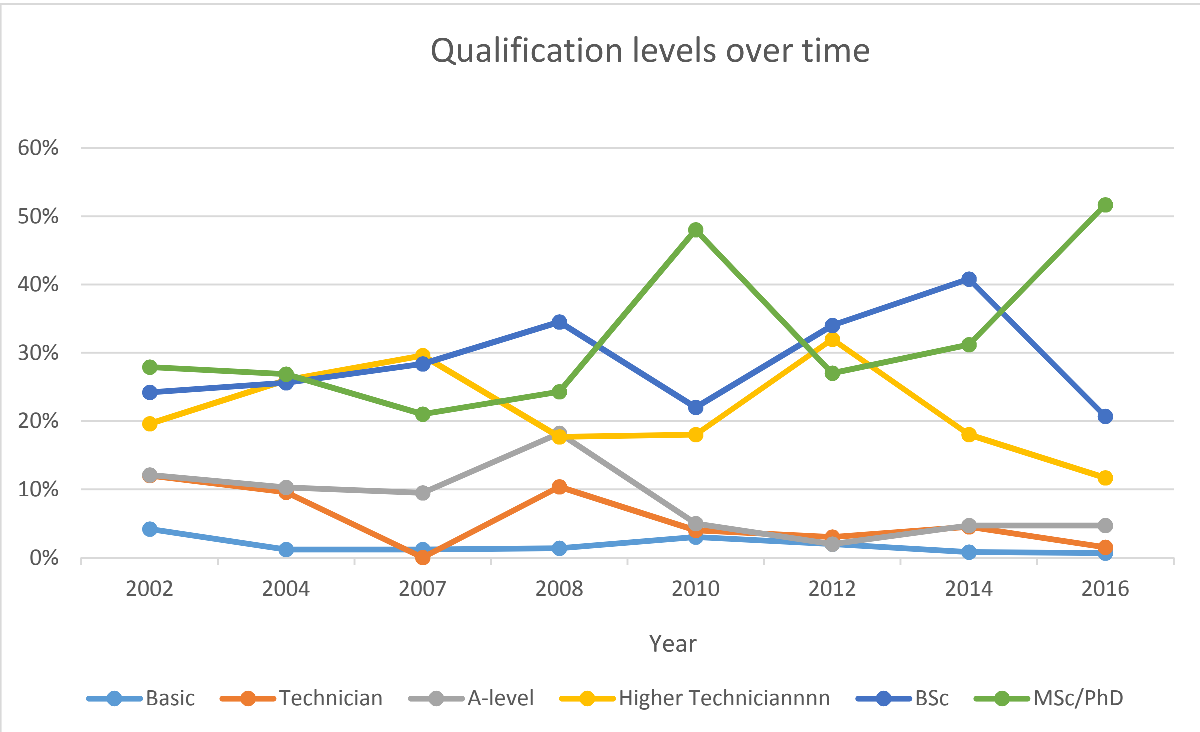

FIGURE 2- QUALIFICATION LEVELS OVER TIME (SOURCE: FEDIL)

Again these findings have also been confirmed in the quantitative study of Fedil, ABBL, & CLC (2016). They found that the qualification level of skills needed appears to be increasing between 2002 and 2016 and that there is now a growing demand for Bachelor, Master and even PhD level qualifications (see Figure 2).

In terms of nationalities, a lot of the existing workforce appears to be of French or Belgium extraction and these employees tend to reside in their respective home countries and commute to Luxembourg on a daily basis. Figure 3 (below) presents an overview of some of the comment made regarding this issue by interviewees. It confirms some of the difficulties that employers face when trying to recruit the necessary job profiles. Apparently, the country is not able to produce its ICT professionals locally.

Figure 3 - an international Workforce

Perhaps this can be partially explained by the fact that there also appeared to be little formal local training and education opportunities for the respective e-jobs and Luxembourgish natives do not seem to be attracted by jobs in ICT[10]. Interviewees mentioned their growing difficulties to attract potential candidates to Luxembourg and keep them motivated to stay there. The interviewees also sometimes identifying the fact that French as the predominant working language would limit their choices with respect to whom they could recruit.

Participants also highlighted the importance of previous working experiences and vocational training given the very rapidly evolving technical and regulatory environment. Work experience was felt to be of importance but companies are also prepared to recruit directly from

[10] A representative of the Ministry of Education indicated to the lead author recently that only about 130 students each year are prepared for a potential career in ICT

school or university as very often it is difficult or impossible to attract experienced people. Many interviewees reported that they recruited junior staff and that substantial investment were made into the continuous vocational education and training of these junior recruits. The difficult then resides in keeping these people on board due to the high competition between employers. Some also mentioned issues related to experienced people leaving companies for sometimes better paid and more secure jobs within the public sector. Figure 4 presents the details of some comments collected about working experience and vocational training.

How important is work experience and vocational training?

"Work experience is important for us but we also recruit directly from University – in particular Master or MBA levels. We go directly to major universities to promote our company. However, we also have a whole range of internal trainings" **International E-commerce provider**

"University level qualifications of any kinds are needed but most important for us if the kind of personality and the candidates' motivation" **SAP consultant and service provider**

"Vocational training and specific ad-hoc development of competences is important. Work experiences in similar jobs are definitely seen as an advance " **Public research centre**

"Vocational training is extremely important for us. We recruit young people and train them. Previous working experiences in a similar sector would be an advantage. As technology evolves quick life-long learning is the basis for our competitiveness" **Satellite operator**

"Previous work experience is important but even more so continuous vocational training and education" **Publicly owned telecom incumbent operator**

"For many technical profiles there simply is no appropriate initial education. Many current job profiles did not exist 10 years ago. Technological space makes ongoing training indispensable" **ICT integrator**

"Previous working experience is not necessarily required. We provide a lot of training in-house with the help of specialised training providers" **Local Radio and TV station**

"Vocational training is highly valued in our company. We also run internal master classes" **Large international software development company**

"Previous experiences can be an advantage. We spend about 20% of our time in trainings in particular in cybersecurity" **Local IT services company**

"vocational training is very important and we run our own international training offer " **local branch of large international communications equipment manufacturer**

"Work experience is important. Basic programming skills are developed at school but understanding customers and their demands comes with experience. It generally takes 6 months to learn a new programming language" **small local software development company**

FIGURE 4 - WORK EXPERIENCE, VOCATIONAL AND FORMAL EDUCATION

When asked which profiles interviewees had the most difficulty to find the relevant skills and resources the following comments, as shown in Figure 5, were made. Given the variety of activities of the different companies in the sample, a wide range of job profiles has been mentioned and no clear priorities emerged. There was however, again a link to the technological trends identified above. Thus, this question was further debated with a subset of interviewees as part of exploratory workshops.

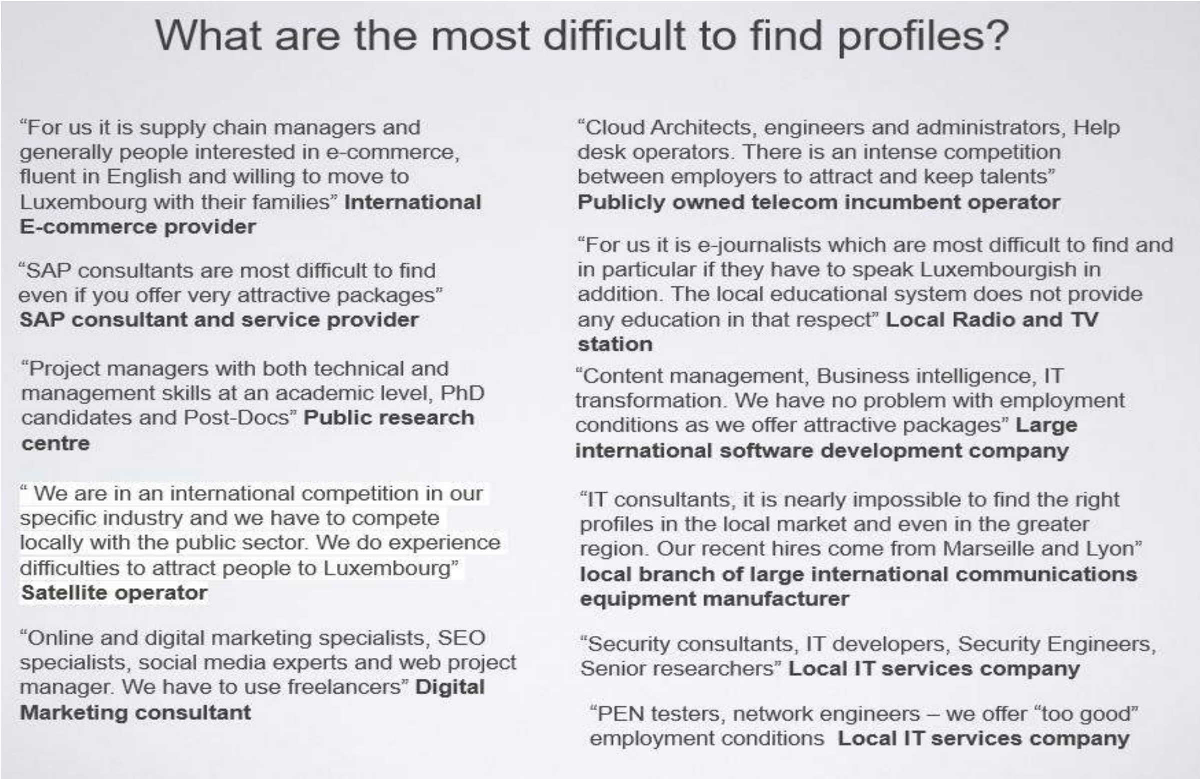

FIGURE 5 – JOB PROFILES MOST LOOKED FOR (2015)

3.3.Exploratory workshops and brainstorming sessions

During these exploratory workshops, participants brainstormed about the types of competences they felt to be most relevant to them and identified three groups of competences:

- key competences that were felt being absolutely necessary;
- important competences that were felt necessary; and,
- "nice-to-have" additional competences.

Obviously, this table is based on a limited subset of companies, though all of the larger actors directly participated in the workshops. It is interesting to observe that none of these competences is directly linked to technical skills. Workshop participants felt that the technical skills can be provided "on-the-job" or via vocational training as long as employees possess a sound basic technical understanding. Some of the human and social skills listed in Table 2 are, however, more difficult to acquire through training or education.

Key Competences
Good written and oral communications skills Innovative and creative mind-set Generate and understanding strategic visions Identify and understand stakeholders needs Being able to work autonomously Being flexible, multi-disciplinary Knowing about norms and standards Good language skills (at least 2 different one) Emotional intelligence Being able to take decisions Problem solving capabilities
Important Competences
Being able to sense and understand the main technological trends and evolutions Working in teams Negotiating capabilities Understanding budgets and financial issues Having an analytical mind Being able to manage and drive change Application development skills Project management skills Safety, security and risk management competences Self-marketing skills
Complementary Competences
Basic understanding of legal aspects Leadership skills Basic understanding of digital marketing techniques Being productive

TABLE 2 - DIFFERENT LEVELS OF COMPETENCES

Participants were also asked to comment on what they felt might be the main underlying reasons for these missing competences and what they felt they could do about and the following present some of the comments which were made. As can be observed from Figure 6, there was some consensus that the local university did not yet offer a curriculum that completely matches the needs of the local ICT sector. As a result, a lot of the training available was coming from outside Luxembourg. There was some disagreement about the importance of technical versus social skills – some participants felt that there was too much focus on technology whereas other were of the opposite opinion.

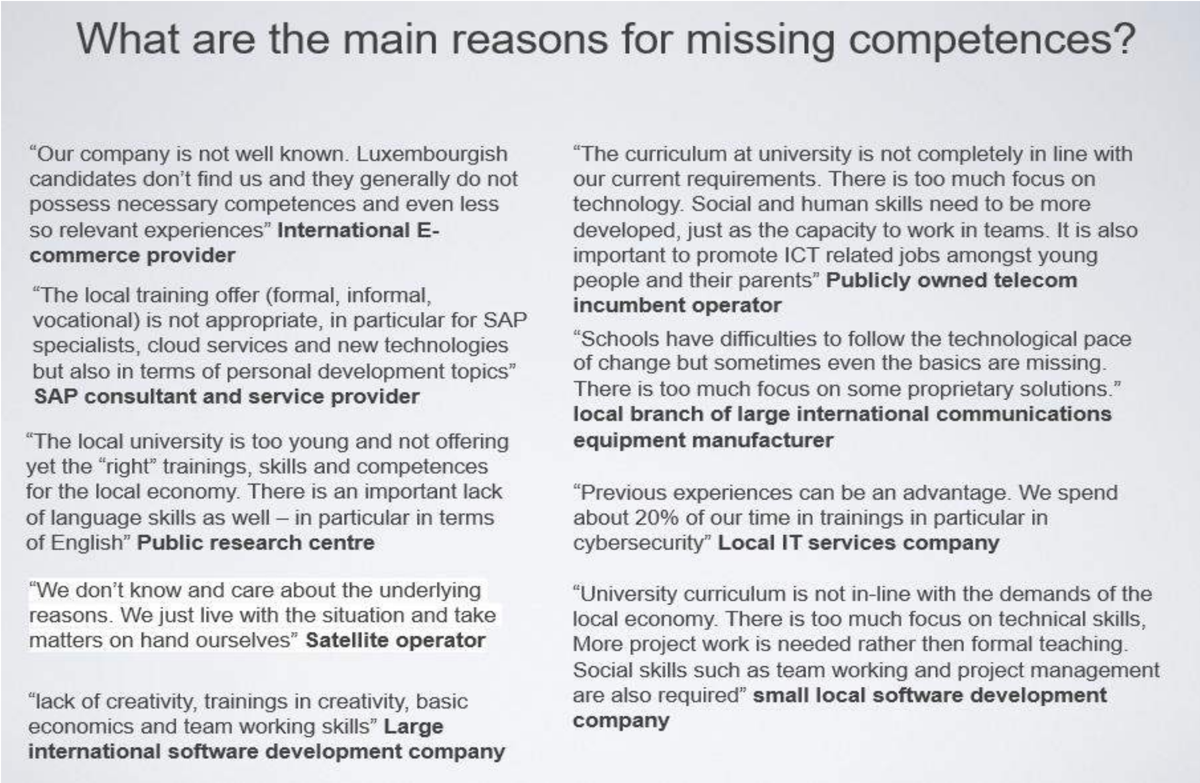

FIGURE 6 - PERCEIVED MISSING COMPETENCES

3.4. Education and training offers

Taking into account the aforementioned comments regarding the lack of appropriate training and education offers, we also examined the relevant training programmes available in Luxembourg and within in the greater region both in terms of formal qualification programmes as well as vocational education and training based on specific certifications. Both the initial education as well as vocational training and education are relying to a large extent on offers available in the surrounding countries.

These findings are supported by OECD who concluded that enrolment rates for higher education in Luxembourg are relatively low, and that a lot of importance and time is devoted to language teaching (OECD, 2014). This, however, is a direct consequence of Luxembourg’s smallness, its reliance on foreign workforces and the necessity to speak at least three or four languages. OECD also comments that the ratio between teachers and students is very low and that Luxembourg’s budget for education is relatively high in comparison to other OECD countries. In another OECD study focusing on Luxembourg’s innovation policy (OECD, 2015), it was found that, although there is a local university and several public and private research centres, these are not actively helping to address the lack of STEM competences. European Schoolnet and University of Liège in particular have looked into the use of ICT in education in Luxembourg as part of a EU wide study (European Schoolnet, 2012) and identified the good availability of equipment and infrastructure, but a below average use of this equipment and a serious lack of confidence of using digital technology among both students and teachers.

If we critique the available education and training offers, we can make the following observations:

- For the jobs related to marketing, communication and business intelligence – there is nearly no training offer available in Luxembourg, nor in the greater region, except for ‘pure’ marketing courses. The IT component in these courses is largely missing just as the business intelligence (data scientists, data analysts etc.) based on “big data” technologies is nearly inexistent.

- For jobs related to IT management, quality, testing and security, a wide range of trainings and education programmes are available (Institut Universitaire International Luxembourg, 2014). However, due to the rapid technological changes to be expected in this area it is important to constantly adapt the training offer to the needs of employers and those being trained.
- For jobs related to infrastructure and network management there is a wide range of trainings available which probably will have to evolve and focus more on “cloud computing” in the future.
- For jobs related to user assistance and support, interviewees perceived a substantial lack of available training. Much of what is available is provided directly by hardware or software vendors often outside of Luxembourg.
- For the jobs related to software development, there is a wide range of trainings, often at an international level, available. A wide range of trainings are offered as on-line, self-study modules. Luxembourg does not offer any local certification related to ICT, all certifications are “imported” from outside of Luxembourg. However, there are some local test centre facilities available.

Given the quickly evolving technological environment, vocational training and life-long learning is particularly important to e-skills. In that respect, interviewees felt that more could be done to communicate the existent training programmes and offers to interested parties. This was also confirmed through discussions with additional stakeholders by Ant et al (2016). Quite simply, there appears to be a lack of information regarding the available training and education offers so far. Ant et al. (2016), therefore, propose the creation of “virtual” ICT centre of competences that would whose mission would be to establish an inventory of the existing offer and provide some kind of a matching tool between this offer and the perceived training needs of companies and individuals.

Furthermore, it was felt that not enough young people (and their parents) know about e-jobs and their potential as a successful future career choice. This was also observed in a study conducted by the local business federation (Fedil et al., 2016), with the authors of this study establishing a dedicated web site in order to contribute to raising awareness[11].

Interviewees also mentioned that all involved stakeholders - employers, the different sector representatives, different government agencies as well as the media - would have to intensify their efforts in order to promote the ICT sector.

3.5. Recruitment needs and training priorities

Building on the findings above, participants during the prospective workshops identified different specific job profiles and classified these in terms of both recruitment priority needs and training needs. These needs are summarised in Table 3 (below). This table is based on a limited number of companies, though all of the larger players in Luxembourg participated directly in this workshops.

Less critical jobs profiles – low recruitment needs – low training needs	**Business dependent job profiles – high recruitment needs – lower training needs**

[11] See www. http://www.tic-tonjobdavenir.lu/ accessed 13.8.2016

Project Manager, E-journalist, Graphical Expert, Telecommunications Engineer, IT Manager, CIO, Data Security Engineer, Online Marketer, Web Designer	Social Media Administrator, Social Media Consultant, Social Media Operator, 3D Designer, Programmer (C, C++), Maintenance Engineer, Maintenance Technician, Software Developer, Helpdesk Technician, IT Technician, IT Administrator, Network Administrator
Technological jobs profiles – high training needs	**Critical job profiles – high recruitment needs – high training needs**
Bioinformatics, Security researcher, ERP consultant, IT trainer/consultant, SaaS consultant, Strategic coordinator, Change and Innovation manager, E-services managers, IT Engineer, Network Engineer, Systems Engineer, Penetration Tester, Internet of Things Specialist, Transition Manager, Video Specialist	Cloud Architect, Cloud Engineer, Cloud Orchestrator, Cloud Technical Product Manager, Cloud Consultant, Cloud Administrator, Security Engineer, Security Consultant, Business Intelligence Analyst, Data Analyst, Data scientist, Legal Experts, Systems Architects, Technical Sales People, Virtualisation Consultants, Application Designer, Application Developer

TABLE 3 - DIFFERENT GROUPS OF JOB PROFILES

In particular, the argument has been compiled with the inputs of the four most important players within the ICT ecosystem in Luxembourg. Four categories of jobs were identified in terms of their perceived business importance, the level of additional training offer and the needs that participants felt would be required. These most critical job profiles are in line with the general technological trends noted above, and in this respect Luxembourg is no different from other countries.

4. Discussion – a second level digital divide and what can be done about it?

The empirical work outlined in the previous main section provides evidence that Luxembourg does indeed suffer from a second level digital divide in terms of professional e-skills. In general, there are not enough ICT professionals available. More particularly, the specific six families of job profiles identified above are not available in sufficient numbers. Young people appear not to be very motivated and interested in working in the ICT sector, or they fail to receive information about its potential. Our research has highlighted an under provision of local educational education and training programmes in Luxembourg and is line with a recent study conducted by Empirica for the EU commission (Gareis, Markus, Dashja, & Stabenow, 2015). On the other hand, the e-skills issue is not very high on Luxembourg's policy agenda, which seems to focus more on the development of the underlying infrastructures (Binsfeld et al., 2015)

In order to address this situation, Luxembourg has so far largely relied on attracting talented individuals from outside the country, especially from the greater Luxembourg region (Digital Lëtzebuerg, 2016; Thibaut, 2016). This source appears to be declining and thus may not be sustainable, and leads to strong competition between employers when seeking to recruit talent. This, in turn, leads to increased wages as documented by, for example, Hays (2016). These high salary levels lead in turn to a reduced overall productivity and potential competitive disadvantages internationally in terms of jobs related to software and application development. As an outcome of the interviews and the prospective workshops, it became apparent that a changed approach is needed involving all stakeholders and involving action on several different levels including both public (different Government administrations and ministries) as well as private actors (companies, industry associations and private training and education providers).

In terms of the existing training offers it is necessary to gain a better understanding of the training needs of companies and the public sector, and to establish better communication and collaboration between training organisations (both public and private) and actors within the ICT ecosystem by, for example, conducting regular enquiries on the skills needed, setting up regular information exchanges with ICT organisations and sector representative such as ICTLuxembourg (Gaudron, 2014a; ICT Luxembourg, 2015; Le quotidien, 2015).

The local training offer needs to change. It needs to become more versatile and include social, business, entrepreneurial and managerial dimensions. The training also needs to become more flexible, focussing on individual competences and certifications rather than diplomas. The training should also be practically orientated and directly applicable to the marketplace and the requirements of the whole economy. Of particular importance is the need to develop training that targets cloud computing, IT security and big data.

Formal initial education, both at elementary and secondary school levels, might integrate far more extensively and far better ICTs as a subject matter but also as means to address problems and support pedagogically other subject matters (Thibaut, 2016). However, this will clearly take time to implement. In addition, new ways of training might be explored - for example, the MOOC's as part of a blended digital learning curriculum, or "serious games" (Derryberry, 2007), which are already used in France among other countries[12]. Coding schools might constitute another interesting alternative, and are currently being introduced into Luxembourg (Luxemburger Wort, 2016). Other alternative training and learning formats could include mentoring, coaching, combining school and job, and training on the job as well as peer-to-peer networks. All of the later could potentially be implemented quite quickly if all stakeholders combine their efforts, but will not lead to formal qualifications which can be offered only by the formal educational sector.

A major change is also needed in terms of moving towards a more collective effort by the learners, the trainers and training institutions, employers, the academic actors and policy makers in order to attract more students to ICT and develop the available training. All of these stakeholders need to become more aware that it is in their common interest to develop e-skills. An interesting initiative in that sense could be the establishment in Luxembourg of a "National Coalition for e-skills", which was both suggested and has been supported by the EU commission (EU, 2013; European Commission, 2015d). Such a national coalition could act as a platform for discussion and information exchange between different stakeholders and their representative bodies. A first meeting of such a coalition has already taken place (March 2016), and a further meeting is scheduled to occur in the autumn.

Cross- or inter-disciplinary learning needs to emerge. A managerial dimension could be incorporated into 'conventional' IT training, and IT included into vocational education and training. Several vocational training providers, who are supported and financed by the Chamber of Commerce and the Chamber of Crafts, have recently announced the creation of a "virtual ICT centre of competences" in order to address this issue (Zabatta, 2015). As these new curricula emerge, trainers and educators will also have to develop their own skills in information security and skills related to the practical use of different new technologies. They need to evolve into learning facilitators and co-builders (or even co-learners) of knowledge. Trainers and educators also need to be more open and prepared to be assessed and challenged

[12] see http://www.cigref.fr/sensibiliser-a-la-cybersecurite-le-serious-game-cigref-dans-les-entreprises accessed 14.12.2016

on their performance (OECD, 2013). Their new training methods may include for example games, programming or entrepreneurial approaches. The preferred educational formats might become coaching and mentoring rather than formal teaching. In that respect several training organisations have recently cooperated to launch a specific "train the trainers" training offer (Thelen, 2016).

Companies have also their share of responsibility in training their current and future employees. To further develop e-jobs skills, stakeholders might unite more to develop a pool of e-jobs skills in Luxembourg. Similarly, cooperation between private and public sectors seems essential for the development of such a pool in Luxembourg. Employers might contribute more to the development of training modules and thus support the development of the economy and the employability of graduates. Some larger international actors such as Cisco, HP or IBM have recently expressed[13] their interest to establish local training centres. One can, of course, reflect about what the objective of these actors really is? Helping to address the situation in Luxembourg, or trying to promote their technology solutions in order to promote their sales.

As the focus is increasingly placed on the creation of expertise within a specific business environment, companies must ensure the practicability of trainings to the specificities of the the Luxembourgish ICT sector's and its economy, and enable the development of skills on the job through internships or other immersions in the business context. In that respect it is interesting to point out that both the Chamber of Crafts and the Chamber of Commerce as well as the banker's association have established new vocational training institutes in 2015 (Adam, 2015; Couset, 2016; Osorio-König, 2015; Schmit, 2015).

All of these suggestions imply that the learners, the teachers and educators, the employers and policy makers feel jointly responsible for improving the quality of existing training and developing new initiatives. Stakeholders would need to invest collaboratively and to apply themselves in the design and realisation of new skill sets and trainings involving technical competences, social and behavioural competences, managerial and business competences, new training and education formats. Better collaboration between all stakeholders is thus required in order to contribute to further strengthening the ICT ecosystem in Luxembourg. This, however, currently proves to be difficult as there is no entity or platform, neither on the public nor on the private side, that could play the role of facilitating communication and coordination between the different stakeholders, In that respect be noted that the Government recently launched the "Digital Lëtzebuerg" initiative (Antzorn, 2014; Gaudron, 2014b; Gouvernment du Luxembourg, 2014). This initiative also set up a working group on e-skills albeit without a specific agenda or budget.

5. Conclusions and future research

The ICT sector is important for Luxembourg's economy and this has been widely acknowledged by public and private actors (Kitchell, 2010; Luxembourg for Business, 2013a, 2013b; PWC, 2011). Many efforts have been made to support the development of the sector, in terms of its infrastructure and legal or regulatory environment. This has allowed Luxembourg to be competitive and thus become well positioned in international league tables (European Commission, 2015a; International Telecommunications Union, 2015; World Economic Forum, 2015). ICT are also widely used by the general public; fixed and mobile high speed internet access is available to nearly 100% of the population (Frising, 2013).

[13] In direct discussions with the lead author

However, these efforts are not enough and risk being lost if Luxembourg does not also address its second level digital divide in terms of ICT professionals.

Through the use of the e-competences framework we have identified some of the underlying reasons of this second level digital divide such as lack of information about the potential of e-jobs, a lack of interest in STEM topics, and the lack of training and education programmes. We also have identified six families of e-jobs which a purposive set of actors from the local ICT sector consider to be most relevant ones now and in the foreseeable future. We also have identified some underlying competences and training needs. We finally have argued for the need of a better communication, coordination and collaboration between the different stakeholders and the need of a single entity to take care of this. Perhaps the establishment of a national coalition for digital jobs (EU, 2013; European Commission, 2015d), as suggested by the EU commission, might be a way forward.

Of course, we have only been able to provide a snapshot at a given moment in time and with a given set of actors, which might be of limited value given the disruptive forces in an extremely quickly evolving ICT environment. We hope nevertheless that our work has helped to raise awareness and to put the second level digital divide topic on the agenda of policy makers, academics and vocational training providers.

Clearly more in-depth research will be necessary on several of the issues identified. For example, there needs to be a better understanding of MOOC's, there availability and how they can be integrated into a learning curriculum. Given the quickly evolving external environment there should also be a continuous monitoring process of professional e-skills needs and availability on an on-going. It would also be interesting to gain a better understanding of the potential implications of the presence of large international ICT players already present in Luxembourg – for example, Amazon, Apple, Cisco and Microsoft – for current and future academic activity at the University of Luxembourg and the curriculum of schools. Quite simply, what does the presence of these companies mean for the job profiles identified given the pace of technological change?

It would also be of interest to extend the scope of the study beyond ICT professionals and to consider the level of general ICT literacy in Luxembourg. A benchmark with other countries could be useful in order to learn how the issue is perceived there, and what initiatives might already have been taken elsewhere that would be of use within Luxembourg.

References

Accenture. (2015). *Accenture Technology Vision 2015 - Digital Business Era : Stretch Your Boundaries*. London.

Adam, A. (2015, November 17). Die Strategie der offenen Tür. *Luxemburger Wort*, p. 2015. Luxembourg.

Agresti, W. W. (2008). An IT body of knowledge: The key to an emerging profession. *IT Professional*, *10*(6), 18–22. http://doi.org/10.1109/MITP.2008.115

Ant, M., Goetzinger, P., & Binsfeld, N. (2016). *E-Skills Study - Strategies for the creation of a virtual e-skills training centre in Luxembourg*. Luxembourg.

Antzorn, F. (2014, June 4). Feu vert pour la stratégie ICT et Digital Lëtzebuerg. *Paperjam*. Luxembourg.

Baller, S., Dutta, S., & Lanvin, B. (2016). *The Global Information Technology Report 2016 - Innovating in the Digital Economy*. Geneva. Retrieved from http://www3.weforum.org/docs/GITR2016/WEF_GITR_Full_Report.pdf

Binsfeld, N., Pugalis, L., & Whalley, J. (2015). ICT ecosystems in small countries : an analysis of Luxembourg. In *26th European Regional Conference of the International Telecommunicatons Society (ITS), Madrid, 24-26 June 2015*. Madrid: www.econstor.eu. Retrieved from http://www.econstor.eu/dspace/handle/10419/127127

Binsfeld, N., Whalley, J., & Pugalis, L. (2015). Competing against yourself: State duopoly in the Luxembourg telecommunications industry. *Telecommunications Policy*. http://doi.org/10.1016/j.telpol.2015.06.002

Bughin, J., Hazan, E., Labaye, E., Manyika, J., Dahlström, P., Ramaswamy, S., & Conchin de Billy, C. (2016). *Digital Europe : Pushing the Frontier , Capturing the Benefits*.

Collectif genevois pour la formation de base des adultes. (2015). *Utiliser les technologies de l'information et de la communication (TIC)*. Geneva.

Couset, I. (2016, January). House of Training La maison de la formation continue du patronat. *Entreprises Magazine*. Luxembourg.

Deloitte. (2015). *Technology, Media and Telecommunications Predictions 2016*. London.

Derryberry, A. (2007). *Serious games : online games for learning*. *Serious Games*. Retrieved from http://www.adobe.com/resources/elearning/pdfs/serious_games_wp.pdf

Digital Lëtzebuerg. (2016, June 30). Former plus de ressources ICT au Luxembourg. *Blog Digital Lëtzebuerg*. Luxembourg, Luxembourg. Retrieved from http://www.digital-luxembourg.public.lu/fr/actualites/e-skills/2016/apsi/index.html

Eichler, S., Holzapfel, H., Jenewein, T., Katzky, U., MacDonald, I., Schmidt, M., … Zimmermann, V. (2016). *Massive Open Online Courses – Hype oder hilfreich?* Berlin. Retrieved from https://www.bitkom.org/Presse/Presseinformation/Flexible-Weiterbildung-mit-Hilfe-von-Online-Kursen.html

EU. (2013, November 8). National Digital Coalition will promote wider use of modern technologies. *EU2013.LT News*.

European Commission. (2014). *e-SKILLS IN EUROPE Luxembourg Country report*.

European Commission. (2015a). *Digital Agenda Scoreboard 2015 : Luxembourg*. Brussels.

European Commission. (2015b). *Digital Economy and Society Index 2015 Country Profile Luxemburg*. Brussels.

European Commission. (2015c). *Digital Economy and Society Index 2016 Country Profile Luxemburg*. Brussels.

European Commission. (2015d). *Toolkit for National and Local Coalitions*. Brussels.

European Committee for Standardization (CEN). (2014a). *Building the e-CF - A Combination of Sound Methodology and Expert Contribution*. Brussels. Retrieved from http://www.ecompetences.eu/wp-content/uploads/2014/02/Methodology_documentation_e-CF_3.0_CEN_CWA_16234-3_2014.pdf

European Committee for Standardization (CEN). (2014b). *Case Studies for the application of the e-CF 3.0*. Brussels.

European Committee for Standardization (CEN). (2014c). *European e-Competence Framework 3.0: A common European framework for ICT Professionals in all industry sectors*. Brussels. Retrieved from http://ecompetences.eu/wp-content/uploads/2014/02/European-e-Competence-Framework-3.0_CEN_CWA_16234-1_2014.pdf

European Schoolnet. (2012). *Survey of Schools: ICT in Education Country Profile Luxembourg*.

European Schoolnet. (2015). *THE e-SKILLS Manifesto* (2015th ed.). Brussels: European Schoolnet.

FEDIL. (2012). *Les qualifications de demain dans le domaine des TIC Edition 2012*. Retrieved from http://www.fedil.lu/fileadmin/user_upload/publications/publications/tic.pdf

Fedil, ABBL, & CLC. (2014). *Les TIC, ton job d'avenir*. Retrieved from http://www.fedil.lu/fileadmin/user_upload/publications/publications/04087_FEDIL_BROCHURE_ENQUETE_2014_web.pdf

Fedil, ABBL, & CLC. (2016). *Les TIC - ton job d'avenir - édition 2016*. Luxembourg. Retrieved from http://www.tic-tonjobdavenir.lu/brochure/

Ferrari, A., Punie, Y., & Brečko, B. N. (2013). *DIGCOMP a framework for developing and understanding digital competence in Europe.* (JRC Scientific and Policy Reports No. EUR 26035 EN). Luxembourg.

Frising, A. (2013). *Regards sur les internautes au Luxembourg et dans l'UE27* (Regards No. Mai 2013). Luxembourg. Retrieved from http://www.statistiques.public.lu/fr/actualites/conditions-sociales/conditions-vie/2013/05/20130515/index.html?from=rss

Gareis, K., Hüsing, T., Birov, S., Budlova, I., Schulz, C., & Korte, W. B. (2014). *E-skills for jobs in Europe: Measuring progress and moving ahead*.

Gareis, K., Markus, P., Dashja, E., & Stabenow, T. (2015). *e-Leadership Skills for Small and Medium Sized Enterprises Country Report Luxembourg*. Brussels.

Gaudron, J.-M. (2014a, July 15). ICTluxembourg : « Une contrepartie homogène ».

Paperjam. Luxembourg.

Gaudron, J.-M. (2014b, October 20). Digital Lëtzbuerg avance ses pions. *Paperjam*. Luxembourg.

Gouvernement du Luxembourg. (2011). Luxembourg e-skills 2011 repertory. Luxembourg: Gouvernement du Luxembourg.

Gouvernment du Luxembourg. (2014, June 5). Lancement de la stratégie " Digital Lëtzebuerg " par le Conseil de gouvernement des 3 et 4 juin 2014. *Gouvernement Du Luxembourg*. Luxembourg.

Hays. (2016). *Etude de rémunération Luxembourg 2016*. Luxembourg. Retrieved from http://paperjam.lu/sites/default/files/edr_luxembourg_hays_2016.pdf

Hüsing, T., Korte, W., & Dashja, E. (2015). *E-skills and e-leadership skills 2020. Trends and forecasts for the European ICT professional and digital leadership labour market*.

ICT Luxembourg. (2015, May 18). ICTluxembourg fixe les prriortes de travail pour 2015. *AGEFI*, p. 36. Luxembourg.

IDC. (2014). *ICT TRENDS 2020 Main Trends for Information and Communication Technologies (ICT) and their Implications for e-LEADERSHIP SKILLS*. Brussels.

Ilomäki, L., Paavola, S., Lakkala, M., & Kantosalo, A. (2014). Digital competence – an emergent boundary concept for policy and educational research. *Education and Information Technologies*. http://doi.org/10.1007/s10639-014-9346-4

Information and Communications Technology Council. (2014). *Highlights of the ICT Competency Profiles framework. Information and Communications Technology Council (ICTC)*. Retrieved from http://www.ictc-ctic.ca/wp-content/uploads/2012/06/ICTC_CPOFrameworkHighlight_EN.pdf

Institut Universitaire International Luxembourg. (2014). *Observatoire des compétences - Rapport final de l'étude thématique "e-jobs."* Luxemboug. Retrieved from http://www.iuil.lu/uploads/documents/files/e-jobs-rapport-final-light.pdf

International Telecommunications Union. (2015). *Measuring the Information Society Report 2015* (2015th ed.). Geneva. Retrieved from http://www.itu.int/en/ITU-D/Statistics/Documents/publications/mis2014/MIS2014_without_Annex_4.pdf

Kitchell, M. (2010). *Luxembourg as a Center for Online and ICT Business*. Luxembourg. Retrieved from http://www.investinluxembourg.lu/ict/download-free-reports-page?sid=632

Krylova, S. (2015). *The ICT inventory in Luxembourg*. Université du Luxembourg.

Le quotidien. (2015, April 9). La formation, priorité d'ICTLuxembourg. *Le Quotidien*, p. 5. Luxembourg.

Luxembourg for Business. (2013a). *LUXEMBOURG and ICT : a snapshot*. Luxembourg. Retrieved from http://ict.investinluxembourg.lu/ict/luxembourg-and-ict-a-snapshot

Luxembourg for Business. (2013b). *Luxembourg's ICT and e-commerce environment 2013 (Q2 update)* (Vol. 2013). Luxembourg. Retrieved from www.investinluxembourg.lu/ict

Luxembourg for Business. (2014, October). Luxembourg's ICT and E-commerce environment. *Luxembourg for Business*.

Luxemburger Wort. (2016, January 14). Webforce3 & Fit4Coding - the coding school for Luxembourg's jobseekers. *Wort*. Luxembourg. Retrieved from http://www.wort.lu/en/luxembourg/webforce3-fit4coding-the-coding-school-for-luxembourg-s-jobseekers-5697c2f90da165c55dc5135f

Mateus, A. (2015). *DESI 2015 Digital Economy and Society Index Methodological note*. Bruxelles.

Mclaughlin, S., Sherry, M., Doherty, E., Carcary, M., Thornley, C., & Wang, Y. (2014). *e-Skills: The International dimension and the Impact of Globalisation*. Brussels. Retrieved from http://eprints.maynoothuniversity.ie/5559/1/CT_e_Skills_report.pdf

Min, S.-J. (2010). From the Digital Divide to the Democratic Divide: Internet Skills, Political Interest, and the Second-Level Digital Divide in Political Internet Use. *Journal of Information Technology & Politics*, *7*(1), 22–35. http://doi.org/10.1080/19331680903109402

OECD. (2013). *Teachers for the 21st Century*.

OECD. (2014, September 9). Regards sur l'éducation 2014: le Luxembourg dans la comparaison internationale. *Gouvernement Du Luxembourg*. Luxembourg.

OECD. (2015). *OECD Reviews of Innovation Policy Luxembourg 2015*. Paris.

Osorio-König, S. (2015, November 17). Ausbau der Weiterbildung. *Tageblatt*, p. 21. Luxemboug.

PWC. (2011). *Luxembourg: an e-hub for Europe Opportunities and actions on the horizon 2015*. Luxembourg. Retrieved from http://www.pwc.lu/en/information-communication-technology/publications.jhtml

Robinson, S., Hendricks, L., Hanny, B., Korte, W. B., & Hüsing, T. (2015). *New Curricula for e-leadership skills*. Bonn.

Schmit, L. (2015, December 31). Ein kohärentes Ökosystem. *Luxemburger Wort*.

Service des Médias et des Communications. (2013). *Luxembourg & ICT - a snapshot*. Luxembourg. Retrieved from http://ict.investinluxembourg.lu/ict/luxembourg-and-ict-a-snapshot

Statec. (2012). *2012 Répertoire systématique: Les entreprises luxembourgeoises*. Luxembourg.

Thelen, C. (2014, September 11). La compétitivité et les autres dossiers de la rentrée. *Paperjam*. Luxembourg.

Thelen, C. (2016). Réussir à former et former pour réussir ! Retrieved July 30, 2016, from http://www.carlothelenblog.lu/2016/07/13/reussir-a-former-et-former-pour-reussir-2/

Thibaut, F. (2016, June 30). Une pénurie de profils ICT à résoudre. *Paperjam*. Luxembourg. Retrieved from http://paperjam.lu/news/une-penurie-de-profils-ict-a-resoudre

Thompson, C. (2008). IT professional role today and tomorrow. *IFIP International Federation for Information Processing*, *280*, 69–80. http://doi.org/10.1007/978-0-387-09712-1_8

van Deursen, A. J. A. M., & van Dijk, J. A. G. M. (2015). Toward a Multifaceted Model of Internet Access for Understanding Digital Divides: An Empirical Investigation. *The*

Information Society, *31*(5), 379–391. http://doi.org/10.1080/01972243.2015.1069770

van Dijk, J. A. G. M. (2006). Digital divide research, achievements and shortcomings. *Poetics*, *34*(4-5), 221–235. http://doi.org/10.1016/j.poetic.2006.05.004

Veling, L., Murnane, S., O'Brien, C., & Mclaughlin, S. (2013). *Governance Framework for ICT professionalism*.

World Economic Forum. (2015). *The Global Information Technology Report 2015*. (S. Dutta, T. Geiger, & B. Lanvin, Eds.). Geneva. Retrieved from www.weforum.org/gitr

Zabatta, J. (2015, November 29). Lancement du nouveau Centre de Compétences Information and Communication Technologies. *Le Quotidien*. Luxembourg. Retrieved from http://www.lequotidien.lu/economie/un-centre-de-competences-pour-les-tic-en-2016/

Appendix — some suggested initiatives that could help to improve the situation as identified during the prospective workshops

Initiative	Examples of proposed Actions
Work towards a revision of the teaching curricula to include more IT	• Train the teachers how to make best use of ICT • Use IT as to support technical and scientific courses • Use more IT devices (tablets, lap-tops) • Start offering IT related courses at elementary level and provide a better integration of IT courses at higher level education
Promote operational and on the job learning	• Promote and facilitate internships • Improve support and supervision of apprentices by better cooperation and collaboration between schools and industry • Set-up formal partnership between academia and industry actors • Promote the use of internships as part of recruitment and selection procedures • Improve matching between interests and skills offered and requested
Use Massive Open Online Courses[14]	• Select relevant and appropriate MOOC's and create a quality label • Establish common e-learning platforms e.g.Moodle • Build modular, tailor-made, webinars and/or blended learning offers
Develop a common pool of skills	• Raise awareness on employers level about current and future needs • Create opportunities for interactions between ICT and non-ICT profiles • Promote lifelong learning and offer possibilities to move from one profile to another • Promote the development of interdisciplinary learning, vocational training and work projects • Make more use of experienced professionals as trainer
Develop Competence Centres	• Coordinate available experts, increase visibility and awareness • Position Luxembourg on the international e-skills map • Encourage the establishment of joint public and private initiatives • Create a catalogue of e-competences and regularly update it • Create and update a training offer allowing to develop these e-competences
Foster entrepreneurial spirit	• Create a favourable environment for entrepreneurship • Create a seed-fund

[14] See for example Eichler et al. (2016)

	• Attract entrepreneurs to Luxembourg and make them stay • Encourage risk taking • Develop entrepreneurial trainings and support programmes • Build on Luxembourg's regulatory and political advantages e.g. stability, trust, languages
Take advantage of specific legislation impacting the economic development	• Strict data protection laws • Financial and operational support via mutualised infrastructures e.g. Technoports • Short distances, quick access to public administrations • Specific laws for cloud offers, e-archiving, electronic signatures, cryptography • Promote Luxembourg and strengthen its reputation, Luxembourg branding
Commitment to customer service	• Set-up service platforms • Raise awareness for e-marketing • Create new job profiles e.g. e-government, e-health, webdesign, webmarketing
Consider security as an issue	• Promote risk analysis framework (in place already in the financial sector) • Raise awareness for SMEs and support their investments in security • Raise awareness and train final users

TABLE 4 - PROPOSED INITIATIVES AND ACTIONS

Binsfeld, N., Whalley, J., & Pugalis, L. (2017a).

An analysis of the structure, actors and interrelationships producing Luxembourg's ICT ecosystem.

In 28th European Regional International Telecommunications Society Conference - Passau. Passau: Econstor.

Binsfeld, Nico; Whalley, Jason; Pugalis, Lee

Conference Paper

An analysis of the structure, actors and interrelationships producing Luxembourg's ICT ecosystem

28th European Regional Conference of the International Telecommunications Society (ITS): "Competition and Regulation in the Information Age", Passau, Germany, July 30 - August 2, 2017

Provided in Cooperation with:
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An analysis of the structure, actors and interrelationships producing Luxembourg's ICT ecosystem

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Abstract

There is substantial analytical value in examining the structure of the ICT sector by deploying the notion of ecosystems, which can help to reveal new insights into the role of key actors and their interrelationships. This paper aims to provide a thorough analysis of Luxembourg's ICT ecosystem, which until now has received limited research attention in the international arena. Key actors comprising and producing the ecosystem are identified and analysed according to a layered model devised by Martin Fransman (2001). The primary output is a detailed mapping of the Luxembourgish ICT ecosystem. The findings indicate that Luxembourg's ICT ecosystem consists of nearly 2000 different actors of which the majority are micro and small software development companies. Nevertheless, some large telecommunications network operators in which the government holds a substantial stake appear to perform a decisive role from an economic perspective. More recently, the role of different types of service providers, particularly subcontractors to financial actors, has grew in prominence, with trends suggesting that this is subject to continue. The research has also identified some limitations to the Fransman model and suggests several extensions as well as a stakeholder analysis to gain a deeper understanding of the issues at stake. It is intended to be of use and interest to policy-makers, managers, and decision makers or actors operating within and across different layers of ICT ecosystems.

Key words: Luxembourg, ICT, ecosystems, Fransman.

JEL codes: L86, L88

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1. Introduction

Information and communication technology (ICT) is a crucial sector of the Luxembourgish economy. According to Eurostat, in 2013, the sector contributed approximately 7% of GVA (Service des Médias et des Communications, 2013).[1] In international terms, particularly compared with other European countries, this is very high. The sector includes about 2000 companies, employing circa 5% of the active working population (European Commission, 2015). In part this is due to a number of internationally renowned actors (such as, for example, Amazon, eBay, iTunes, KABAM, Microsoft, PayPal, Rakuten, RealNetworks, Skype and Vodafone) that have chosen Luxembourg as their base to access the European market and in part due to the high demand of ICT services in Luxembourg's well developed financial industry (Luxembourg for Business, 2013a).

Luxembourg's ICT sector is also one of the most innovative sectors in Luxembourg, with over 20% of "persistent innovators" (Statec, 2014). According to the Global Information Technology Report, Luxembourg offers an "ideal environment to support new technology innovations" (World Economic Forum, 2015). In 2015 the country ranked ninth worldwide when it came to leveraging ICTs for social and economic impact[2], the importance of the ICT sector for the Luxembourg government is also highlighted by its ranking as fourth and fifth, respectively in terms of government success in ICT promotion and the importance of ICT to the government's vision (Luxembourg for Finance, 2015).

For several years, the government has been promoting Luxembourg as a key location for ICT with the aim of attracting new activities, establishing new businesses and encouraging private investment (Luxembourg for Business, 2013b). Efforts have also been made to develop ICT research and development, with a focus on security, reliability and the trustworthiness of ICT systems and services (Funck, 2013).

In order to provide policy-makers with a comprehensive analytical foundation, scholars often propose to examine the ICT sector as an business ecosystem, which consists of a number of interconnected organisations and actors (Kim, Lee, & Han, 2010). Fransman (2010 p. xxi) suggests that "every country has an ICT ecosystem, although the players, their symbiotic interactions and the institutions in which they are embedded are different. The task of national policy-makers and regulators in all countries is to understand how their ICT ecosystem works, its strengths and weaknesses, and what might be done to improve its contribution". Thus, it is the purpose of this paper to shine an investigative light on Luxembourg's ICT ecosystem, which until now has received limited research attention in the international arena.

Although there exists a wide range of studies examining ICT ecosystems in different countries (Elixmann, Schwab, & Stappen, 2003; Hulsink, 1999; Sutherland, 2013; Symeou, 2009), none of these provides an overview of the ICT sector in Luxembourg. Consequently, this paper will rectify this shortcoming and focus on the structure of the ICT ecosystem in Luxembourg. In order to do this, the actors in the ecosystem are identified and mapped against Fransman's four-layer model and the main characteristics of the ICT ecosystem in Luxembourg identified using the different secondary statistical data sources that are available. More specifically, the paper will describe and explain the structure and

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[1] This paper builds on the definition of the ICT sector and the underlying classification suggested in OECD (2011). This definition of ICT includes IT goods and services, information content as well as telecommunications goods and services including their manufacturing and production.

[2] in the Networked Readiness Index (World Economic Forum)

main characteristics of Luxembourg's ICT ecosystem, with a particular focus on economic characteristics, and analyse the roles and interrelationships of different actors and organisations.

It this study will lead to a better understanding of the innovative forces that shape the ecosystem. As one of the few, perhaps only study, analyses of ICT ecosystems in small countries, this study is important and unique. Moreover, it is intended to be of use and interest to policy-makers, managers, and decision makers or actors within the different layers of the ICT ecosystem in Luxembourg and beyond.

The remainder of this paper is structured as follows. Section 2 briefly presents models used to analyse and evaluate the ICT sector and argues the case for the application of the layered model proposed by Fransman. Attention then shifts to the main outcomes of the study. In section 3, the main actors are identified and their activities within the different layers detailed with a focus on layer 3 (service layer) highlighted. Section 4 presents an overview of the ICT ecosystem in Luxembourg, identifies limitations of the Fransman model. It suggests complementing the layer model with a stakeholder analysis approach and suggests avenues for future research. Finally section 5 provides conclusions and shows avenues for further research.

2. From Value Chains to Ecosystems

There is a wide range of models available to make sense of the structure of the ICT industry. Many of these apply or develop Porter's value chain to the ICT (Maitland et al., 2002) or have extended this model to become a so-called value networks (Li & Whalley, 2002, Peppard & Rylander, 2006, Rafique et al., 2012). This idea, which has also been taken up and developed further by, for example, Hallikas et al. (2008) or Oestreicher et al (2012). Similarly, Porter's model of competitive forces (Porter, 1990) has been adapted to the ICT environment (Karagiannopoulos, Georgopoulos, & Nikolopoulos, 2005). Along the same lines, Briglauer (2004) has developed a generic reference model in order to asses competition in different communications markets from a regulatory perspective. Additional work has been done in characterizing the ICT ecosystem as a network (Garcia & Vicente, 2012), as well as looking into how such networks are built and maintained (Partanen & Möller, 2011).

These models are essentially linear ones, but today's business environment is complex and dynamic and presents multiple relationships where companies are interacting to deliver their products and services. As a consequence, the ICT sector is increasingly characterized as a socio-technological (eco)system facing asymmetric and delayed feedback structures, which lead to turbulent changes (instability/existence of multiple equilibria) and high uncertainty.

Koslowski, Longstaff, Vidal & Grob (2012) see the ICT sector as an ecosystem with many heterogeneous organizations that are woven together into a web of links and responds interactively to forces in the environment. The understanding of the dynamics of one domain in isolation from others is impossible and demands both a systemic and evolutionary view to be adopted. The ecosystem approach to describe markets and hierarchies has first been mentionned by Moore (1993). According to Kim, Lee, & Han (2010) an ecosystem can be defined as an economic community involving many companies working together to gain comparative advantages as a result of their symbiotic relationships. The authors also argue that ecosystems permit companies to create new value that no company could achieve alone. Likewise, they identified symbiotic relationships that can provide some benefits for related parties such as consumers and partners. For a more recent discussion about using the ecosystems model to analyse the ICT sector see, for example, Basole, Park, & Barnett (2015). The authors have used advanced mapping techniques to quantify and visualise the competitive dynamics shaping the ICT ecosystem.

Hence, it is important to examine ICT ecosystems in order to understand the co-evolution between technological and economic as well as regulatory forces and developments to provide a comprehensive basis for policy makers, For the purpose of understanding the structure of the ICT ecosystem in Luxembourg, we propose here to use a layer model described by Fransman (Fransman, 2001, 2002a, 2002b, 2004, 2006, 2014).

When looking at the supply side of the ICT ecosystem, four types of actors are identified:

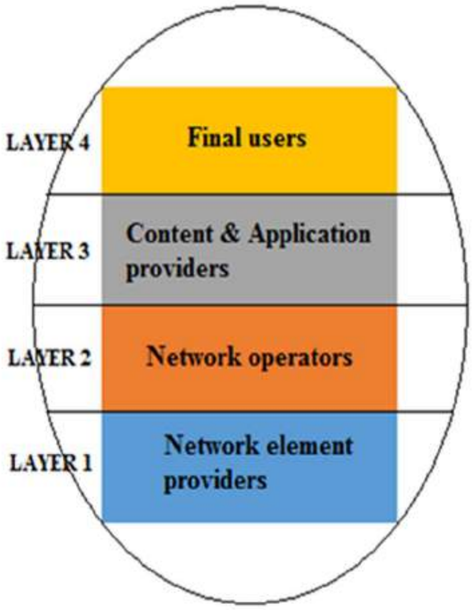
Layer I: Network element providers (e.g. Cisco, Samsung, Alcatel-Lucent, Ericsson, Nokia Networks)

Layer II: Network operators (fixed and mobile) (e.g. BT, Deutsche Telekom, Vodafone)

Layer III: Content & application providers (e.g. Google, Apple, YouTube)

Layer IV: Final consumers and users of ICT services

Figure 1 - The 4 Layer model according to Fransman



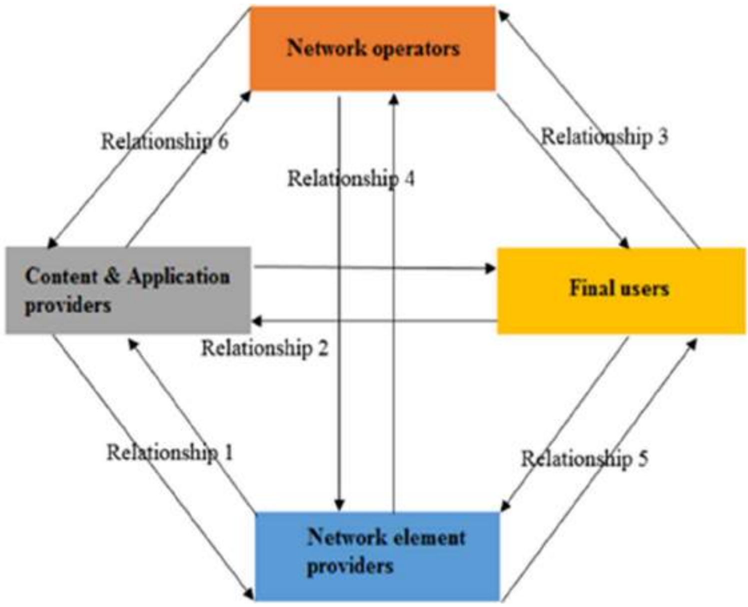
Fransman (Fransman, 2007) suggested this model building on experiences made by telecommunications and ICT engineers over time in using layered models for organising their work and knowledge interdependencies. Such a model allows a clear definition of the industry or ecosystem boundaries and subsectors, a modularisation and hierarchy of the the different categories of actors within the system as well as the 'interfaces' and relationships between actors. It also allows to describe the industrial organisation of the ICT ecosystem, the identificarion of the location of R&D. It allows to identify entry and exit barriers and most importantly the role of the customers or consumer. It thus provides a simple yet effective way to gain a good understanding of the different types of actors, their respective roles and importance to the sector as well the interrelations that occur between them.

On the other hand, it is essentially a static model, which fails to reflect the dynamics of change. Moreover, it is not well suited to identify modes of cooperation and coordination between the different actors nor does it cope with diversity within the different layers. Finally, it does not take into account externalities such as interacting institutions or organisations as for example regulators or financial institutions.

Acknowledging these developments, Fransman (2007, 2010, 2011), has focused on the role of the dynamic, or, as Fransman calls them 'symbiotic' relationships between the different layers and their role in innovation (Fransman, 2014). This is shown in figure 2. These relationships can be described as multi-dimensional, representing financial and material flows as well as information and input flows into the innovation processes within the ecosystem.

In the 'new ICT ecosystem' (i.e., post-internet), users are gaining a presence on the supply side of the system by co-creating with suppliers. In contrast to the so-called 'old ICT ecosystem' (i.e., pre-internet), which could be described as a closed innovation system with the most important links being between network operators and network suppliers (Layers I and II), the new ICT ecosystem is more open, more dynamic and more complex. In recent years, the focus has shifted to the interaction between platform, content and application providers (Layer III) and the ecosystem has become more dynamic, with the relationships between the different actors and the environment also becoming more complicated.

Figure 2 - Symbiotic relationships between the 4 layers



An example of how this model can be used to understand the interactions between different actors is provided by, among others, Arlandis & Ciriani (2010). Their paper includes a detailed database of players in the different layers but takes a high- level view by looking at different economic clusters such as the EU, the US and Asia and they have been able to the relative (compared to the EU) dominance of US and Asia's ICT ecosystems. Another application of the Fransman model can be found in Veugelers (2012). Here the model is also used to understand why Europe's ICT companies are lagging behind the US in particular with regard to the "leading platform providers who are capturing most of the value in the ICT ecosystem". It is argued that a very fragmented EU market, lack of entrepreneurial mind-set, as well as lack of risk capital are the main stumbling blocking points to the development of the ecosystem.

3. Applying Fransman's model to Luxembourg

3.1. The key economic indicators and the performance of the ICT ecosystem

This section presents economic indicators pertaining to the ICT ecosystem in Luxembourg. The figures provided are based on the data on the classification NACE rev.2 (STATEC, 2008), which does not include manufacturing and trade of ICT products but does include media and content production. It is, therefore, necessary to remember this when interpreting the figures and tablea provided below.

Table 1: Key economic indicators from 2008 to 2013 (source: Eurostat)

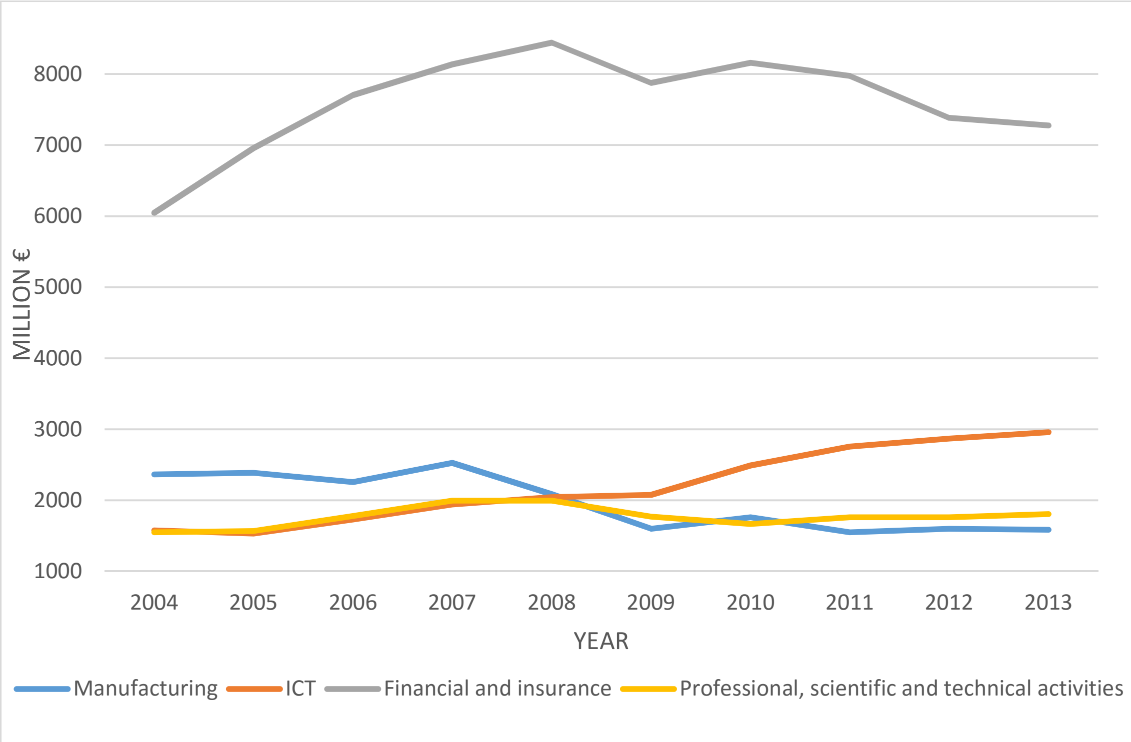
Economic indicators / Year	2008	2009	2010	2011	2012	2013	Growth rate 2008-2013
Number of companies	1565	1584	1682	1792	1920	2013	-
Percentage of total companies (%)	6.0%	6.1%	6.2%	6.4%	6.6%	6.8%	13%
Employment (1000 people)	13.6	13.8	14.0	14.7	15.0	15.4	13%
Percentage of total employment (based on persons)(%)	3.9	3.9	3.9	4.0	4.0	4.0	3%
Gross value added (at basis prices)(in million Euro)	2031.3	1980.9	2253.8	2454.6	2462.4	2537.7	25%
Gross value added (at basis prices)(%)	6.0	6.2	6.3	6.5	6.4	6.2	3%
Turnover (in million Euro)	5940.5	6045,2	6535,8	6507,8	8051.0	na	na
Compensation of employees (%) of total	4.9	5.1	5.0	5.2	5.1	5.1	4%
Compensation of employees (in million Euro)	850.6	913.5	947.6	1,034.3	1,060.7	1,099.6	4%
Business enterprise R&D expenditure (BERD) (in million Euro)	na	22.4	na	19.0	na	na	na
Business enterprise R&D expenditure (BERD) (% of GDP)	na	0.06	na	0.04	na	na	na

Table 1 confirms that the ICT sector plays an important role in the economy of Luxembourg and contributes significantly to its employment. All economic indicators of the ICT sector in Luxembourg show continuous growth in the period under review despite the financial crisis of 2009. During this crisis, the share of ICT employment in total employment and the turnover demonstrated a stable growth, whereas gross value added (GVA) showed little decrease in 2009 and rapid growth in again in 2010.

The contribution of ICT services to the total GVA is higher than the share this sector takes in total employment. The figures for business enterprise R&D expenditure (BERD) are not available for the recent years, but those for 2009 and 2011 show nearly insignificant investments in R&D by ICT actors.

In comparison to other economic sectors such as manufacturing, financial and insurance services, the evolution and impact of the ICT sector on GVA shows a continuous growth from to 2004 to 2013 - see Figure 1 below. As of 2009, the significance of the ICT sector for GVA became even greater than that of manufacturing and professional, scientific and technical activities becoming the second most important of Luxembourg's economic activities behind its financial sector. In that respect, the ICT ecosystem contributes to the efforts of subsequent Governments to diversify Luxembourg's economy (Barthelemy, 2014; PWC, 2011).

Figure 3: The evolution of GVA by sectors from 2004 to 2013



Source: adapted from OECD. Calculations of OECD based on Statec data (OECD, 2015)

3.2. Evolution of the number of actors according to company size

As shown below (table 2 and figure 4), the number of actors in the sector has also grown substantially (34%) since 2008. The number of young small and medium size companies contributes most to this growth, they grew by 296 (37% increase) and by 148 (33% increase), respectively. The increase in the number of companies with more than 50 employees was less important. At the same time, the number of companies with more than 250 employees grew by 2 (67% increase).

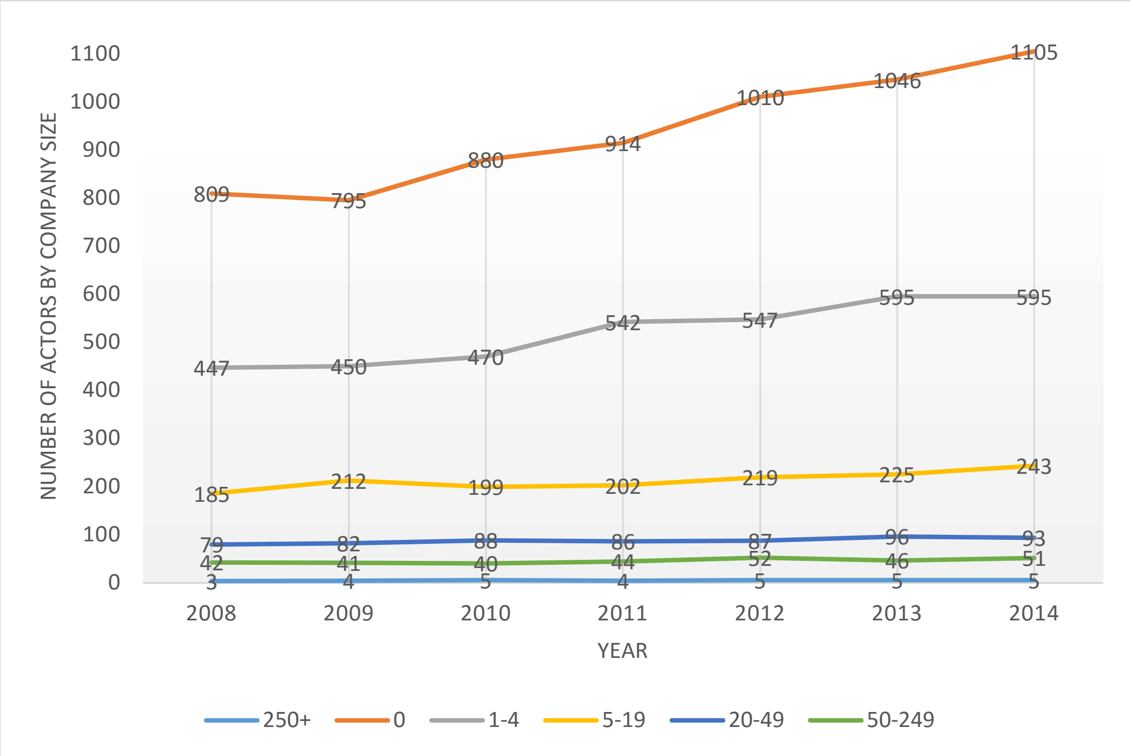
Table 2: Market structure and growth rates by company size

Year / № of employees	2008	2009	2010	2011	2012	2013	2014	Growth rate 2008-2014
0	809	795 -2%	880 11%	914 4%	1010 11%	1046 4%	1105 6%	296 37%
1-4	447	450 1%	470 4%	542 15%	547 1%	595 9%	595 0%	148 33%
5-19	185	212 15%	199 -6%	202 2%	219 8%	225 3%	243 8%	58 31%
20-49	79	82 4%	88 7%	86 -2%	87 1%	96 10%	93 -3%	14 18%
50-249	42	41 -2%	40 -2%	44 10%	52 18%	46 -12%	51 11%	9 21%
250+	3	4 33%	5 25%	4 -20%	5 25%	5 0%	5 0%	2 67%
Total	**1565**	**1584 1%**	**1682 6%**	**1792 7%**	**1920 7%**	**2013 5%**	**2092 4%**	**527 34%**

Source: Statec Répertoire systématique des entreprises luxembourgeoises (2008-2014)

Figure 4 shows also that over 90% of the companies with the ICT sector in Luxembourg have less than 20 employees and that there are only a handful of mid-size or larger actors.

Figure 4: Growth (number of actors) by company size



Source: Statec Répertoire systématique des entreprises luxembourgeoises (2008-2014)

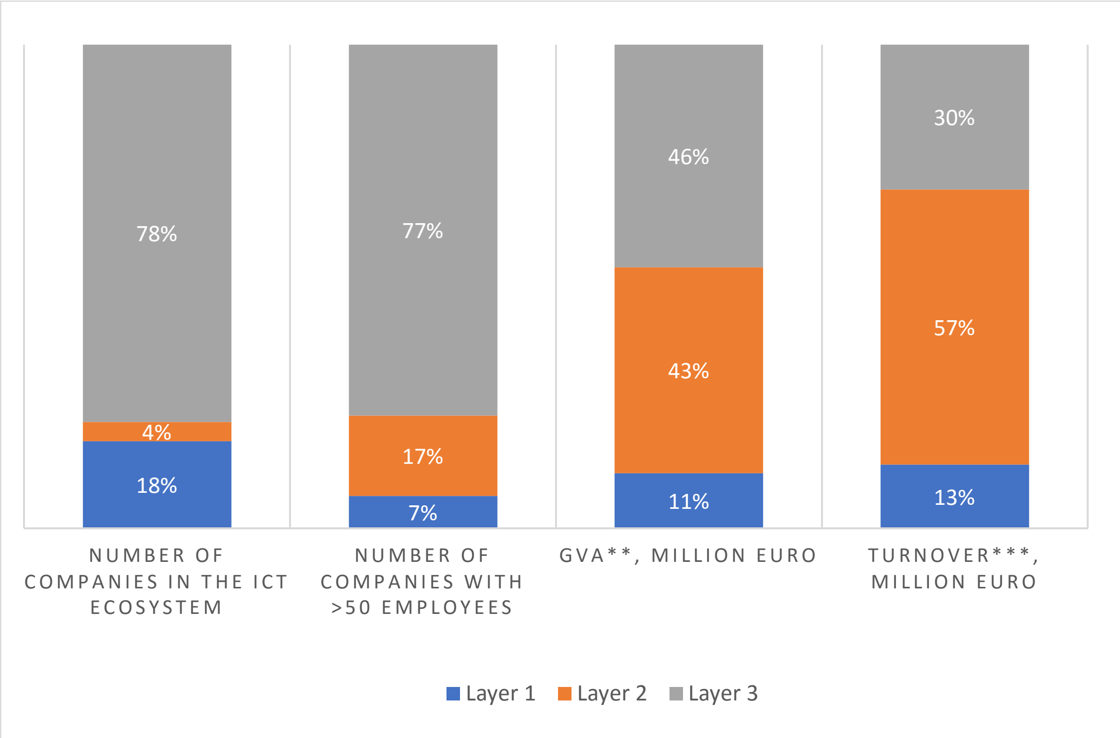
3.3. Evolution of actors according to Fransman's layers

While the previous section presented an overall picture, we will now apply Fransman's model to identify more precisely those activities located within the different layers. Table 3 and figure 5 below have been build up by counting the actors within the different NACE codes. This means that media and content production have now been excluded, whereas manufacturing and trading of ICT goods has been included.

The highest impact on the total growth in terms of the number of companies has been achieved in layer 3, the content and applications layer. This layer also dominates in the ICT ecosystem of Luxembourg, with 1670 companies in 2014. The biggest growth is visible in the subsections 'Other software publishing' (28 items and 88%), 'Computer programming' (314 items and 82%), 'IT consulting' (88 items and 17%) and 'Data processing, hosting and related activities' (48 items and 160%).

There were about 240 companies active in layer 1 (network element and infrastructure providers). Most of these are distributors of international or global hardware manufacturers, as only 5 local ICT manufacturing companies were registered in Luxembourg. There is no manufacture of consumer electronics, magnetic and optical media in the country given the fact that the high standard of living implies high salaries and therefore high production costs. This clearly confirms the importance of services for Luxembourg's economy. Layer 2 (network providers) is the smallest in the ICT ecosystem of Luxembourg in terms of the number of actors consisting of only 88 companies. As can be observed from table 3 (below), all subsections except fixed line telecommunication providers show uniform growth. It is also layer 2 that provides the largest contribution in terms of GVA to Luxembourg's economy.

Figure 5: The relative importance of different layers



Source: author's calculations based on database of Eurostat, Statec, Editus, Paperjam Guide. Notes: **GVA in 2009, ***Turnover in 2011

The market share within the ICT ecosystem is presented from different perspectives in Figure 5 and Table 3. It appears that layer 3 is by far the largest in terms of the number of companies at both the sectorial level as well as in terms of key actors followed by layer 1 and, finally, layer 2. In terms of GVA and turnover, the analysis of the market share suggests that although layer 2 is considerably inferior to layer 1 and layer 3 regarding the number of companies, it plays the most important role in the economy of Luxembourg. As can be observed, layer 2 and layer 3 share GVA and jointly compose 89% of the total. The following sub-sections will provide a more in-depth look into the activities within the different layers.

Table 3: Evolution of actors in different layers and subcategories

NACE	Description	2008	2009	2010	2011	2012	2013	2014	2008-2014
58.210	Publishing of computer games	2	2 0%	2 0%	1 -50%	2 100%	5 150%	5 0%	150%
58.290	Other software publishing	32	33 3%	41 24%	40 -2%	41 3%	48 17%	60 25%	88%
62.010	Computer programming	383	412 8%	451 9%	499 11%	588 18%	641 9%	697 9%	82%
62.020	IT consulting	530	528 0%	544 3%	582 7%	597 3%	619 4%	618 0%	17%
62.030	Computer facilities management	24	22 -8%	26 18%	29 12%	37 28%	39 5%	43 10%	79%
62.090	Other information & computer activities	158	145 -8%	140 -3%	143 2%	129 -10%	128 -1%	120 -6%	-24%
63.110	Data processing, hosting and related activities	30	36 20%	46 28%	47 2%	54 15%	59 9%	78 32%	160%
63.120	Internet portals	10	11 10%	12 9%	19 58%	22 16%	26 18%	31 19%	210%
63.990	Other information services n.e.c.	15	13 -13%	16 23%	15 -6%	16 7%	12 -25%	11 -8%	-27%
95.110	Repair of computers and peripheral equipment	9	10 11%	11 10%	10 -9%	8 -20%	7 -13%	6 -14%	-33%
95.120	Repair of communication equipment	1	1 0%	1 0%	1 0%	1 0%	1 0%	1 0%	0%
Layer 3 (Content & Applications Providers)		**1194**	**1213 2%**	**1290 6%**	**1386 7%**	**1495 8%**	**1585 6%**	**1670 5%**	**40%**
61.100	Fixed Line Telecommunications	15	16 7%	15 -6%	16 7%	14 -13%	12 -14%	13 8%	-13%
61.200	Wireless Telecommunications	6	8 33%	9 13%	9 0%	9 0%	7 -22%	8 14%	33%
61.300	Satellite Telecommunications	6	7 17%	12 71%	14 17%	14 0%	15 7%	16 7%	167%
61.900	Other telecommunications activities	47	44 -6%	44 0%	42 -5%	47 12%	48 2%	51 6%	9%
Layer 2 (Network Operators)		**74**	**75 1%**	**80 7%**	**81 1%**	**84 4%**	**82 -2%**	**88 7%**	**19%**
26.110	Manufacture of electronic components	1	0 -100%	0 -	1 -	1 0%	1 0%	1 0%	0%
26.200	Manufacture of computers and peripheral equipment	1	1 0%	1 0%	1 0%	1 0%	1 0%	2 100%	100%
26.300	Manufacture of communication equipment	1	1 0%	1 0%	1 0%	2 100%	2 0%	2 0%	100%
46.510	Wholesale of computers, computer peripheral equipment and software	178	178 0%	182 2%	175 -4%	176 1%	172 -2%	170 -1%	-4%
46.520	Wholesale of components and electronics and telecommunication	60	64 7%	59 -8%	62 5%	59 -5%	62 5%	67 8%	12%
Layer 1 (Network Element Providers)		**241**	**244 1%**	**243 0%**	**240 -1%**	**239 0%**	**238 0%**	**242 2%**	**0%**
Total ICT companies		**1509**	**1532 2%**	**1613 5%**	**1707 6%**	**1818 7%**	**1905 5%**	**2000 5%**	**33%**

Sources: Statec Répertoire systématique des entreprises luxembourgeoises (2008-2014)

3.4. Layer 1 – network element providers

Layer 1 (network element providers) consists mainly of distributors or local branches or subsidiaries of international or global ICT equipment providers like for example Cisco, Ericsson, Huawei, Nokia Networks, HP, IBM, Oracle, EMC etc. Most of these international companies have established small sales offices[3] in Luxembourg, attracted by its favourable economic conditions, the geographic location of the country and, most importantly, the demands of a well-developed financial industry. There is no foreign direct investment by these companies in local research and development activities. There are,

[3] Eg. Cisco's office does only employ 5 people in charge of the local market (source: Cisco Luxembourg)

however, also 5 small (less than 10 people) local manufacturing companies that are mainly active in the design and production of specific communication interfaces for example in satellite communication. This can be explained by the small size of the country, the lack of investment in manufacturing and the lack of skilled workforce.

3.5. Layer 2 – network operators

Layer 2 (network operators) consists of 88 companies, out of which 11% are companies with more than 50 employees. Companies acting in layer 2 provide high speed internet, cable TV, fixed line telephony, satellite and mobile connections.

According to the Institut Luxembourgeois de Régulation (Institut Luxembourgeois de Régulation, 2015) , there were 4632 people employed in this layer, while its revenues totalled €534.7 million and investments amounted to €215 million. Broadband coverage reaches 100% and Luxembourg is among the European leaders in terms of broadband penetration. As of 2013, the only income growth drivers are high speed broadband Internet and mobile Internet, which are marked by increasing revenues. However, they represent only 6% of the total telecom revenue.

POST Telecom is the major contributor to layer 2. It is the incumbent national telecom operator, providing fixed, wireless, mobile network and other ICT services. In terms of the revenue, market share held by POST Telecom remains stable and superior to alternative operators, showing more than 50% in 2013 (Institut Luxembourgeois de Régulation, 2015). Other companies that compete with POST Telecom are Telindus Telecom, Tango, a subsidiary of Proximus Belgium and part of the Vodafone group, and Joinexperience, a recently established Luxembourgish company.

Another big player in layer 2 is SES (Société européenne des satellites), one of world leaders in the provision of satellite services. Having been founded in Luxembourg in 1985 with the support of the Luxembourg government, it still maintains its global headquarters there. SES operates 42 satellites, providing services to 99% of the world's population. SES offers a wide range of services such as high-speed data transmission, TV channels, internet access, secure network and communication solutions.

Actors in layer 2 are partly regulated by "Institut Luxembourgeois de Régulation (ILR)" which is the national regulatory authority for Luxembourg (Binsfeld, Whalley, & Pugalis, 2015). [4]

3.6. Layer 3 – content and application providers

As discussed in the previous section, layer 3 (content & application providers) is the 'largest' layer in terms of the number of actors. It consists of 1670 companies, out of which a major part (97%) are companies with less than 50 employees. The larger companies in this layer are mainly active in e-commerce, software, ICT-consulting and -integration as well as data centre operators. In the following, we will identify specific sub-layers of actors and briefly describe these.

3.6.1. E-commerce

E-commerce is defined here as "buying and selling of products and services through an electronic medium over the internet". Luxembourg was the first European country to create a specific, clearly defined and secure legal framework for e-commerce (PWC, 2011) and it also had, at least until 2015, the lowest standard VAT rate of 15% on e-commerce services within the EU and just 3% on e-books. This attractive rate of taxation, together with good communication infrastructure, has led several

[4] A complete and permanently updated list of all actors in this layer can be found on the web site of ILR.www.ilr.public.lu accessed 23.4.2016

players in the gaming (online video games) and gambling sector to set up their headquarters in Luxembourg or even install their technology centres for Europe in the country. This, is turn, has attracted low-latency Internet providers to expand their ICT operations to include Luxembourg (PWC, 2011). Global brands in the media and Internet world such as Amazon, eBay, iTunes, PayPal and Skype or global telecommunications provides such as Vodafone all have their European headquarters or major operations based in Luxembourg. Revenues from e-commerce in Luxembourg grew 32% in 2013. Online stores sold products and services for about €950 million. The total online sales for this year are expected to reach €1.03 billion. That would represent a percentage growth of 8% (Marx, 2014). However, the fiscal advantages mentioned above are about to disappear in 2015 in accordance to EU regulations (Fayot & Funck, 2012; Funck, 2013). It is expected that this will have a substantial negative pisseneffect on e-commerce activities in Luxembourg.

3.6.2. Software publishing

Software development and publishing have been growing substantially over time. The software development market in Luxembourg consists a wide range of small and very small (1 person), some medium sized local players as well local branches of global actors They produce computer and mobile applications and software products for different business sectors (e.g., financial applications to facilitate the management of operational risk linked to foreign exchange, and straight-through processing software for connectivity between banks which need to communicate directly), healthcare (e.g., health data management and archiving), transport (e.g., for aerial cargo services), web development, etc.

3.6.3. Professionals of the financial sector

Professionals in the financial sector (PSF) are regulated entities offering financial and related services. PSF are supervised by the 'Commission de Surveillance du Secteur Financier (CSSF)'. PSF are divided into 3 subgroups depending on the type of business conducted and services provided: investment firms, specialized PSF and support PSF (Deloitte, 2013). Support PSF act as subcontractors offering operational services on behalf of banks or other PSFs. According to CSSF (2014), in the end of 2014, 315 PSF firms were identified in Luxembourg, 81 of them being support PSF (26% of PSF market) with 9 043 employees.

3.6,4, Fintech companies

Financial services fechnology (FinTech) is the application of technology (software, hardware and services) to financial services. According to KPMG (2014), there were about 150 companies in Luxembourg in 2013 that provided software, infrastructure and IT services to all financial segments (including the PSFs). Although the majority of FinTech companies (93%) have less than 250 employees, 50% of the revenues were generated by companies with more than 250 employees. Fintech is currently considered as having a high potential for development given the size and importance of the financial sector in Luxembourg and is one of the focus areas evident in the actions of the current government (Gray, 2017; Labro, 2015; Luxembourg for Finance, 2015; Thibaut, 2015).

3.6.5. Datacentres

Luxembourg boasts one of the most modern data centre parks in Europe and currently has 19 data centres, all of which offer a high level of security and availability with low latency connections to all of the major European Internet hubs (Luxembourg for Business, 2013c). The absence of a server tax and low energy prices made establishment of data centres in Luxembourg attractive for public and private customers, including European Commission as well as for many financial institutions. A full suite of hosting services is provided: colocation services, virtual private servers, managed hosting and web hosting.

3.6.6. Cloud service providers

Cloud services provide businesses with the possibility to having their data and files stored on IT infrastructures accessible through the Internet. This helps to reduce the companies' costs associated with the installation and maintenance of equipment. Companies in Luxembourg offer cloud services on an infrastructure as a Service (IaaS), Platform as a Service (PaaS) and Software as a Service (SaaS) basis. They offer secure, low latency, highly available cloud services. Nevertheless, many organizations in financial sector avoid using cloud services for security reasons. In order to support this developing area, and to secure cloud services in Luxembourg, the government has undertaken a range of investments. Existing legal and regulatory frameworks are aimed at providing a higher level of protection for organizations that operate with sensitive and confidential data (PwC, 2011).

3.6.7. ICT consulting and Integration

Companies need to efficiently use IT resources, in order to achieve their business objectives. Due to a high demand in this field, many companies in Luxembourg provide a variety of IT consulting services that may include the design, implementation and support of IT systems. The primary objectives of IT consulting include simplification, improvement or redesign of business processes using IT solutions, ensuring data security, etc. According to Statec, Luxembourg hosted 618 companies whose main activity in 2014 was IT consulting (Poujol, 2014b). The companies with more than 50 employees are presented in Appendix 3. In addition to these companies, IT consulting is provided by audit firms such as the 'Big Four' (KPMG, Deloitte, PwC, Ernst & Young) and other companies from the ICT sector.

3.6.8.E-archiving

There is already a legal framework concerning electronic archiving in place in Luxembourg. However, this framework does not provide sufficient legal guarantees regarding the destruction of an original document that had already been digitalised. To overcome this limitation, a team of experts was brought together to design a legal framework based on a new law on electronic archiving and an update of other impacted laws (Civil code, Commercial code, Financial sector law). The proposed new regulation has recently been adopted by the parliament and it is expected that this will lead to the creation of a set of new service providers similar to the "PSFs" mentioned above (Poujol, 2014a; Raizer, 2015).

4. Discussion

An analysis of the ICT sector in Luxembourg shows that the sector has endured pronounced growth and, consequently, is a core component of the Luxembourgish economy generating about 7% of the country's GVA . Applying Fransman's model to Luxembourg's ICT ecosystem allowed to identify a huge number (almost 2000) of actors, many of which are focusssing on software development activities. It also allowed to identify that most of the GVA is generated in the network layer 2 by telecommunications network operators in which the Luxembourgish Government holds a substantial stake and that there is nearly no real local production activity of ICT goods and equipment (layer 1).

In addition, the research found that the majority of companies in the ICT sector are small-to-medium sized enterprises (50 employees or less). Indeed, many are micro-enterprises with only one owner/employee. The ICT sector's contribution to the country's GVA shows continuous growth from year to year, while other industries, e.g., manufacturing, financial and insurance, professional, scientific and technical activities show a slight decrease. Hence, whilst some traditional sectors of Luxembourg's economy are declining, the importance, size and economic contribution of the ICT sector continues to grow. In comparison to other European nations, the Luxembourgish ICT sector performs admirably, particularly in terms of employment (including a net increase of approximately 700 new jobs per annum) and GVA uplift.

Layer 3 (content & application providers) is the biggest and the most rapidly growing layer. It provides a diversity of content, applications, software and services and mostly consists of small companies. It should be noted that big worldwide ICT companies (e.g., Amazon, PayPal, iTunes, eBay) also belong to this layer. The financial orientation of the country's economy influences the evolution of the ICT sector in general and, in particular, of layer 3. The high demand of high quality secured IT services from the financial sector stimulates the development of new services and products aimed at supporting the sector. As a consequence, financial technologies (FinTech) have been rapidly growing over the last years in Luxembourg (KPMG, 2014). Layer 3 particularly focuses on support Professionals of the Financial Sector (PSF)(Commission de Surveillance du Secteur Financier, 2014).

Layer 2 (network operators) is the smallest part of the ICT ecosystem in terms of the number of actors, however, its contribution to the economy of country is high. The main contribution to this layer is delivered by incumbent telecommunications operator POST Telecom as well as by the 4 mobile network operators.

Layer 1 (network element providers) has the lowest contribution to the GVA. There are a few small manufacturing companies and this layer is dominated by sales representations of ICT equipment manufacturers.

4.1. Moving beyond the Fransman model

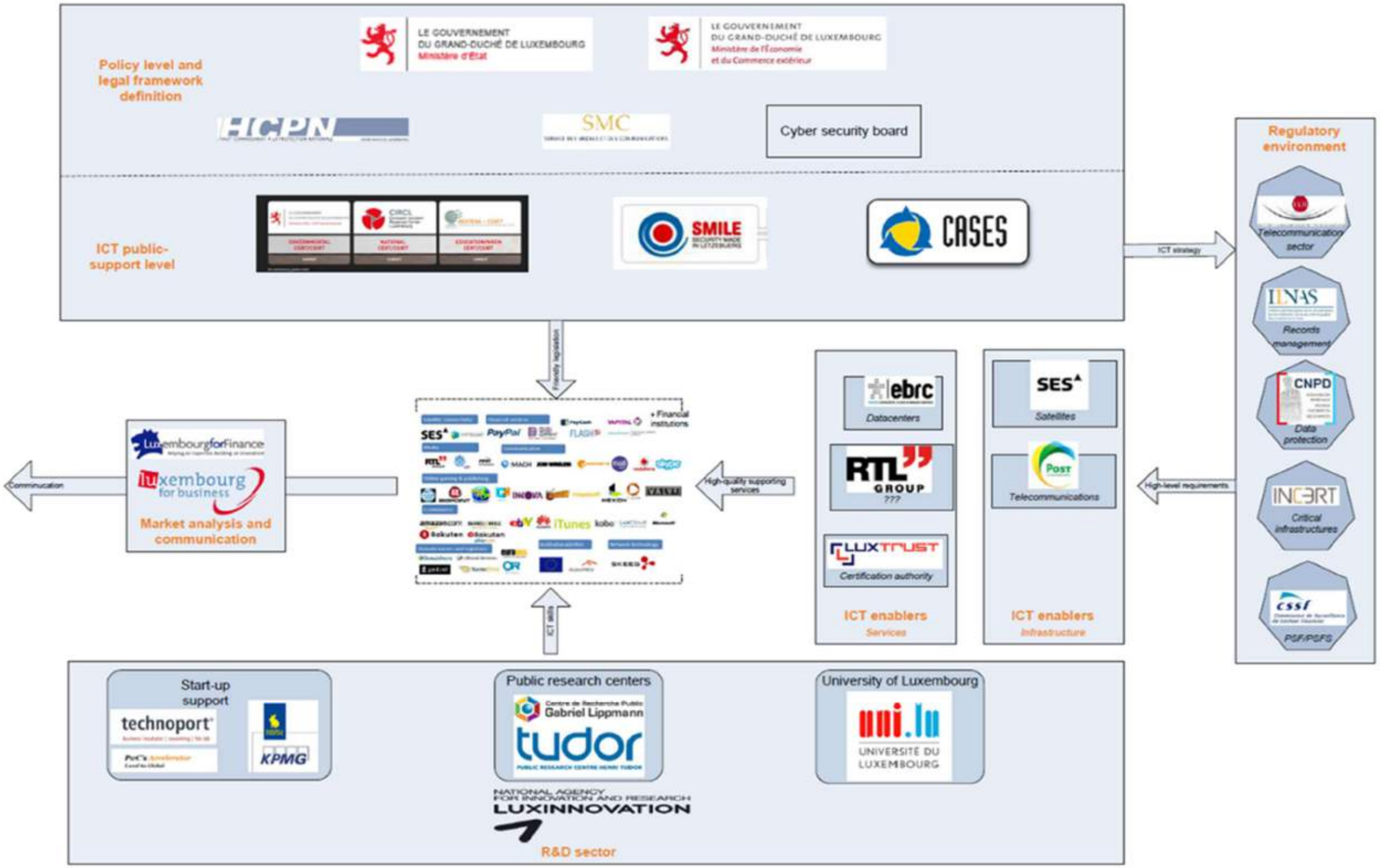
As shown above, the Fransman model helps to examine how the sector is structured, identify key actors and investigate their roles, interrelationships and contribution to the ICT ecosystem. The major actors in the sector can be readily identified and mapped according to Fransman's model. It should be noted however, that the model is static whilst ecosystems are dynamic. In addition, the analytical distinctions of Fransman's layers are not necessarily appropriate for all ICT actors. Therefore, any application of the model can only provide a limited snapshot at a specific moment in time.

Moreover, and perhaps more importantly, the Fransman model does not fully aknowledge the role and importance of institutions or organizations not belonging to the core 4 layers but nevertheless affect and interact with the ecosystem. The authors propose therefore to extend the model as shown in figure 6 below in order to include these, particularly external stakeholders such as administrations, institutions, regulators, R&D organisations etc.

Focussining on the above mentioned "symbiotic relationships" within the ecosystem, we identified stakeholders at the government and political level that shape the regulatory and policy environment for ICT within the framework of the regulatory packages set by EU (European Commission, 2014).

Similarly, the scope of the analysis had also to be extended to the different state-owned agencies and institutions that provide support to the ICT sector in terms of public funding, awareness raising and training (upper box in figure 6). See for example the strategy called "Digital Lëtzebuerg" which aims to set a framework for the development of the ICT ecosystem in medium terms (Bettel, 2014).

Figure 6: The ICT ecosystem and external influencers.



Source: Luxembourg Institut for Science and Technology

The next group of additional actors identified concerns regulation in the broadest sense, including the national regulatory authority[5], the competition authority[6], the national standards agency[7], the data protection commission[8] as well as regulatory authorities for the financial sectors (right box in figure 6). The ICT ecosystem is also supported by R&D activities and organizations such as the University of Luxembourg, public research centers but also venture capitalists and incubators (lower box in figure 6).

When looking closer into the ecosystem itself (middle part of figure 6), Fransman allows to identify ICT enablers that provide the underlying infrastructures; these include network element providers and network operators corresponding to the layers 1 and 2 of Fransman's model. Building on this, one can find the ICT service enablers that would fit within Fransman's third layer and the customers or users of ICT of which some have been identified in the diagram above. These correspond to Fransman's fourth layer. They include most of the actors in Luxembourg's well developed financial sector (KPMG, 2013).

Finally, we can also identify several institutions or organizations, private and public that are active in promoting the sector both nationally and internationally. In addition, the ICT ecosystem is supported, represented and promoted by a number of different associations, governance bodies and media: Thus, for example media have created several specialized monthly publications which illustrate the development of the sector[9] or incubators have launched several business games or hackatons[10].

Professionals and users of different parts of the ICT ecosystem create federations and business platforms, and organize events with the aim of exchanging their knowledge, ideas, broaden their network and promote the sector on the national, European and international levels. These activities confirm the interest to this sector and its importance to the country. The interest to the sector is also attributed to the number of business incubators established by different public and private actors suhc as for example the professional chambers or some of the larger local banks, and accelerators focused on the development of ICT.

In order to better understand the interests and influences of these actors, the authors conducted a stakeholder analysis as shown in figure 7. A full list of these actors as well as a brief description of their activities is provided in annex.

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[5] Institut Luxembourgeois de Régulation, see www.ilr.public.lu accessed 16.5.2016

[6] Conseil de la Concurrence, see www.concurrence.public.lu accessed 16.5.2016

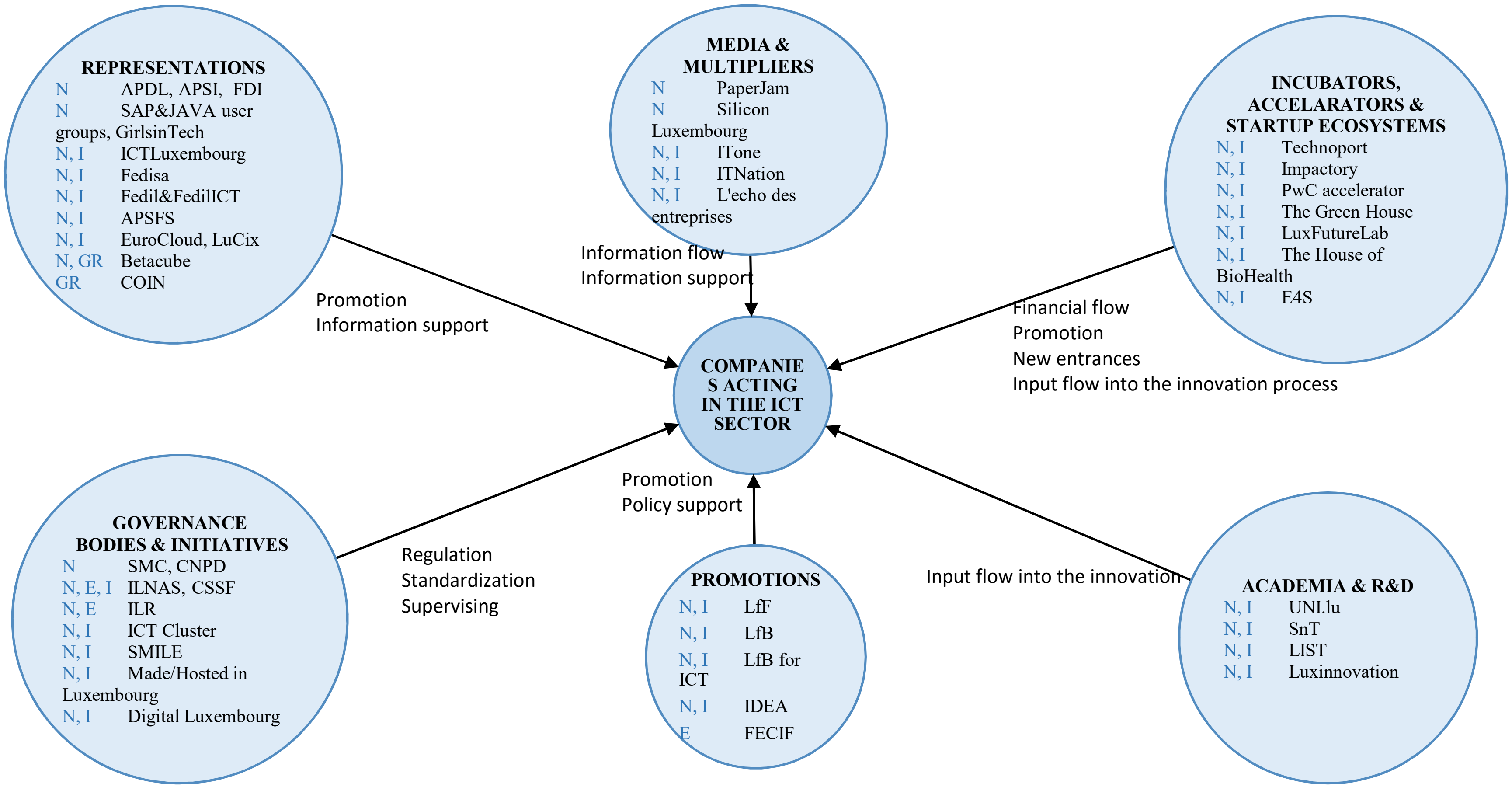
[7] Institut Luxembourgeois de la Normalisation, de l'Accréditation, de la Sécurité et qualité des produits et services, see www.ilnas.public.lu accessed 16.5.2016

[8] Commission Nationale pour la Protection des Données, see www.cnpd.public.lu accessed 16.5.20164

[9] See for example www.itnation.lu or www.itone.lu accessed 1.7.2017

[10] See for example http://www.luxfuturelab.lu/hackathon-2017/ accessed 1.7.2017

Figure 7 – External stakeholder map of Luxembourg's ICT ecosystem



Notes: The ICT sector promoted or represented on national (N), European (E), international level (I) or in the Greater Region of France, Belgium and Germany (GR),

Sources: author's compilations from different websites

5. Conclusions

This study has applied the Fransman layered ICT Ecosystem model to the ICT Ecosystem in Luxembourg. It has shown the evoluation and the importance of the ecosystem for with Luxembourg's economy. It has identified that nearly 2000 actors are active within the ecosystem most of which are very small or even one-person software development companies. It has shown that whilst layer 2 is very important in terms of its turnover and value added because of some larger telecommunications operators, most companies are located within layer 3. Consquently, layer 3 has been analysed further and different categories of actors have been identified.

The study has also considered the so-called symbiotic relationships between actors within and across different layers and developed an extended model that shows some of these relationships (see figure 6).

Finally, the role of external but supporting or at influencing stakeholders has also been identified and, bearing in mind the specificities of Luxembourg as a small country, our research suggests, in order to better understand the ICT ecosystem, to extend the Fransman 4 layered model and combine it with a stakeholder analysis looking 6 external groups of stakeholders as shown in figure 8 below:

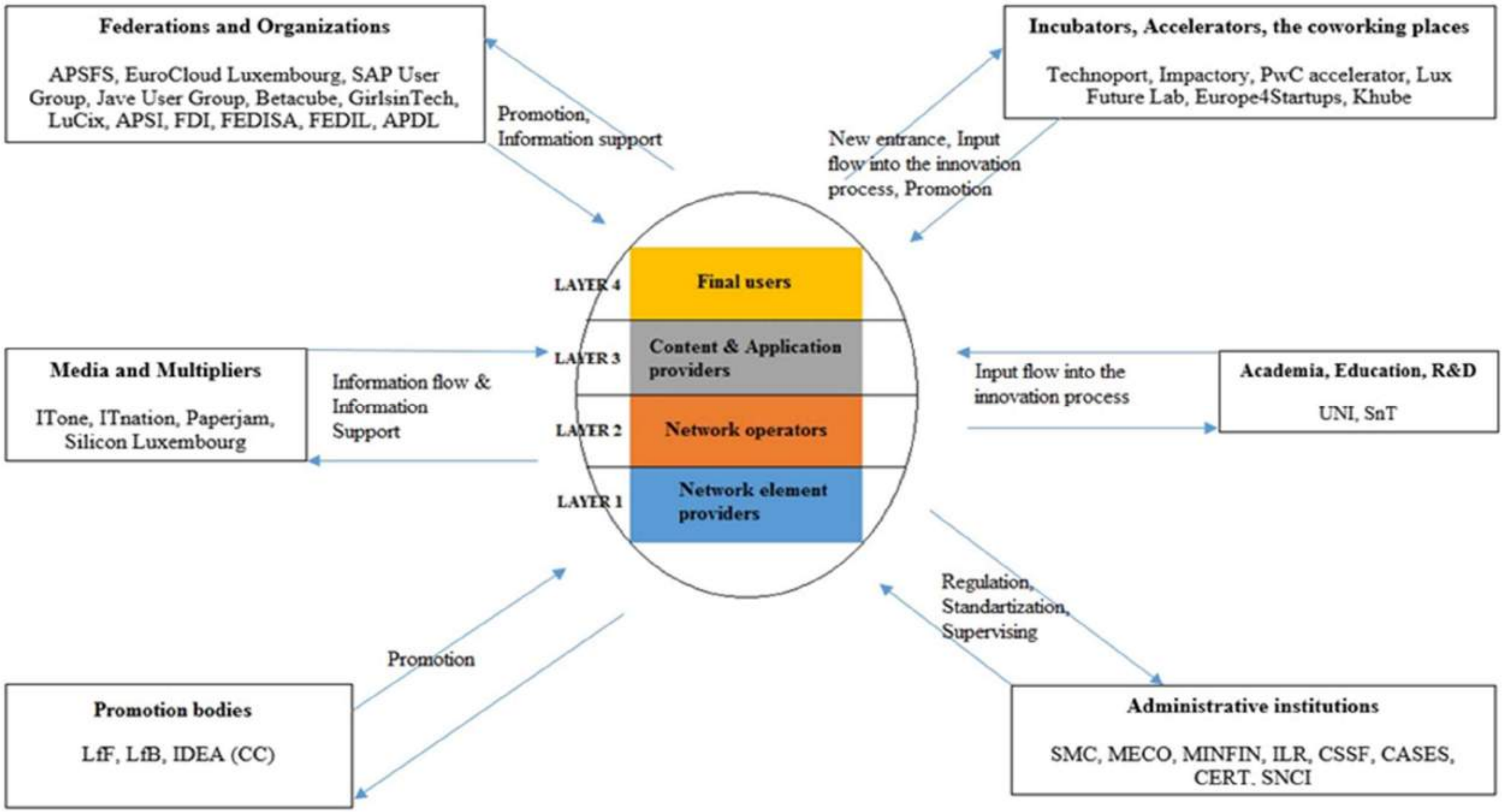
- Government and administrative bodies
- Media and multipliers
- Representation bodies (federation, organizations and users' platforms)
- R&D and academia
- Business incubators, accelerators
- Promotion agencies

Overall, the authors have shown how the Fransman model can be applied to a specific country case and have also identied several potential extensions or improvements to this model.

The difficulty of this study consists of the limited publicly available information. Although detailed information about companies such as financial figures, core business, year of foundation, investment in R&D is collected by Statec and Eurostat, it is not openly available to the public due to data protection issues. The data available in the Statec and Eurostat databases, are often not divided into subsections (according to NACE nomenclature), is limited and not up-to-date.

Therefore, some results, such as GVA, turnover, number of employees, in this study could not be collected and analyzed over the complete period under examination. Getting access to information about the companies' profitability, returns, R&D expenditure would allow to go far deeper in the analysis on a firm level and also look more in-depth into the 'symbiotic relationships' such as networks, cooperation or instead competition relationship between the different actors in the ecosystem.

Figure 8 - the Fransman layers within a network of stakeholders



In addition, more work is necessary to move beyond identifying the different actors and identifying interactions in terms of cooperation, collaboration, co-evolution or indeed otherwise. At this stage, the study identified the actors in the different layers in terms of size, numbers, GVA added. It identified also a wide range of partially or completely external stakeholders. It did not, however, at this stage identify whether and how these stakeholders have been able to collaborate in order to develop and promote the ecosystem. The authors have looked at some of these questions in different other contributions and further work is in progress (Binsfeld, 2013; Binsfeld, Pugalis, & Whalley, 2015; Binsfeld & Whalley, 2016; Binsfeld, Whalley, & Pugalis, 2013, 2014, 2016, 2017; Binsfeld, Whalley, et al., 2015).

These limitations notwithstanding, to the best of our knowledge, this is the first time that an in-depth analysis of Luxembourg's ICT ecosystem has been undertaken and the first time that the Fransman model has been applied to a small country.

This helps to redress the research imbalance; whereby small countries are often overlooked by scholars. Such 'smallness' engenders a unique opportunity for research engagement with a majority of primary actors in ecosystems, which might be unfeasible in larger countries.

A comparative analysis between ICT ecosystems of different small countries or specific regional area might be an interesting avenue of further research to identify whether the same proposed extended model could be of a more general application.

Annex – External Stakeholders

This annex presents external stakeholders in the ICT ecosystem of Luxembourg. In total, 6 groups of external stakeholders are identified based on their activity.

1. Governance and administrative bodies

Media and Communication Service **(Service des Médias et des Communications - SMC)** was established in 1991. Its missions are media regulation, protection of data and the digital economy.

Luxembourg Institute of Standardisation, Accreditation, Safety and Quality of Products and Services l **('Institut Luxembourgeois de la Normalisation, de l'Accréditation, de la Sécurité et qualité des produits et services - ILNAS)** is a public service under the authority of the Minister in charge of the Economy. ILNAS is a competency network at the service of competitiveness and consumer protection. ILNAS represents Luxembourg's interests in the European and the international standardization organizations.

ILNAS's terms of reference in the field of standardization are:

- to organize, coordinate and develop the wording, dissemination and implementation of normative documents at national level;
- to ensure the participation of the various economic sectors in the development of European and International standards;
- to implement European standards at national level;
- to set up a standards watch;
- to promote the use of standards.

L'Institut Luxembourgeois de Régulation (ILR) which regulates the telecommunications, energy sector and postal services. It is an independent regulator, which is financed by the operators of the sector. The ILR competence is to stimulate and guarantee competitiveness, to determine the fees and conditions at which communication networks are operated, to prepare statistics, annual reports and regulations. Also ILR can lead sanctions against operators, which infracted laws or regulation. Its competence is set by Electronic Communication Law and the Spectrum Law. The ILR sets rules in accordance with European directives and national laws.

The **National Commission for Data Protection** (Commission Nationale pour la Protection des Données – CNPD) is an independent authority created by the Act of 2 August 2002 on the protection of individuals with regard to the processing of personal data. It verifies the legality of the processing of personal data and ensures the respect of personal freedoms and fundamental rights with regard to data protection and privacy.

The **Commission de Surveillance du Secteur Financier** (CSSF) is a public institution which supervises the professionals and products of the Luxembourg financial sector. It supervises, regulates, authorizes, informs, and carries out on-site inspections and issues sanctions. Moreover, it is in charge of promoting transparency, simplicity and fairness in the markets of financial products and services and is responsible for the enforcement of laws on financial consumer protection and on the fight against money laundering and terrorist financing.

Objectives:

- to promote a considered and prudent business policy in compliance with the regulatory requirements,
- to protect the financial stability of the supervised companies and of the financial sector as a whole,
- supervising the quality of the organization and internal control systems,
- Strengthening the quality of risk management.

Some more recent governance initiatives

SECURITYMADEIN.LU is an initiative **“security made in Lëtzebuerg” (SMILE)** launched in February 2015. SMILE is the online source for cyber security in Luxembourg. Its goal is to provide news, relevant information as well as a toolbox with useful cyber security solutions for private users, organizations and the ICT community. It centralizes, all news and other valuable material from its three fields of activity (CASES, AWARE and CIRCL). It builds on the integration of the pre-existing services, infrastructures, platforms, experience and competence of partners, and thus represents a central place for information security awareness-raising, information, support and problem solving material. SMILE also initiates new markets with high added value to deliver high-quality services accessible to municipalities, SMEs and companies of every size, by developing new solutions and competent services for the Luxembourg economy.

Cyberworld Awareness and Security Enhancement Services (CASES) and **Cyber Emergency Response Community Luxembourg (CERT).** Their objectives are to create a community gathering all security professionals under one label and platform and to represent market on national and international levels.

The Computer Incident Response Center Luxembourg (CIRCL) is an initiative designed to provide a systematic response facility to computer security threats and incidents.

CIRCL provides a reliable and trusted point of contact for any users, companies and organizations based in Luxembourg, for the handling of attacks and incidents.

CIRCL’s aim is to gather, review, report and respond to cyber threats in a systematic and prompt manner.

The Luxembourg **ICT Cluster** is part of the Luxembourg Cluster Initiative, launched by the Luxembourg Government to encourage networking between the private and the public sectors. The Luxembourg ICT Cluster brings together various actors in the field of ICT in Luxembourg with the goal of fostering new and sustainable business opportunities through collaborative research, development and innovation projects. The cluster provides specific support activities and services to its members and offers a platform for networking, collaboration and exchange of experience. It aims to optimize enabling technology for various sectors and the further development of the existing ICT sector in Luxembourg by encouraging networking and collaboration between the private and public sectors. The Luxembourg ICT Cluster is a network that supports and brings together the various actors in the field of ICT in Luxembourg with the goal of fostering new and sustainable business opportunities through collaborative research, development and innovation projects.

The objective of the initiative **"Digital Lëtzebuerg"** is to strengthen and consolidate the forward positioning of the country in the field of ICT and make it the international ICT center. It promotes the existing initiatives in different sectors and combines them into a comprehensive strategy to increase their visibility. This is done to highlight and promote the completed and ongoing projects in the various ministries to identify opportunities for collaboration and potential coordination measures and to draw perspective areas for development.

The label **"Made in Luxembourg"** is a registered trademark since 1984 at the initiative of the Ministry of Foreign Affairs, the Chamber of Commerce and the Chamber of Trade. The label is used to identify the Luxembourg origin of products and services.

The label **"Hosted in Luxembourg"** is a trademark for holding companies used to identify web applications and webservices hosted in Luxembourg.

2. Academia and R&D

Computer Science and Communications Research Unit (CSC) of the University of Luxembourg (Uni.lu). Its mission is to conduct fundamental and applied research in the area of computer, communication and information sciences. The goal is to push forward the scientific frontiers of these fields. CSC focuses on such areas as communicative systems, information security, intelligent and adaptive systems, software and systems in particular to strengthen the interdisciplinary centers LCSB and SnT.

The research unit **Laboratory of Algorithmic, Cryptology and Security (LACS)** is part of the CSC. It focuses on cryptography, building secure public-key cryptosystems, computational number theory systems and network security and information security management. As parts of its activities, LACS organize a regular seminar, and an annual workshop.

The **Luxembourg Institute of Science and Technology (LIST)** active in the fields of materials, IT, environment, the space, public and health sectors. LIST was created from the merge of the Public Research Centers Gabriel Lippmann and Henri Tudor in 2015. It benefits from the competences and of these two major actors of the Luxembourg research, established in 1987. LIST participates in several national and European competitive research programs. In order to support companies in their innovation projects, LIST enables them to enhance their competitiveness in regional, national, and international markets. It also contributes to the setting up of new companies in Luxembourg through the development of innovative technology and expertise.

The Interdisciplinary Centre for Security, Reliability and Trust (SnT) at the University of Luxembourg contributes to establishing Luxembourg as the European center of excellence and innovation for secure, reliable and trustworthy ICT systems and services. The interdisciplinary approach brings together expertise from engineering, natural, law, and human/social sciences to address common challenges. SnT fosters interaction and collaboration with industrial, international and government partners.

The Research Unit in Engineering Science (RUES) is an interdisciplinary group active in the classical domains of civil, electrical and mechanical engineering. The main focus of research is the development of technological solutions, the sustainable and economical use of all kind of resources, the establishment of a center of expertise for the technological requirements of Luxembourg's industrial and public actors.

Luxinnovation, the national Agency for Innovation and research, is the first-stop shop for information and guidance on innovation and R&D in Luxembourg including national and European programs. Luxinnovation assists companies in identifying abilities and requirements, finding the right instruments for financial and technological support and facilitating access to support programs for innovation and research at national and European levels.

Its missions are:

- to promote research, innovation, technology transfer and the creation of innovative companies in Luxembourg,
- to inform and support company creators, enterprises, and research organizations,
- to support enterprises, research organizations and promoters of innovative projects at each phase of their projects, from the identification of their needs to assistance in finding financing and the launch of a product or service,
- to assist and advise the government in the area of research, development and innovation,
- to raise public awareness on research, development, innovation, creativity and design

Luxinnovation offers services to actors involved in the fields of R&D and innovation (enterprises, researchers, research organizations, company creators, students, etc.).

3. Promotion bodies

Luxembourg for Finance (LFF) is the Agency for the Development of the Financial Centre. It is a public-private partnership between the Luxembourg Government and the Luxembourg Financial Industry Federation (PROFIL). Founded in 2008, its objective is to promote the expertise of the financial center and the diversification of its services abroad through different communication channels. The agency continuously monitors global trends and evolutions in finance to identify development opportunities for the Luxembourg financial center and to serve different target markets and target groups. In cooperation with the various professional associations, LFF develops documentation on products and services available in Luxembourg and their relevant legal and regulatory framework. LFF organizes seminars in international business locations and takes part in selected world-class trade fairs and congresses.

Luxembourg for Business (LfB) was founded in April 2008. LfB operates as a trade promotion agency and functions as a network agency establishing a platform for its members to review, coordinate and improve their trade promotion efforts.

The objective of the **ICT division of LfB** is to provide companies with a "one-stop-shop" for detailed information on business opportunities in Luxembourg and hands-on administrative guidance and contacts in the ICT and media sectors. It gives company leaders easy access to key decision-makers in Luxembourg. It also aims at developing Luxembourg as an attractive environment perfectly fit to the needs of the digital economy. Finally, the ICT division of LfB commissions' studies on the Luxembourg market, edits information material and promotes Luxembourg as an ICT and media hub abroad.

IDEA is an economic policy Think Tank launched by the Chamber of Commerce of Luxembourg. IDEA endeavors to work as an autonomous, versatile and open entity and strives to lead reflections in terms of sustainable development in Luxembourg by pursuing the general economic interests of the country, and to contribute to the improvement of the socio-economic debate. Its ambition is to contribute to this debate through high-quality economic analyses and innovative ideas presented and discussed in public within the framework of open debates with various audiences.

The European Federation of Financial Advisers and Financial Intermediaries (FECIF) was chartered in June 1999 for the defense and promotion of the role of financial advisers and intermediaries in Europe. It is the European body representing European financial advisers and intermediaries. FECIF is keen to promote PSF.

4. Representation

The Support PSF Association (APSFS) is a non-profit organization founded in 2007 in order to represent the interests of companies operating under the status of support PSF. The mission of the association is to inform, help and encourage synergies between member companies and the proactive treatment of subjects directly linked to the development of the Support PSF industry. It promotes PSF status on the international level."

EuroCloud Luxembourg acts as a coordination platform to position Luxembourg as a leader in the field of Cloud computing and SaaS applications. It aims to contribute to the development of the cloud computing business in Luxembourg by creating an exchange platform for cloud service providers, to promote and encourage the uptake of cloud services and applications, and to develop legal framework for cloud computing on a national, European and international levels. EuroCloud Luxembourg organizes EuroCloud Luxembourg Awards.

Association for Data Protection in Luxembourg (APDL) is a non-profit association aimed to promote the exchange of experiences, knowledge and ideas within all individuals regularly practicing law, economics, engineering and research. It aims to contribute to the dissemination of knowledge, particularly through the organization of conferences, by the communication and documentation of the actions or training partnerships and to create links in Luxembourg and abroad and particularly in the European Union with any entity of the same material.

Association of the Society information (APSI) is a business federation focusing on the ICT industry in general. Its mission is to inform, represent and defend the interests of member companies and participate in the promotion of the ICT sector information in Luxembourg. Since 2009 association organizes APSI days to introduce the ICT sector.

Comité d'Organisation des Interactivités Numériques (COIN) is an association and online community established in 2012. It aims to federate the actors of the video game creation in a network, to promote the careers and trainings, help in starting businesses, to promote cultural aspects related to video game creation through events, such as the organization of Game Jams in the Greater Region.

The Integrators Federation in Telecommunications, IT, Multimedia and Security (Fédération des Intégrateurs - FDI). The group of professionals with interests that cover all activities professional groups in ICT, multimedia and security systems. Their clients are companies in all sectors of the economy, from public sector to private clients via banks, hospitals and SMEs.

Business Federation Luxembourg (Fedil) was founded in 1918, is representing companies in the sectors of industry, construction and business services. FEDIL's main objectives are to defend the professional interests of its members and analyze all economic, social and industrial issues relating thereto, to develop the spirit and solidarity among Luxembourg employers. Maintaining regular contact with the national and European levels with politicians, public authorities, the business community and trade unions, the FEDIL strives to influence political and administrative decisions in the interests of free enterprise. In order to promote the Luxembourg economy, the FEDIL also participates in numerous trade missions abroad. They also have set-up a subgroup **FedilICT** – the platform for ICT companies that are member of Fedil-

The **Federation of Alternative Operators Luxembourg** (La Fédération des Opérateurs Alternatifs du Luxembourg - OPAL) was founded in 2007, the association aims at the promotion of telecommunication services and the representation and defense of the interests of alternative operators to the bodies in charge of the market, including the ILR, relevant ministries, business and labor rooms and European authorities.

The **Association des Antennes Collectives AAC** – represents both commercial and public cable TV network operators and promotes internetwork competition between traditional fixed networks and cable TV networks.

The Luxembourg SAP User Group created in 2006, forms part of the FEDIL, it regroups all companies (e.g., international groups, SMEs, actors from the public sector or the industry, the health care, transportation and logistics) using SAP. Its mission is to share project experience between different SAP users, to detect and address local specific requirements towards SAP.

Betacube organizes regular Hyperlink meetups. This event allows web professionals, developers, designers, entrepreneurs and startups share their knowledge and expertise about new technologies, methodologies, ICT, new media, marketing and other web related disciplines. The aim of Betacube is to build an active web community in Luxembourg and in the Greater Region.

Girls in Tech Luxembourg is part of Girls in Tech Worldwide (created in 2007 in USA), and has been founded in January 2014. The organization promotes, supports and educates entrepreneurial and innovative women in the technological space.

LUxembourg Commercial Internet eXchange (LU-CIX) was founded in 2009 as a cross-industry initiative of national and international internet players. It hosted in four data centers in Luxembourg. The organization allows internet service providers to exchange internet traffic between their networks. To promote the exchange of contacts, experience and ideas in the ICT sector of Luxembourg and beyond, LU-CIX organizes Luxembourg Internet Days.

The Luxembourg Java User Group (LuxJUG) is a independent, non-profit and moderated newsgroup. It provides a place and an infrastructure to share experiences and knowledge about the Java platform and related technologies.

Federation of ILM (Information Lifecycle Management), Storage and Archiving in Luxembourg (FedISA) act as a part of FedISA International. The purpose of FedISA is to create a relevant forum for professional users, providers and consultants in the field of archiving and information security. It aims:

- to bring together stakeholders and inform them by working with existing national associations to educate the public and the private sectors to the concepts of ILM and digital archiving,
- to promote the use of digitized information by contacting the public law and private law organizations, national, regional and local authorities,
- to inform and assist project managers on technological developments, new processes and new regulations in performing work of many technological monitoring that legal and normative,
- to promote the introduction of norms and standards in the professional repository involved in conservation processes, exchange, and digitized information.

The YAJUG is a Java User Group. It aims to promote the technologies, applications and methods related to Java, to foster the associated open-minded culture, to be the link between research, users and suppliers of Java, to support the exchange of experience and expertise gathering all stakeholders around Java.

ICTluxembourg is a non-profit coordination platform for trade associations. The organization brings together ICT professionals for discussions on the future of the sector, represents the interests of all national and international companies and supports key initiatives. It aims to enhance synergies, exchange of information and best practices between all the players of the sector and to create a welcoming environment that will attract and retain ICT companies. It supports and fosters ICT related projects and initiatives throughout the country for a strong national positioning and a more effective international reach. It is made up of several major federations and associations in the field of IT and its ICT users: FDI, APSI, EuroCloud APSFS, FEDIL-ICT, OPAL, the association of CATV operators and ABBL (the Luxembourg Bankers's Asssociation). On the international level, ICTluxembourg works in close cooperation with Luxembourg for Business and Luxembourg for Finance. ICTluxembourg participates in the business and trade missions organized by the Luxembourg government.

5. Incubators, Accelerators and Coworking Places

Technoport® ltd. is a coworking place and technology oriented business incubator, was created in June 2012 as the result of the merge between the former technology-oriented business incubator Technoport® and business support infrastructure Ecostart.

The goal of Technoport® is to promote and support the creation and development of innovative and technology-oriented companies. It provides entrepreneurs with office space, equipment, human and technical resources.

Technoport® organizes Startupweekends, Apps Foundry Contests events.

The Impactory is a coworking space and a business incubator where creative people come to share their knowledge, discuss on projects and ideas and learn from the others. The Impactory has been created in March 2012, which promotes social entrepreneurship and innovation in Luxembourg. Recently Impactory merged with a similar initiative called 123GO to become **Nyuko**.

PwC's Accelerator helps companies to become global, providing access to business networks and decision makers, reviews sales and delivery approach to create value, ensures instant visibility in selected markets.

The Green House incubator promotes startups in ICT, mobile, social media, gaming and digital health sectors.

The Lux Future Lab is a business incubator, created in 2012 by Luxembourg bank BGL BNP Paribas as a part of its corporate social and economic responsibility program. The Lux Future Lab providing office space, training programs, coaching, access to the lux future lab networks, both national and international, and support for marketing services, events management, new entrepreneurial activity in Luxembourg. Majority of companies which work in The Lux Future Lab have business related to ICT.

The House of BioHealth incubator inaugurated in 2015, supported by the Ministry of the Economy, BioHealth and ICT clusters, promotes startups and existing businesses in the areas of biotechnology, ICT and environmental technologies.

Europe4StartUps (E4S) is a non-profit organization which helps e-business and multimedia companies coming from all over the world and wishing to develop, startup or boost their ventures in Europe by providing 12 preselected companies with 12 months of premium cloud storage, network and other business services for free.

6. Media support and Multipliers

ITOne, created in 2007, IT One strives for the recognition of Luxembourg's ICT community, the development of the entire sector and the promotion of its professionals as well as for the diffusion of best practices, innovative solutions and valuable services. IT One's web portal deals with ICT trends and topical issues at national and international scales. In order to promote sector, IT One organizes awards and events (an annual event, the IT One Gala, where national practices are rewarded with the Luxembourg ICT Awards), the ICT Spring Europe, a two-day international event and IT Days Luxembourg, the Information Security Days, an event focused on security-

ITnation is the magazine specialized in B2B communication, news and event organization for IT professionals.

Paperjam is the leading magazine for the business world in Luxembourg and strongest media brands in the country founded in 2000.

The Paperjam Club which was launched in 2008, consists of over 600 member companies and over 4,000 executive members. It offers its members a variety of events, allowing exchange of knowledge and ideas through networking. The Club is approved by the Ministry of Economy.

Founded in 2013, **Silicon Luxembourg** is a media channel designed to profile startups and promote entrepreneurial activity in Luxembourg. Media platform aims to bring together all entrepreneurial and startup information from Luxembourg and become contact for entrepreneurs and investors from around the world."

L'Echo des entreprises, publication of FEDIL, is devoted to economic and social issues affecting companies in the sectors of manufacturing, construction and business services. As such, it represents a targeted advertising medium of choice, its readership is composed, mostly, executives, business managers and other decision makers, including political on national and international levels.

Bibliography

Arlandis, A., & Ciriani, S. (2010). How Firms Interact and Perform in the ICT Ecosystem? *Communications & Strategies*, *79*(3), 121–141.

Barthelemy, C. (2014, March 9). Out of the Shadows, a Tech Hub in Luxembourg. *NY Times*.

Basole, R. C., Park, H., & Barnett, B. C. (2015). Coopetition and convergence in the ICT ecosystem. *Telecommunications Policy*, *39*(7), 537–552.

Bettel, X. (2014, October 20). Xavier Bettel présente l ' initiative " Digital Lëtzebuerg ." *Gouvernement Du Luxembourg*. Luxembourg.

Binsfeld, N. (2013). The Luxembourgish Telecommunications Market. *Cahier Scientifques Revue Technique Luxembourgeoise*, *1*, 24–37. Retrieved from www.revue-technique.lu

Binsfeld, N., Pugalis, L., & Whalley, J. (2015). ICT ecosystems in small countries : an analysis of Luxembourg. In *26th European Regional Conference of the International Telecommunicatons Society (ITS), Madrid, 24-26 June 2015*. Madrid: www.econstor.eu. Retrieved from http://www.econstor.eu/dspace/handle/10419/127127

Binsfeld, N., & Whalley, J. (2016). Measuring Luxembourg's State of ICT Development. *Cahier Scientifques Revue Technique Luxembourgeoise*, *2016*(1), 30–47.

Binsfeld, N., Whalley, J., & Pugalis, L. (2013). *Luxembourg – a bastion of state-ownership in Europe*. *International Telecommunications Society Regional Conference*. Brussels.

Binsfeld, N., Whalley, J., & Pugalis, L. (2014). Luxembourg a bastion of state ownership. In *25th European Regional Conference of the International Telecommunicatons Society (ITS), Brussels, 22-25 June 2014*. Brussels: Econstor.

Binsfeld, N., Whalley, J., & Pugalis, L. (2015). Competing against yourself: State duopoly in the Luxembourg telecommunications industry. *Telecommunications Policy*.

Binsfeld, N., Whalley, J., & Pugalis, L. (2016). Competing through e-skills : Luxembourg and its second level digital divide. In *27th European Regional International Telecommunications Society Conference*. Cambridge.

Binsfeld, N., Whalley, J., & Pugalis, L. (2017). Playing the game: Explaining how Luxembourg has responded to the Networked Readiness Index. *Digital Policy, Regulation and Governance*, *19*(4), DPRG-02-2017-0008.

Briglauer, W. (2004). Generic reference model for the analysis of relevant communications markets: fundamental competition concepts. *Info*, *6*(2), 93–104.

Commission de Surveillance du Secteur Financier. (2014). *Rapport annuel*. Luxembourg.

Deloitte. (2013). *Professionals of the financial sector (PSF) in Luxembourg Overview and outlook of a resilient sector*. Luxembourg. Retrieved from http://www.deloitte.com/view/en_LU/lu/library/publications-whitepapers/industries/psf/index.htm#.UpWtruKeHJO

Elixmann, D., Schwab, R., & Stappen, C. (2003). Development of the telecommunications market in Germany since liberalisation. *Info*, *5*(1), 41–51.

European Commission. (2014). *Digital Agenda Scoreboard 2014 – Digital Performance of Luxembourg*. Brussels.

European Commission. (2015). *Digital Economy and Society Index 2016 Country Profile Luxemburg*.

Brussels.

Fayot, F., & Funck, L. (2012). Luxembourg's TMT Sector. In J. P. Panka (Ed.), *The Technology Media and Telecommunications Review* (3rd ed.). Law Business Research Ltd.

Fransman, M. (2001). Evolution of the Telecommunications Industry into the Internet Age. *Communications & Strategies*, (43), 57–113.

Fransman, M. (2002a). Mapping the evolving telecoms industry: the uses and shortcomings of the layer model. *Telecommunications Policy*, *26*(9–10), 473–483.

Fransman, M. (2002b). *Telecoms and the internet age - from Boom to Bust to...* (1st ed.). Oxford: Oxford University Press.

Fransman, M. (2004). The telecoms boom and bust 1996-2003 and the role of financial markets. *Journal of Evolutionary Economics*, *14*(4), 369–406.

Fransman, M. (2006). *Global Broadband Battles*. (M. Fransman, Ed.) (1st ed.). Stanford: Stanford University Press.

Fransman, M. (2007). Innovation in the New ICT Ecosystem. *International Journal of Digital Economics*, (68).

Fransman, M. (2010). *The New ICT Ecosystem - Implications for Policy and Regulation* (New and re.). Cambridge: Cambridge University Press. Retrieved from www.cambridge.org/9780521171205

Fransman, M. (2011). The evolving ICT industry in Asia and the implications for Europe. *JRC Technical Notes*, *63986*, 78. Retrieved from http://ipts.jrc.ec.europa.eu/

Fransman, M. (2014). *Models of Innovation in Global ICT Firms : The Emerging Global Innovation Ecosystems* (No. EUR 26774 EN). (M. Bodganowicz, Ed.). Luxembourg: European Commission.

Funck, L. (2013). Luxembourg. In J. P. Janka (Ed.), *The Technology, Media and Telecommunications Review* (4th ed., pp. 247–268).

Garcia, A. S., & Vicente, M. R. (2012). *ICT Technologies in Europe : A Study of Technological Diffusion and Economic Growth under Network Theory* (No. WP-AD 2012.21).

Gray, S. (2017, June 23). Luxembourg ' s politicians pin economic hopes on fintech drive. *Financial Times*. London.

Hallikas, J., Varis, J., Sissonen, H., & Virolainen, V. M. (2008). The evolution of the network structure in the ICT sector. *International Journal of Production Economics*, *115*, 296–304.

Hulsink, W. (1999). *Privatisation and Liberalisation in Europe Telecommunications: Comparing Britain, the Netherlands and France*. Oxford: Routledge.

Institut Luxembourgeois de Régulation. (2015). *Rapport statistique des télécommunications du Luxembourg de l'année 2014*. Luxemboug. Retrieved from http://www.ilr.public.lu/communications_electroniques/statistiques/rapp_statistiques_ILR/rapport-statistique-telecom-2014.pdf

Karagiannopoulos, G. D., Georgopoulos, N., & Nikolopoulos, K. (2005). Fathoming Porter's five forces model in the internet era. *Info*, *7*(6), 66–76.

Kim, H., Lee, J.-N., & Han, J. (2010). The role of IT in business ecosystems. *Communications of the ACM*, *53*(5), 151.

Koslowski, T. G., Longstaff, P. H., Vidal, M., & Grob, T. (2012). Resilience Analysis of the ICT Ecosystem. In *23rd European Regional International Telecommunication Society conference; Vienna* (pp. 1–18).

KPMG. (2013). *Luxembourg Banks Insights 2013*. Luxembourg. Retrieved from http://www.kpmg.com/LU/en/IssuesAndInsights/Articlespublications/Pages/LuxembourgBanks-Insights2013.aspx

KPMG. (2014). *The Fintech Landscape in Luxembourg*. Luxembourg.

Labro, T. (2015, May 18). FinTech le coup va partir. *Wort*, p. 9. Luxembourg.

Li, F., & Whalley, J. (2002). Deconstruction Of The Telecommunications Industry : From Value Chains to Value Networks. *Telecommunications Policy*, *44*(9–10), 451–472.

Luxembourg for Business. (2013a). *Luxembourg's ICT and e-commerce environment 2013 (Q2 update)* (Vol. 2013). Luxembourg. Retrieved from www.investinluxembourg.lu/ict

Luxembourg for Business. (2013b). *Luxembourg & ICT: a snapshot*. Luxembourg.

Luxembourg for Business. (2013c). *LUXEMBOURG and ICT : a snapshot*. Luxembourg. Retrieved from http://ict.investinluxembourg.lu/ict/luxembourg-and-ict-a-snapshot

Luxembourg for Finance. (2015). *FinTech in Luxembourg*. *Luxembourg for Finance Magazine*. Luxembourg.

Maitland, C. F., Bauer, J. M., & Westerveld, R. (2002). The European market for mobile data: evolving value chains and industry structures. *Telecommunications Policy*, *26*(9–10), 485–504.

Marx, L. (2014, May 14). Ein teurer Nachmittag TVA-Richtlinie über Online Handel angenommen. *Tageblatt*, p. 12. Luxembourg.

Moore, J. F. (1993). Predators and Prey: A New Ecology of Competition. *Havard Business Review*, *May-June*, 75–86.

OECD. (2011). *OECD Guide to Measuring the Information Society 2011*. OECD Publishing.

OECD. (2015). *OECD Economic Surveys: Luxembourg 2015*. OECD Publishing, Paris.

Oestreicher, K., Walton, N., & Grove, H. (2012). *New Internet-Based Technology Ecosystems*. Worcester.

Partanen, J., & Möller, K. (2011). How to build a strategic network: A practitioner-oriented process model for the ICT sector. *Industrial Marketing Management*, *In Press,* 1–14.

Peppard, J., & Rylander, A. (2006). From Value Chain to Value Network : Insights for Mobile Operators From Value Chain to Value Network : Insights for Mobile Operators. *European Management Journal*, *24*(2).

Porter, M. E. (1990). Competitiveness: Challenging the Conventional Wisdom. *Harvard Business Review*, *68*(3), 190–192.

Poujol, V. (2014a, January 16). Archivage électronique : vote programmé au printemps. *Paperjam*.

Poujol, V. (2014b, July 21). Erreur de casting au Statec et à l'Uni ? *Paperjam*. Luxembourg.

PWC. (2011). *Luxembourg: an e-hub for Europe Opportunities and actions on the horizon 2015*. Luxembourg. Retrieved from http://www.pwc.lu/en/information-communication-technology/publications.jhtml

Quatraro, F. (2009). Martin Fransman: the new ICT ecosystem. Implications for Europe. *Journal of*

Evolutionary Economics, *20*(2), 321–328.

Rafique, K., Yuan, C., Tareen, A. W., Saeed, M., & Hafeez, A. (2012). Emerging ICT Ecosystem - from Value Chain to Value Ecosystem. In *8th International Conference on Computing Technology and Information Management (ICCM),* (pp. 95–100).

Raizer, T. (2015, July 3). L'archivage électronique 2.0 devient réalité. *Paperjam*. Luxembourg.

Service des Médias et des Communications. (2013). *Luxembourg & ICT - a snapshot*. Luxembourg. Retrieved from http://ict.investinluxembourg.lu/ict/luxembourg-and-ict-a-snapshot

Statec. (2014). *Dynamiques des entreprises du Luxembourg, compétitivité de la nation* (No. 118). Luxembourg.

STATEC. (2008). *NACELUX Rév. 2*. Luxembourg. Retrieved from http://www.statistiques.public.lu/catalogue-publications/nace/PDF-NACE-2.pdf

Sutherland, E. (2013). Independence and the regulatory state—Telecommunications in Scotland and the rest of the United Kingdom. *Telecommunications Policy*, *37*(11), 1046–1059.

Symeou, P. C. (2009). Does smallness affect the liberalisation of telecommunications? The case of Cyprus. *Telecommunications Policy*, *33*(3–4), 215–229.

Thibaut, F. (2015, March 26). Devenir le prochain hub Fintech. *Paperjam*. Luxembourg.

Veugelers, R. (2012). *New ICT sectors: Platforms for European Growth?*

World Economic Forum. (2015). *The Global Information Technology Report 2015*. (S. Dutta, T. Geiger, & B. Lanvin, Eds.). Geneva. Retrieved from www.weforum.org/gitr

Binsfeld, N. (2013).

The Luxembourgish Telecommunications Market.

Cahiers Scientifiques Revue Technique Luxembourgeoise, 1, 24–37.

Like many other European Union member states, the Luxembourgish telecommunications fixed network infrastructure was liberalised in 1998. While many aspects of this liberalisation are similar to those in other European Union member states, some aspects are very distinctive. The government has simultaneously sought to liberalise the small telecommunications market while protecting the wholly state owned incumbent. The incumbent has only recently been forced to provide a reference interconnection or unbundling offer, and has been allowed to build the country's only fibre-to-the-home network, given preferential access to publicly owned infrastructure and been permitted to extend and bundle together its services.

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Moreover, the state has created or participated in the creation of new companies that operate within the telecommunications market. High-speed fibre connectivity to international Internet peering hubs has been provided, and a commercially orientated local Internet exchange has been established. An alternative national high-speed network has been developed, and several data centres built to stimulate competition.

The incumbent operator is the dominant operator in Luxembourg. It dominates both the fixed and mobile markets, and is particularly dominant in the enterprise part of the market. Unsurprisingly, competitors have struggled in this market. Alternative fixed operators have found it difficult to gain access public infrastructures and have not been able to build out their own network infrastructure. A fourth and fifth third-generation (3G) mobile licence were awarded, but neither launched their services onto the marketplace. Similarly, a WiMax licence has been issued but services not launched. Cable networks can be found throughout the country and widely used, but deliver just TV services.

DSL-based broadband is available throughout Luxembourg, and ambitious plans for fibre-to-the-home (FTTH) are currently being rolled out. Extensive international connectivity exists that links Luxembourg to the main European peering hubs, with Luxembourg having the highest Tier IV datacentre density in the world. The country's financial services sector has attracted several international carriers to locate in Luxembourg.

The current nature of the market, that combines elements of state-ownership and entrenched operators with (domestic and foreign) investment and competition, raises questions in several areas. Firstly, how competitive is the market? Secondly, how has the extensive presence of the state in the market shaped its development? Thirdly, will Luxembourg be able to maintain its current international ICT competitiveness in the short and medium term? Fourthly, why have international operators invested (or not) in a market as small as Luxembourg?

This paper addresses these questions by establishing a timeline of political, technological, regulatory and competitive developments. It also provides a general overview of the current state of the market and identifies the main operators as well as the different institutions involved.

Literature review

Relatively little has been written about the Luxembourgish telecommunication market. Indeed, to the best of the author's knowledge, this paper represents the first attempt to provide a comprehensive review and evaluation of how the market has developed.

Some details on the historical development of the sector in Luxembourg, focussing on the legal aspects, is available in (Fayot & Funck 2012). This also provides an overview of the media sector as well as satellite communications because of the local presence of RTLGroup[1] and Société Européenne des Satéllites[2], these two aspects of the wider ICT ecosystem[3] will not be looked at further in the following.

In addition, there is a substantial amount of relevant research available on the state of development of ICT in Luxembourg and the role of ICT for innovation, E-commerce and the local financial industry. Thus, OECD has published a study on the sustainability of the financial sector as engine for growth for the Luxembourgish economy (Bourgain et al. 2009) in which they argue that Luxembourg might face serious difficulties unless it is able to maintain and expand its attractiveness of investing and working in Luxembourg and to adjust tax, housing but also infrastructures to attract foreign investments and future growth in ICT.

Some research has been conducted on the drivers for the implementation of an e-business strategy by firms located in Luxembourg (L. Martin 2008). The relevant ICT infrastructures and IT literacy have been identified as important drivers to this market. Similarly (Leduc & Poussing 2003), discuss the importance of ICT to facilitate the contact of the firms with external structures. In consequence, firms can create new opportunities by finding new partners in other countries.

Methodology

The broad approach adopted, of a country/region centred case study, is consistent with found in the literature, for example, case studies of Germany (Elixmann et al. 2003), Nepal (Jason Whalley 2006), the Netherlands (Rood & Te Velde 2003), the United Kingdom (Deshpande 2013), Scotland (S Howick & J Whalley 2007), (Tookey et al. 2006), rural areas (Galloway & Mochrie 2005) (Preston et al. 2007), developing countries e.g. Peru (Yamakawa et al. 2012), Poland (Grajek 2010).

Particularly relevant in this context, is a study about small economies in the case of Cyprus (Symeou 2009), as it discusses a country and economy of comparable size than Luxembourg. It argues that the success of liberalisation might be affected by the smallness of a country and therefore the evaluation of success of liberalisation based on industry concentration might be inapplicable. Liberalisation might not even be necessary but similar overall economic welfare might be achieved by regulators if they allow only a small number of market participants.

To achieve a review and evaluation of the situation in Luxembourg, the author draws on a range of secondary sources such as the annual reviews published by the Luxembourg regulator (see, for example, ILR, 2011a). In addition, data have been used from the statistical analysis of the market published by ILR (see, for instance, ILR, 2011b) as well as the implementation reports and digital scorecard of the European Union (EC, 2012; EU, 2011). The annual reports and websites of the different operators in the Luxembourg market were consulted.

In addition, relevant information from the Luxembourgish statistical office[4] (Statec) and Eurostat[5] has been included when relevant. In particular, a study about the importance of the "service industry" in Luxembourg and its evolution since 1960 (Gargano 2012), the size and activities of the financial sector (Michaux 2013) as well as a study about the use of ICT have been used (Airoldi 2012).

Furthermore, some information has been extracted from a commercially available country analysis report (Datamonitor 2010) as well as from some consultant reports about the attractiveness of Luxembourg (KPMG 2012b), (PWC 2011).

As the author is actively involved in the telecommunications industry, data from (unstructured) interviews with current and past actors have been undertaken and included in the analysis. Finally, some internal documents from the incumbent operator (Entreprise des Postes et Télécommunications – EPT) have been made available to the author as well.

Luxembourg and ICT

ICTs are well developed in Luxembourg. In 2013, about 92% of households own a personal computer and about 93% have some form of internet access. About 64% of the population is using mobile internet access (Airoldi 2012).

Year	2005	2006	2007	2008	2009	2010	2011	2012
HH with PC	75	77	80	83	88	90	92	92
HH with Internet Access	65	70	75	80	87	90	91	93
Broadband (DSL, Fibre, CATV)	52	63	77	76	82	78	75	73
Analogue/ISDN dial-up	51	36	26	24	20	30	27	22
DSL line	49	59	76	74	79	70	63	61

In 2012, amongst the enterprises with 10 or more employees, practically all (98%) have internet access, virtually all (95%) through a broadband access and many (54%) also through a mobile connexion (Statec 2012a). Three quarters of the enterprises have their own website. In terms of available IT structure in 2012:

_48% of the enterprises features an Intranet

_39% use an electronic group calendar

_32% have an extranet

_16% have videoconferencing facilities and among the enterprises using computers

_100% work with a wired local area network (LAN)

_43% have also a wireless local area network (WLAN)

Information technologies and e-commerce are a growth areas in Luxembourg. Luxembourg was the first European country to create a specific, clearly defined and secure legal framework for e-commerce and it also has the lowest standard VAT rate on such services within the EU (15%) and 3% on e-books. Theses attractive taxes together with good (see below) communication infrastructure has led several players in the gaming sector (online video games) and gambling sector to set up their headquarters in Luxembourg or even install their technology centres for the European area in Luxembourg[6]. This, is turn, has attracted low-latency Internet providers who expand their ICT location to Luxembourg (PWC 2011).

Global brands in the media and Internet world such as Amazon, eBay, iTunes, PayPal and Skype all have European headquarters or major operations in Luxembourg. However, the fiscal advantages mentioned above are due to disappear in 2015 in accordance to EU regulations (Fayot & Funck 2012).

The government encourages the establishment of new businesses (notably through 'Luxembourg for Business – proud to promote ICT[7]) and is keen to further develop the ICT sector in line with the major industry trends. Efforts are also being made in ICT research with a focus on security, reliability and trustworthiness of ICT systems and services[8].

The market after liberalisation

Size and Evolution

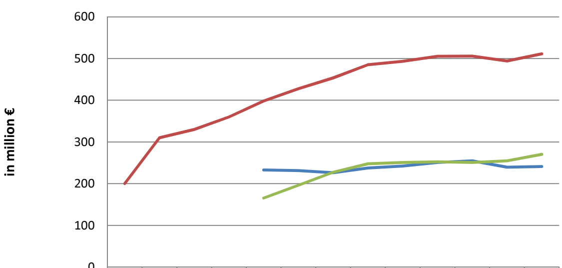
Starting in 2003, the regulator published an annual assessment of the telecommunications market. This chapter presents an overview of the most recent available figures (ILR 2011b) – further details can be found in (ILR 2004b), (ILR 2004c), (ILR 2005b), (ILR 2006b), (ILR 2007b), (ILR 2008c), (ILR 2009b) and (ILR 2010b) as well as in the digital agenda scoreboard published annually by the European Commission[9].

Revenues and fixed/mobile split

As figure 3 below shows, the market has grown considerably since 1999. This is largely due to several consecutive technological changes i.e. the upcoming of digital mobile networks (GSM, UMTS) as well as the wide-spread introduction of internet and broadband internet access in the early years of the 21st century and not necessarily a pure consequence of liberalisation. From 2007 onwards, the market is rather flat with a slight drop in 2009, 2010 because of economic crises.

Mobile revenues grew very quickly from 2000 to 2003 until saturation was reached with about 140% of population penetration. Because of the small size of the country and the high number of foreign workers, roaming charges constitute a substantial part of the mobile revenues. These revenues, however, have reached stagnation or even decline because of the price reductions imposed by European Commission. Overall since 2010, however, the mobile market volume exceeded the fixed one, mainly due to mobile (broadband) internet access.

Fixed revenues were flat over the whole period of analysis. However, when looking into the details it appears that revenues from fixed voice have decreased but revenues from leased lines and broadband internet access have been able to compensate for this decrease.

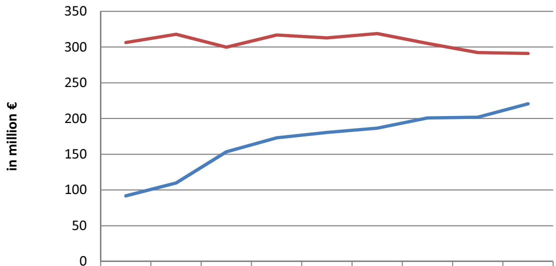


	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Market Size	200	310	330	360	398	427	454	485	493	506	506	494	511
Fixed					233	231	226	238	242	251	255	240	241
Mobile					165	196	228	248	251	252	251	255	270

Figure 1_ Market size and split fixed/mobile

Market share incumbent – alternative operators

At a first glance, alternative operators[10] appear to have developed very well since the liberalisation with a market share that more than doubled. On the other hand, EPTs revenues have been fairly stable over time with only a very slight decrease in the last few years. A more detailed assessment of the different market segments will be conducted below.



	2003	2004	2005	2006	2007	2008	2009	2010	2011
EPT	306	318	300	317	313	319	305	292	291
Alt. Ops.	92	110	153	173	180	187	201	202	221

Figure 2_ Market share incumbent versus alternative operators

Entreprise des Postes et Télécommunications – the incumbent

Created in 1842 as a public administration of Post and Telecommunications, EPT was converted into a 100% state owned enterprise in 1992. However 150 years of existence as a public administration have a left a deep impact in terms of structure and culture of the organisation and even in 2012 the company still hired new staff members as civil servants. In addition all of the top management roles are held by civil servants and the 8 board members are state representatives. The company is organised in 3 divisions of which telecommunications is by far the largest in terms of turnover (see figure 5 below).

Year	Development	Comments
1842	Creation of Public Post and Telecommunications Administration	
1992	Creation of "Entreprise des Postes et Télécommunications"	A 100% state owned enterprise
1993	Launch of LuxGSM – the first 2G mobile network	Replacing the old "Benelux" wide analogue system
1994	Launch of "integrated services digital network"	Migration of analogue fixed line to digital fixed line
1995	Launch of "Dial-up" internet access	
2001	Commercial launch of broadband internet access Launch of General Packet Radio Services	LuxDSL Mobile data access
2003	Launch of 3G UMTS network	
2005	Launch of "integral" first "triple-play" offer	
	Launch of Blackberry services	In cooperation with Vodafone
	Launch of Public WIFI hotspots	In major hotels and public places
2006	Teralink	International high speed fibre connectivity
2007	Inauguration of EBRC second data centre	
	Pilot Project for IP-TV	
2008	Commercial launch of IP-TV services	
2009	Participation in Lu-CIX	Commercial internet peering point
2010	Fourth Data centre opened	
	3D and HD TV services offered	
2011	Launch of Ultra-high bandwidth Internet access	Luxfibre
2012	5th Datacentre opened	
	First Cloud services	
	Full liberalisation of postal services	

Sources_ www.pt.lu accessed 23.2.2013, focus in the telecommunications activities, Author's interviews

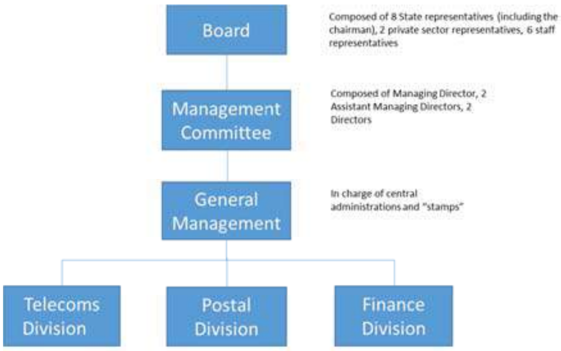


Figure 3_ EPT's high level organisational chart

Furthermore, the telecommunications division is the only profitable one as of today. The company is controlled by the Ministry of Economy and Foreign Trade. Its board is composed primarily by government and union representatives. The management team has to take all decisions unanimously and all strategic issues need to be confirmed by the board. All staff related decisions are therefore highly political and different stakeholder groups try to influence these via either the government or their union representatives

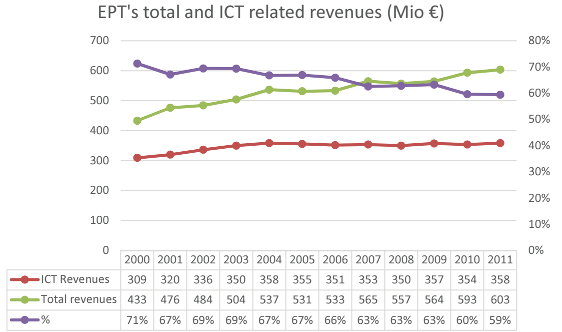
Company	Activities	Stake
Ebrc	Datacenter and Business Resilience Services	100%
P&T LUXGSM	Sales of Mobile and Fixed Communications	100%
P&T Consulting	Software Development	100%
Netcore[11]	ICT Integrator	100%
Luxembourg e-archiving	Electronic archiving services	100%
Victor Buck Services	Printing and Financial reporting	90%
Editus	White and yellow pages and databases	89,92%
Michel Greco	Express delivery of mail and small parcels	60%
Infomail	Distribution of advertising material	55%
Visual Online	Internet Service provider	51%
TNT Express	International express and courier services	50%
Hotcity	Public WLAN in major cities	49%
Eltrona	The country's largest CATV operator	34%
Regify	Secured Email	11%

In order to escape from some of these pressures, the company has followed since 1995 a diversification strategy based on acquisitions and has set up or acquired a number of independent subsidiaries in which it always tries to gain a majority stake. Altogether, EPT group employs about 3800 people which makes it the 5th largest employer in Luxembourg (Statec 2012b).

Over time, it became increasingly difficult to manage this diverse set of subsidiaries and a recent strategic analysis concluded that a consolidation leading to an integration of several of these subsidiaries would be advisable. This process is currently ongoing, but a lot of issues need to be addressed due to the widely different company cultures and organisational settings.

In addition, the regulator has requested, end of 2012, a functional separation between network infrastructure (and a whole sale offer for alternative operator) and the company's own sales organisation.

On the other hand, some of these subsidiaries have been very successful and contribute a substantial amount to the company's ICT related revenues e.g. ebrc about 30 Mio€, Netcore about 25 Mio€ which explains the substantial increase in telecommunications revenues shown in the chart below and the difference between the numbers reported to ILR.



	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
ICT Revenues	309	320	336	350	358	355	351	353	350	357	354	358
Total revenues	433	476	484	504	537	531	533	565	557	564	593	603
%	71%	67%	69%	69%	67%	67%	66%	63%	63%	63%	60%	59%

Figure 4_ EPT's revenues in Telecommunications

As the historical information above shows, the company has never been an early adopter of any new technological development. This is often explained by the lack of technical experience, competences and resources due to the small size of the organisation[12]. Indeed, EPT does not have an R&D nor a product development or innovation department. On the other hand, EPT has a strong reputation for good quality and high reliability and does want to risk this reputation due to unsuccessful introductions of new technologies.

The company, through their link to the Ministry of Economy, has been successful in influencing politicians to protect their market domination in fixed network, broadband access and international connectivity up until 2006 and has been charged by the Government to build the country's FTTH network in 2010 (SMC 2010a).

In terms of mobile market, initially EPT focussed on operating the network whereas the services were sold through several service providers. However, when products and services became more complex and quick lived, EPT gradually acquired all of these and integrated them into their P&T LuxGSM subsidiary.

According to recent study, the main issues that EPT is facing beginning of 2013 are:

_A complex structure which is preventing them from developing the complete value chain of ICT services in an efficient way using the synergies between their different subsidiaries.

_The high operating costs of their postal services in a fully liberalised market.

_An outdated business model for their banking services which is based on high interest rates.

A new CEO was brought in May 2012 by the Ministry of Economy, a new chairman has been nominated in January 2013 and the company is currently setting out a new strategy and organisational structure to actively address the issues mentioned above. However, due to the complex and sometimes political decision processes, getting this strategy into action might take a long time, time which competition is likely to use to strengthen their position in the quickly changing ICT market.

Government initiatives

The national regulatory authority – Institut Luxembourgeois de Régulation (ILR)

Initially set-up in 1997 as "Institut Luxembourgeois des Télécommunications" (ILR 2008a) with 2 members of staff from EPT and an externally recruited director, it developed in 2000 into a 50 persons administration in charge of regulating the telecommunications, electricity, gas, railways and postal sectors as well as coordinating the use of the rare radio frequency resources and protecting customers. ILR is not directly involved in defining telecommunications policies; its mission is to implement these as well as to implement the different EU directives related to the so-called "telecom packages".

Its first major task was a licence application process in 1998 for the second mobile operator which was organised with the help of external consultants as a "beauty contest" based on coverage, service offering and quality. This approach was repeated for all major licence application processes ever since as it was felt that it would not be appropriate to jeopardize the business cases of the candidates with huge up-front payments.

ILR then focussed on the liberalisation of the fixed networks by defining different categories of licences (now replaced by declarations) and forcing EPT to publish reference interconnection and later reference unbundling offers at more and more competitive prices over time.

Following EU regulations, number portability for fixed (in 2000) and mobile numbers (in 2005) was introduced and around that time ILR was also involved in the licence applications for the different 3G UMTS networks.

More recently ILR focussed on the development of broadband internet access again pushing the incumbent to develop a reference DSL offer and stimulating alternative access technologies like CATV networks or WiMax.

A lot of efforts were spent over time in radio frequency coordination processes. This activity is particularly complicated due to the small size of the country and its important needs for international satellite communication frequencies to be used by SES[13] and to a lesser extend RTL Group[14].

ILR has never been a very "aggressive" regulator and has rarely imposed its decisions. Instead, it always tried to negotiate compromise solutions that would be acceptable to all parties involved. The most visible evidence of this has been the split of the 4th UMTS licence in two "halves" in order for both candidates to be successful. Additionally, it has never been at the forefront of the European Liberalisation process. Instead it used its presence in the European Regulators Group and later the body of European Regulators for Electronic Communications[15] to follow closely the development in the surrounding countries and to avoid possible "mistakes" made by some of their regulators e.g. the action processes for 3G licences that lead to a difficult start for many of the successful bidders and often high prices for their customers.

Politically, ILR is controlled by a board of directors nominated by the Minister of Communications to ensure its independence from any of the operators.

Service des Médias et des Communications

The Service des Médias et des Communications[16] (SMC) also depends on the Minister of Communications, but contrary to ILR is in charge of defining and an promoting the policies decided by the Government in the areas of electronic communications, e-commerce, electronic security and media. Its main activities consist in promoting Luxembourg internationally, advising the Minister of Communications, supervising the local media landscape and representing the State in different national and international organisation and companies. Its members of staff are directly involved at board level of the main stakeholders e.g. EPT, LuxConnect, RTLGroup, SES etc. They represent Luxembourg on economic missions and try to promote Luxembourg as an international centre for media, audio-visual productions[17] and ICT[18]. They also supervise the media sector including its content[19].

In 2001 a first action plan, called eLuxembourg was put in place to promote the use of the internet and to move public administrations to all electronic communications with the general public. The result was the so-called "unique eSpace" to interact with most of the public administrations.

In 2004, SMC presented the national action plan[20] for broadband internet access (SMC 2009) in which the objective was to reach 95% of population (mainly with ADSL). This goal was achieved quickly and Luxembourg was one of the first OECD countries to reach 100% DSL coverage.

In 2005, the Government, together with several local banks and EPT set up Luxtrust, a local electronic signature system which has become the standard for local eCommerce and eBanking activities as well as for communicating with public administrations. Luxtrust[21] plays the role of the "certification authority" and delivers certificates on USB sticks or SIM cards.

In 2006, SMC was the driving force behind the creation of LuxConnect[22] and was actively involved in Luxembourg to become the first EU member to transpose the directive about eCommerce and electronic signatures.

In 2008, a specific legal framework was created to facilitate the management of intellectual property and internet domain names(SMC 2010b). Again Luxembourg was the first EU member state to offer an interesting fiscal environment for handling of domain names.

In 2009, SMC contributed to set up Lu-CIX – a commercial internet peering point to which all of the local operators quickly connected including EPT.

Over the years, SMC managed to attract several multinational or global ecommerce players such as Amazon.com, eBay, PayPal, iTunes, Skype and Vodafone Procurement Company to establish their EU base in Luxembourg. However, the most attractive incentive for these players ie the reduced VAT rate is going to disappear in accordance to EU rules in 2015.

LuxConnect

In 2004 and 2005, ILR assessed the situation in fixed network market focussing on the international and national high-bandwidth connectivity for commercial users. National operators were complaining that they were having troubles to get access to "rights of ways" and to existing trenches to install their fibre optical cables. International operators were often stopped at the national boarder and forced to use expensive leased lines from EPT to reach the main business areas in Luxembourg City. During international economic missions, the Government tried to promote Luxembourg's interesting tax situation to attract foreign investors. In particular E-commerce providers, who were forced by EC to have a base somewhere in the EU[23]. However, most of these initiatives failed because of technical reasons linked to missing international connectivity.

After some discussions with the Ministry of Economy and EPT, it was decided to set up a second 100% state owned operator with the mission:

_To develop a national dark fibre network and make this network available to the Telecom Operators so that they can build and enhance their footprint in Luxembourg,

_to operate a network that connects Luxembourg to the Amsterdam, Brussels, Frankfurt and Paris Internet exchanges while minimizing fibre distances and maximizing route and fibre diversity,

_to support the national ICT, media and e-business sectors by providing carrier-neutral, state-of-the-art Data Centre space.

LuxConnect does not define itself as a telecommunications operator and can probably be best described as a carrier's carrier. It provides "raw" datacentre capacity as well as dark fibre or high bandwidth connectivity using a cost-plus pricing scheme. The company provides its services only in a B2B environment under a strict wholesale model. Its customer base is made up exclusively of telecom operators, system integrators, hosting and SaaS companies, but no end-users. The services are offered in a strictly neutral and non-discriminatory way: identical pricing and support are provided to customers accessing the same product or service under matching conditions.

Operations started in 2009 with a first data centre and an international fibre optical network. Since then, the company has been very successful. They also have contributed to create a second and commercial national internet peering point called Lu-CIX[24] and facilitated the setup of a wholesale cloud service provider LuxCloud[25].

Considering all of the above, it is obvious that EPT missed the opportunity to play this role themselves and that the Government was forced to invest into two operators in order to really trigger competition.

Ultra-High Broadband Strategy

In 2010, ILR together with the Ministry of Economy and the Minister of Communications (SMC) presented a strategic document defining Luxembourg's future Broadband Strategy (SMC 2010a) claiming that both productivity and GDP growth would need ultra-high bandwidth connectivity for all households. Broadband connectivity was defined by the government as part of Universal Service and by 2020 every household should have access to 1Gbit/s upstream and 500 Mbit/s downstream capacity with the following roll-out targets:

_25% of population by 2013

_50% of population by 2015

_100% of population by 2020

_As an intermediate target by 2015 every household should have at least 100/50 Mbit/s

_Creation of ultra-high bandwidth business zones which would be connected by 2 independent networks in order to guarantee full redundancy

_Become one of the world-wide leaders in terms of broadband connectivity roll-out

_Achieve competitive pricing in line with EU standards

The Government, as their sole shareholder, asked EPT to invest about 180 million Euro until 2015 to start initial roll-out. It was agreed that EPT would install at least 4 fibres into each home and grant access to alternative carriers to one or several of these on a non-discriminatory basis. CATV operators were encouraged (but not supported financially) to develop their networks as an alternative, independent, and therefore redundant access to the 94% of the households in Luxembourg. Several additional measures were decided e.g. central database of network infrastructure[26], central database of civil works projects[27], compulsory in-house cabling for new buildings. LuxConnect was also asked to push the development of their national networks and in particular to connect to the main "business zones".

In addition, ILR was invited to proceed as quickly as possible with the frequency planning and licensing process for 4G LTE services and the Government promised to transpose the 2009 EU telecom package immediately into national law.

In 2012, Service des Médias et des Communications and the Ministry of Economy commissioned a study to review the (perhaps overambitious) broadband strategy announced in 2010 (BooZ&Co 2012). This study proposes a more active collaboration between EPT and the CATV with the aim to use existing CATV networks to offer broadband connectivity in the less densely populated areas in the North of the country. It is not clear yet how this should work in practice. On the other hand, EPT has calculated that with the current rate of investment the "Ultra High-Broadband" business case will not be profitable before the year 2035[28].

Technologies

International connectivity networks

Since 2005, various initiatives have been supported by the government to build multiple high capacity IRU fibre networks, connecting Luxembourg to the major hubs in Europe. Today, a number of international operators provide dark fibre or leased connectivity. Beside these operators, some global bandwidth operators as well as international carriers lease capacity into Luxembourg and are operating one or more PoPs (Point of Presence). Luxembourg is located in the middle of the so-called "Golden ring", which shapes the major Internet hubs of Europe: London, Amsterdam, Frankfurt and Paris.

Broadband connectivity by technology

According to a report prepared for the European Commission in the framework of EU's Digital Agenda (EU 2011) Luxembourg enjoys 100% coverage of standard ADSL broadband (up to 25 Mbps) and 99.6% coverage of HSPA (High Speed Packet Access – an upgraded version of 3G mobile networks providing mobile broadband at a maximum download speed of 21.1 Mbps). Its basic broadband needs are therefore well supplied.

The "Next Generation Access" (NGA) broadband coverage (using technologies which are needed to meet the EU's Digital Agenda 30Mbps objective) is also well above the EU average; ranking fourth among the 29 countries considered in the study (the 27 EU Member States, Iceland and Norway).

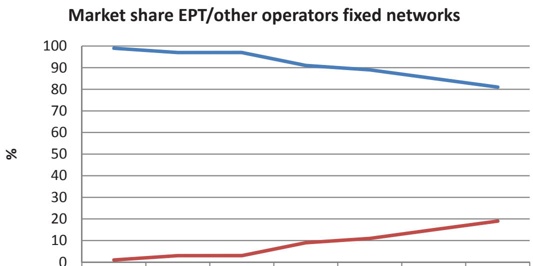
Luxembourg also has an extensive cable network, with about 95% of population coverage and 64% "internet" ready. This cable network is currently being upgraded to the so-called "DOCSIS 3" standard, meaning broadband access delivered over a fixed TV network using coaxial cable and providing download speeds of 30Mbps and above.

In terms of mobile networks, both alternative operators offer a commercial LTE product and EPT has announced that it intends to follow in May 2013.

Competition in fixed networks

Despite a total of 88 different operators, 37 networks and 240 service providers notified to ILR (ILR 2012), EPT remains by far the dominant player in fixed networks (voice & data).

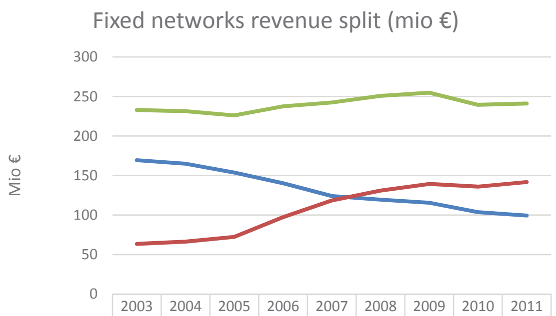
The regulatory measures during the last few years have encouraged broadband competition through local loop unbundling, yet the proportion of unbundled lines remains relatively low. There are few broadband subscribers on fibre networks but this is set to change as the country migrates to FTTH architecture. EPT has set aside €500 million (far more than the initially planned 180 millions) to build its NGN, an open access platform which should allow for effective competition though high wholesale access prices.



	2005	2006	2007	2008	2009	2010	2011
EPT	99	97	97	91	89	85	81
OAO	1	3	3	9	11	15	19

Figure 5_ Competition in fixed networks

In common with most other markets, revenue from the fixed line sector has been falling steadily. Indeed since 2005 income generated by mobile telecoms has by far exceeded that from of fixed lines, while revenue from the broadband sector has propped up total revenue.



	2003	2004	2005	2006	2007	2008	2009	2010	2011
Voice	169,4	165	153,7	140,2	124	119,5	115,5	103,7	99,3
Internet	63,4	66,3	72,4	97,3	118,4	130,9	139,3	135,9	141,7
Total	233	231	226	238	242	251	255	240	241

Figure 6_ Evolution of fixed networks revenues

The figure above shows that, as of 2007, alternative operators seem to catch up a bit and their market share, albeit below 20% is steadily growing. This is the year that Luxconnect went into operations providing alternative operators the underlying network infrastructure both on a national and international scene. This has allowed several local and international players to start offering services to enterprise customers. On the residential side however, Luxconnect is not an alternative and the recent state decision to allow EPT to build a national FTTH network is not stimulating competition in this segment.

Telindus Telecom

Telindus was created initially as an ICT integrator[29] by a private investor in cooperation with Arcelor-Mittal[30] in the 1980s. It became over time the country's largest ICT integrator with over 350 employees and a turnover of about 75 Mio Euro[31].

In 2006, after the death of the private investor, Belgacom acquired Telindus Belgium and Luxembourg in order to extend their value chain and to offer enterprise customers not only traditional connectivity and leased lines, but also LAN, Voice and IT infrastructures.

In 2011, using the infrastructures offered by LuxConnect, the Luxembourgish arm of the company changed its name into Telindus Telecom and became Belgacom's ICT full service provider for commercial customers in Luxembourg. It offers connectivity services, Infrastructure, Communication, Desktop and Software as a service as well as mobility services and has become EPT's main competitor in the attractive enterprise market.

Several other, smaller operators followed this example e.g. Telecom Luxembourg[32], BCE[33], Datacentre Luxembourg[34], Root[35], Orange Business Services[36]. They individually play a minor role in comparison to EPT and Telindus Telecom. However, it would appear that the Government's intention to stimulate competition has worked in this specific segment.

Artelis

Artelis was initially set up in 1999 under the brand name of Cegecom[37] by the local electricity company then called Cegedel (now Enovos[38]). The intention was to use the fibre optical cables in the high tension lines to offer services to enterprise customers. It quickly became clear however that these lines were not close enough to the end customers and certainly would not cover the main business centres. Therefore Artelis tried to developed local access and tested several technologies over time (Powerline, Wireless Local Loop and Microwaves) and acquired the country's only ever WLL operator Firstmark. After some unsuccessful experiences, they finally relied on EPT's reference unbundling offer and focussed on developing their own national fibre infrastructure.

At the time, the company considered itself as the main national competitor for EPT and even tried to enter the residential market with internet access and fixed voice services. They also intended to apply for the 2nd and 3rd mobile licences but gave up twice in the last minute. The issue was that the company's unique shareholder is also partially state-owned and that management had difficulties to get their strategies accepted by the board. This became even more visible when, the electricity market itself was liberalised and Cegedel had to focus on protecting their "home" market and core activities.

In 2006, the company merged with VSENet, a similar organisation in the German State of Sarre that they had already cooperated with for some time and rebranded on the name of Artelis[39] .The shareholders of Artelis are the energy-providers VSE AG (53.05%) and enovos International S.A. (36,95%), with the financial partner Saar LB in Saarbrücken (10%).

The focus moved towards providing high-speed data connectivity and carrier's carrier services to main business centres and SMEs in the greater Luxembourg region and the surrounding areas of Germany. Artelis therefore claims to be the only "international" operator based in Luxembourg. Their national roll-out plans have been adversely affected by the roll-out of LuxConnect's network and it took some time for them to agree on a co-ordination on the local level.

Luxembourg Online

Founded by two private investors in 1995 as an internet service provider, this company gradually emerged as the only independent local operator that is fully owned by private local investors. The company started by offering an internet portal (comparable to the then popular AOL, Compuserve etc.

In 1997, Luxembourg-Online (LOL) launched one of the first e-commerce platforms in Luxembourg.) and in 1999 the so-called free-internet dial-up access which is based on "call-termination revenues" from in-bound calls. This was very successful and took EPT by surprise. In 2001, it applied for a full voice "licence" and became the first operator to offer both free internet and free voice based on a flat-fee local loop bought in from EPT and Cegecom.

In 2003, LOL launched its broadband internet access again based on the "reference unbundling offer" from EPT as well as an internet access product over CAT networks as it had no own infrastructures. In 2004 it started to offer alternative voice products to the residential market with a limited success however. As a consequence, it moved to Voice/IP and became the country's first operator to offer such a service to its broadband internet access customers.

In 2006, LOL applied for the 4th UMTS licence but failed against Astralis[40]. It appealed and was awarded "a half-licence" in 2008. Indeed, the regulator, in order to avoid the necessity to take a decision, just split the available wireless spectrum in two halves. However, LOL never used their licence so far but instead established a mobile virtual operator based on resale of the services of Orange in 2007 branded LOL mobile.In 2007 as well it applied together with Broadcasting Center Europe[41] for a 3,5 GHz Wimax licence, which again, so far, did not go into operation.

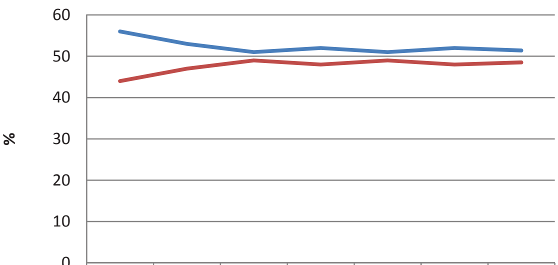
In 2011, LOL launched its own IPTV solution in competition with CATV operators, Tango and EPT but again with a marginal market penetration. Strangely in 2012, it created a joint venture with Eltrona (the country's largest CATV operator) to offer triple play services over CATV networks.

Overall, LOL has always been a very creative and dynamic operator which was successful in "shaking up" the market but never managed to really gain a substantial market share.

Competition in mobile networks

As shown in Figure 2 above the mobile market size exceeded the fixed market since 2005. Revenues have been relatively flat between 2005 and 2011 but have started to growth again since. This market is also dominated by EPT's LuxGSM mobile operations. They cover more 50% of the market with two alternative operators sharing the remaining 48%. This situation has been very stable over time, there has been a slight decrease when the 3rd mobile operator went into service in 2005 but the subsequent introduction of Mobile Number Portability has not led to noticeable change.

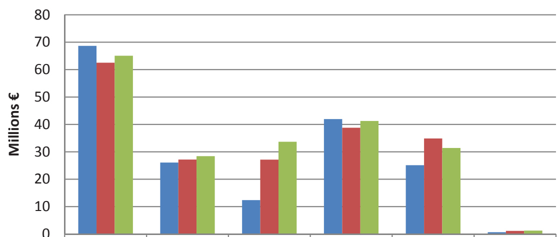
Market share EPT/other operators mobile networks



	2005	2006	2007	2008	2009	2010	2011
EPT	56	53	51	52	51	52	51,4
OAO	44	47	49	48	49	48	48,5

Figure 7_ Competition in mobile networks

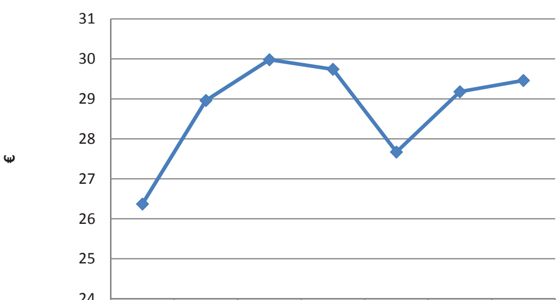
Due to the specificity of the Luxembourgish Labour market and the small size of the country roaming revenues are very important and all operators have been affected by the recent decisions of the EU commission to impose price caps on voice and data roaming.



	Nat. Voice	Int. Voice	Mob.Int.	Roaming	SMS	other
2009	68,67	26,08	12,38	41,95	25,12	0,66
2010	62,53	27,19	27,16	38,81	34,89	1,15
2011	65,06	28,41	33,68	41,27	31,41	1,27

Figure 8_ mobile revenue split

This together, with substantial reduction in Average revenue per user around 2009, due to economic crisis has led to a fairly flat evolution of mobile revenues. As of 2010 this effect has been compensated by the up-come of Smartphone and the subsequent increase in revenues for mobile data.



	2005	2006	2007	2008	2009	2010	2011
ARPU (€)	26,37	28,96	29,98	29,74	27,67	29,18	29,46

Figure 9_ monthly average revenue per mobile users

Two alternative operators are active on the market. In addition there are some Mobile Virtual Network Operators (MVNO), but these are merely generating revenues for their respective host networks.

Tango

Tango[42] has been active in the Luxembourg fixed voice and mobile market since 1989. During its first decade, when it was known as 3C Communications Luxembourg, the company attracted the interest of a number of investors (Banque Invik, Millicom International Cellular, Mach, Transcom, Transac and Tele2 Europe).

This group won the "beauty" contest (based on speed of roll-out and coverage) in 1997 and started operations in 1998 under the brand name of Tango. Success was immediate, the company's services and products won thousands of new clients a week during the launch phase. The GSM coverage network was extended and a fixed-line network created in parallel which was commercialised under the brand name of Tele2 Luxembourg.

The early 2000s, Tango was the first to launch UMTS, the first data (GPRS) network and the first WAP services. In 2005, the company launched the first bundled (fixed, ADSL and mobile) offers, followed in 2007 by the first HSPA "Mobile ADSL" network supporting 7.2 Mbit/s.

In 2008, Belgacom Group bought Tango from Tele2 Europe. The Tele2 Group has a tradition of acquiring mobile networks licences (mainly in Africa), developing and then selling these. They did so as well in Luxembourg after the death of its founder – who used to live in Luxembourg[43]. This was the first major commitment by a larger international operator in Luxembourg. Since then, Tango continued to invest into its network infrastructure and was the first operator in November 2012 to start a commercial LTE data service. They also launched around the same period of time an IP-TV service using EPTs and Artelis' unbundled DSL offer.

The company claims to have over 40% market share with about 270.000 mobile subscribers[44]. Being part of the Belgacom group, it co-operates actively with Telindus Telecom[45] to offer specific fixed/mobile bundles to corporate customers.

Orange

In 2003, the two (then) CEOs of Tango and together with several local investors decided to set-up a third mobile UMTS only operator called VOXmobile[46]. The licence was awarded quickly. Interestingly they also convinced EPT to act as an MVNO host in GSM so that they could start operations very rapidly. Again, the success was immediate mainly because of a strong marketing campaign and a life-time without subscription offer. However, the company experienced problems with the availability of 3G devices up to the point that most customers were using 2G which drained a big part of the revenues to EPT as the MVNO host.

Consequently, the company took in 2005 the decision to also launch a 2G network which had a major negative impact on their business case so that additional money was needed. In 2007, this was provided by Orange through Mobistar (its Belgium mobile arm) that took a 90% stake in the company. In 2008, the remaining 10% were also acquired and beginning of 2009, the company changed its brand into Orange. In autumn 2012, the company launched its 4G network. The company remains today the smallest of the 3 mobile operators with about 100.000 subscribers (claimed).

Additional licences available

In line with EU requirements, ILR has advertised a 4th mobile 2/3G licence in 2006. Two national candidates applied. The first was a joint venture between Artelis[47] and SES[48] and the second a local independently owned internet access provider called Luxembourg Online (LOL)[49]. After some legal and procedural discussions, ILR finally decided to split the licence in two and award each half to one of the competitors. Interestingly, since then none of the two candidates actually went live.

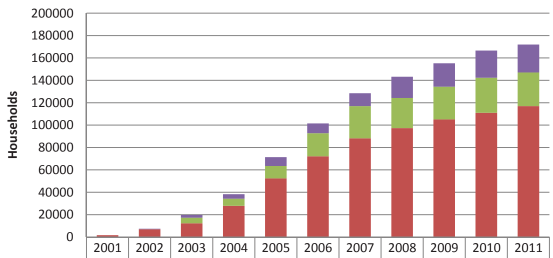
In 2007, a WIMAX licence in the 3.5 GHz was advertised and awarded to a joint venture consisting again of Luxembourg Online and Broadcasting Center Europe[50]. Again, this project, so far, did not go into operation.

All existing operators had to renew their licences recently and in this process they all were allowed to also operate 4G LTE services. By doing so, ILR avoided long and complicated procedures and prevented potential new entrants to enter the market.

Competition in (broadband) internet access

In terms of broadband access, the market currently is dominated by XDSL technologies based on EPT's network infrastructure. Alternative operators do have not invested in their own network infrastructure and are therefore forced to use either EPT's Reference Unbundling Offer (RUO) or to find some agreement with cable network operators.

Since 2010, EPT has also started to offer the so called "Luxfibre" FTTH access instead of XDSL. They do so in offering attractive packages with IP-TV and mobile voice and internet included which makes it nearly impossible for alternative operators to compete. FTTH penetration has not yet been officially communicated by ILR but EPT recently claimed to have 10.000 households connected.



	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
CATV	0	400	2500	4081	7956	8710	11531	18972	20958	24233	25000
DSL Other	0	0	5000	6336	11065	20614	28747	26920	29244	31346	30000
DSL EPT	1700	7000	12281	27906	52402	72170	88235	97326	105069	110999	117000

Figure 10_ Competition in Internet Access

For commercial customers Luxconnect does offer an alternative network infrastructure, for residential users, however, the only alternative could consist in using the cable TV networks as an alternative access technology.

CATV – a fragmented market

Due to its small size, Luxembourg did not have an own local TV channel until in the 1990s. Instead, viewers tried to receive the TV channels from France, Germany and Belgium which sometimes was only possible in the border areas. Consequently, local communities decided to build a common TV reception head-end on a suitable hill and distribute the signals to the different « members ». Over 120 of these head-ends appeared in the 1970s before some commercial operators saw the opportunity and invested in larger networks.

This eventually led to a very fragmented market and a large number of independent operators with networks of sometimes less than 100 households connected. ILR has tried, together with the association of cable network operators[51], to stimulate co-operation amongst these. Three commercial operators i.e. Eltrona[52], Siemens and Coditel[53] started in the early 2000s to consolidate and to offer services from a single but more professionally equipped head-end. This process was adversely affected by limited availability of fibre optical cables necessary to set up a suitable back-bone network.

When DOCSIS 2.0 and DOCSIS 3.0 standards for data communication over CATV became widely available, most of the local cable networks were not technically able to allow bi-directional communications and heavy investments were needed which most of the smaller organisations could not afford. In addition, in 2005, digital TV was coming up which also required huge investments in new receiving and decoding equipment. Furthermore, the broadcasters could encrypt their signals and it became necessary to pay author's rights and transmission fees. All of these events have caused Siemens to stop their operations and sell them to Eltrona and for many small organisations to do the same. Consequently, a major consolidation is currently taking place with Eltrona reaching about 110000 households and Coditel now called Numéricable another 25.000, leaving about a third of the households to small independent operators or relying on other means to watch TV.

In 2008, EPT started to compete in this market (despite their 34% stake in the country's largest CATV operator) and this pushed the cable operators to finally also develop aggressively their own broadband access and triple play offers as well as High Definition TV. As can be seen in figure 13 however, they still only play a minor role[54] in terms of broadband internet access.

Discussion

How competitive is the market?

By looking at the developments above, it follows that Luxembourg has not been amongst "early adopters" of liberalisation. The approach taken was rather the one of an "informed follower". This may partially be due to the small size[55] of the country and its telecommunications market leading to limited competitive pressures and relatively low interest from larger international carriers to set up operations in Luxembourg. It is certainly also due to the political intention to protect the incumbent, who, with over 3800 employees, is one of the largest employers in the country, representing an important reservoir of "voters" and pays a considerable amount of taxes. In addition, the regulatory body was created from scratch, with very limited resources and little experience, at least initially.

The incumbent itself, who is still today 100% state-owned and fully integrated with Postal and Banking services, did not push for innovations, new technologies or services. They tended to look around and follow the developments of the neighbouring countries and their incumbent operators and then to "mimic" their behaviours. Therefore, mobile data, broadband access to the internet and more recently LTE or cloud services were usually only introduced with a 12 to 18 months delay to the surrounding countries. It is fair to say, that their small size and therefore their limited experience sometimes also prevented them to move ahead quicker[56].

In the early days of liberalization, some national players e.g. utilities or media organisations also took the chance to diversify their activities focussing purely on the local market. Thus organisations active in energy distribution (electricity, gas), media or local communities acquired telecommunications licences. However, two factors affected negatively the development of the sector at the time. Firstly, the internet bust (Fransman 2001) forced some of the operators to focus on their core activities and home markets and made them either to put on hold activities in Luxembourg or to leave the country completely. Secondly, many of the alternative operators faced day-to-day problems to get access to public infrastructures to build their own infrastructures. Several of the administrations (roads, railways, local communes) were not aware and not accepting the fact that the market had been liberalised and "naturally" continued to inform just their former "colleagues" from EPT about planned civil and infrastructural works. It took several years, to overcome this "cultural" barrier and finally the creation of LuxConnect to overcome this hurdle.

However, the incumbent is still dominating partially or completely most market segments and in that sense, liberalisation does not appear to have been very successful. EPT still holds about 50% of all mobile customers, about 90% of internet and broadband internet access customers and about the same amount of fixed voice customers. ICT revenues of EPT are flat, those of competition are growing steadily but still far lower than those of EPT.

On the mobile side, the country still does only have 3 active operators (EPT, Tango and Orange) whilst 4 GSM and 5 UMTS licences have been awarded. LTE was started recently and it appeared again that EPT was lacking behind their competitors.

No broadband fixed wireless network infrastructure exists despite the fact that a WIMAX licence has been awarded in 2010.

How have the government initiatives shaped the market?

Since 2004, the development of the ICT sector in Luxembourg became a focus of the Government and in particular the Minister of Communications. International consultants were hired to assess the state of play; discussions with Alternative Operators, CATV[57] operators and the representatives of the ICT[58] industry were actively sought for.

In 2005, it turned out that, whilst the mobile market was working on a competitive basis, the fixed marked was still largely dominated by the incumbent. In particular, international broadband connectivity and access to the main internet peering points was a big issue. The Government first increased pressure on EPT but soon took the completely unexpected decision to create a second "state-owned" operator to stimulate competition and LuxConnect was created in 2006[59].

This has stimulated competition in terms of network infrastructures and datacentre capacity and has allowed several national and international players to offer services to enterprises. It has also attracted many international e-commerce and gaming providers to establish technical infrastructures in Luxembourg, to generate substantial tax incomes and to create jobs in the ICT sector which currently generated about 8% of the country's GDP.

In 2010, Luxembourg defined ambitious goals for developing its "ultra-high bandwidth[60]" (SMC 2009), (SMC 2010a) infrastructure and asked EPT to build a nationwide FTTH network. In 2012, it became clear that the given objectives could not be achieved and an alternative plan is currently sought in particular for the northern part of the country in which the population density is lower.

According to OECD (Greenstein & Mcdevitt 2012), when considering the per capita broadband bonus in quality-adjusted terms (i.e. simultaneously experiencing large improvements in broadband quality and declining real prices), Luxembourg, Switzerland and the Netherlands have done remarkably well over the past half-decade.

Overall, the market has grown considerably since 1997 both in terms of absolute values and in terms of market participants. Luxembourg is well connected to the main international internet hubs, is able to offer broadband access to 100% of its population, has high quality data centre capacity and is about to roll-out next generation networks, LTE and Fibre to the Home. Internet usage and computer literacy are high and there is a substantial ICT home market stimulated by the needs of the financial sector.

Are international operators interested in the Luxembourgish market?

Some of the larger international or even global operators have always been interested in Luxembourg because of their own global customers who often do have a subsidiary or a local operation in Luxembourg (so-called B-end customers). Even before telecommunications liberalisation, BT for example, was already present with a small local sales office relying on infrastructures by EPT.

During the initial phase of liberalisation i.e. from 1998 to 2001, many international players showed interest in developing activities in Luxembourg and about 20 licences for fixed network services were awarded in 1999 alone (ILR 1999). Thus, Global One (a JV between Deutsche Telekom and France Telecom), GTS, Level3, Worldcom, KPN and GTS set up local operations and some like Worldcom and GTS even invested in a local Point-of-Presence.

The "internet bust" in 2001 forced most of these operators to focus on their home market and so they gave up their local presence. Only Worldcom, which later became Verizon, stayed with their local datacentre offering hosting and disaster recovery services to financial institutions mainly.

When LuxConnect started operations in 2009, some of these operators returned and thus currently KPN, Level3, Verizon, BT, AT&T, Colt, Cable&Wireless, Cogent, Interoute, Telefonica, T-Systems all have small sales offices in Luxembourg. Still only Verizon has its own datacentre and own fibre connectivity from and to Luxembourg. The overall market share of these operators is fairly limited and mostly based on (value added) services like global VPN, global managed voice, which are not regulated and therefore not included in the statistics above[61].

In 2006 Belgacom showed interest in the local market and started to invest in Telindus, they later acquired Tango, the country's second mobile operator and in 2011 transformed Telindus into Telindus Telecom to become a major alternative operator for professional customers. Tango (just as Belgacom) cooperates with Vodafone in terms of product development and international roaming packages.

In 2010 France Télécom, who had made several attempts to enter Luxembourg before, acquired the country's third mobile operator through its Belgium Mobistar subsidiary. Rebranded into Orange in 2011 they play a major role in the local market and also offer services to professional customers through Orange Business Services.

Both operators have deployed their own mobile network infrastructure but are relying on Luxconnect for professional fixed network customers and EPT for residential customers. Both operators use their parent companies to offer attractive international packages for voice and date roaming.

Will Luxembourg be able to sustain its international ICT competitiveness in short and medium term

International ICT competitiveness is often measured with composite indices. For example, in its Global Information Technology Report 2013, the World Economic Forum defines the so-called network readiness index which is "composed of a mixture of quantitative and survey data" and allows a "measuring of the degree to which economies across the world leverage ICT for enhanced competitiveness" (Dutta & Lanvin 2013). Many writers build on these and other indicators e.g. from International Telecommunications Union (ITU 2012), OECD (Koski & Majumdar 2000) or national sources. An overview and discussion of the different indicators can be found in e.g. (Mahan 2007).

Following this approach, Luxembourg has been performing well in recent years on many of these indicators and it can be argued therefore that the interventions discussed above have been successful in increasing Luxembourg's international ICT competiveness.

The central element of the state intervention has been the creation of LuxConnect as a 100% state-owned and therefore the Government is stimulating competition by competing with itself. Can this situation be sustained given the difficulties the Luxembourgish economy, as well as most European Economies, is facing now and which is leading to substantial state budget deficits?[62] How then to make sure that LuxConnect is not simply integrated or taken-over by EPT?

Due to the same budget limitations, the extremely ambitious ultra-high bandwidth plan can't be implemented as planned, at least not in the northern regions of the country where population density is low. EPT is not able, nor interested, to finance the roll-out of the FTTH in these areas. Even in the southern part of the country, take up of FTTH is fairly restricted; about 10.000 customers have migrated yet. The question is: do residential customers need a connectivity of 1 Gbit/s? What is the killer-application? CATV networks might constitute a viable alternative, but currently only about 10% of households use their internet offer and the market is still very fragmented especially in the Northern part of the country. What is more, EPT is competing with CATV operators by offering IP-TV as part of triple or quadruple-play packages.

In addition, the focus of EPT on high quality, high reliability TierIV datacentres has led to an overcapacity in this specific segment and consequently some of the recently built infrastructures are not used. Nevertheless, there is a political pressure on LuxConnect to also get their datacentres TierIV certified[63]. The development of cloud services has changed the market and customers are looking for simpler, less redundant infrastructures that they can replicate in different places or even outsource completely into a public cloud infrastructure.

Moreover, EPT, as the largest player in the market, is facing substantial structural and organisational problems. These are mainly linked to their postal and banking services e.g. the postal market has been completely liberalised on the 1.1.2013. These problems are likely to attract management and political attention and drain financial resources which will be badly needed to stay competitive in the ever changing ICT market.

Finally, a crucial question remains: will international eCommerce operators stay in Luxembourg once the fiscal incentives will be reduced and if so, what can Luxembourg do to compensate this effect.

Conclusions and further work

Looking at the above it can be concluded that the market has only seen a very limited liberalisation. EPT is still the dominant player on many fronts. However, the market has grown substantially, Luxembourg has a good ICT infrastructure, good international connectivity and substantial datacentre capacity. Local customers are presented with attractive triple and quadruple play offers, nationwide XDSL and 3G availability. Luxembourg is well positioned on many of the international ICT indices and enjoys a good international ICT competitiveness.

In that sense, the Luxembourgish situation seems to confirm previous findings from e.g. Cyprus in that liberalisation is not necessarily the right answer for small economies.

However, all of this has been achieved by massive state intervention on the supply side and huge investments in order to create a network "duopoly" in which the state competes with itself. Will this be sustainable on the long run and how can it be financed? These are questions that need further attention and research.

The main intention of this study was to present a snap shot of the current situation in Luxembourg and the historical evolution that led to it. It clearly has important limitations in that it is nearly exclusively based on secondary courses and only a very limited number of largely unstructured interviews with the main stakeholders have been conducted so far. A more in-depth approach with a structured interviews with representatives from the different categories of stakeholders (EPT, Regulator, Ministry, Alternative Operators) will been needed to gain a deeper understanding. A more rigorous and structure analysis of the critical success factors for future sustainability of the current achievements should be conducted as well as detailed comparison and discussion of the different secondary sources.

Finally, the analysis could be supplemented by a detailed comparison of Luxembourg's position and its evolution with regard to the different ICT indices, a discussion of the validity of their underlying sources.

Appendix – A timeline of major milestones since liberalisation

Year	*Development*	*Comments*
Before 1990s	Telecommunications Services were provided as state monopolies. Some countries e.g. US and UK were liberalising parts of their markets allowing a limited number of competitors	
1987	European Commission publishes its Green Paper to initiate liberalisation reforms all over Europe	Initial goal was the creation of a common market for services and equipment
1990	EC Directive 90/388 requesting member states to open up telecommunications services for competition	Separation of operator and regulator became necessary
1992	Entreprise des Postes et Télécommunications (EPT) is created[64]	Change from public administration to a 100% state owned company
1992	Ministry of Communications is created	Takes over regulatory activities from former P&T administration
1992	Luxembourg gets connected to the internet	Internet access for schools, teachers and some government agencies[65]
1993	Launch of LUXGSM, EPT's mobile 2G network	Replacement of existing BENELUX analogue network
1995	Launch of "dial-up" internet services by EPT	Internet access becomes available to the general public
1997	Luxembourgish law on liberalisation of telecommunications	Defines universal service, rules of competition and interconnection, creates independent regulator
1997	Creation of "Institut Luxembourgeois des Télécommunications" later "Institut Luxembourgeois de Régulation (ILR)"	Takes over regulatory work from "Ministry of Communications" – which is disbanded[66]
1997	Second mobile licence awarded to Millicom SA[67]	Beauty contest approach
May 1998	Second mobile operator starts operations under the brand name of "Tango"	
July 1998	Fixed network market officially "liberalised"	All procedures in place in December only
1999	"Dot.com" boom – 19 licences awarded to alternative operators	
2000	Introduction of new numbering plan, first Reference Unbundling offer, trials with Wireless Local Loop and "Powerline" technologies[68]	
2001	"Dot.com" bust – consolidation and drop-outs	No new operators, year of stagnation
2002	3 Mobile licences for 3G networks awarded to EPT, Tango and Orange First Internet access over CableTV	No candidate for the 4th available licence
2003	4th Mobile 3G licence awarded to Luxcommunications SA Broadband Internet access via ADSL by EPT became saw great success First "official" statistics about the local telecommunications market became available	Later called Voxmobile
2004	Orange returns its 3G licence, VoxMobile was awarded a 2G licence, many specific service providers appeared	
2005	New regulatory framework was put in place transposing the new EU set of directives	
2006	Second state owned operator "LuxConnect"[69] was created, EPT started to build Teralink[70] its own international backbone network EPT acquires 100% of European Business Recovery Center The fourth 3G licence was split into two and awarded to Luxembourg Online[71] and Astralis a joint venture between SES and Artelis[72] The city of Luxembourg and EPT launched a city-wide WLAN network[73] Belgacom enters Luxembourg market by acquiring the country's largest ICT integrator Telindus[74]	It was hoped that this would stimulate competition, major investments in international connectivity and data centres were made
2007	Mobistar, the Belgium arm of Orange acquired Voxmobile	First time that a global operator committed to major investments in Luxembourg
2008	Belgacom acquires Tango EPT also invests into ICT integration business	Belgacom now present in fixed and mobile market
2009	LuxConnect opens its first datacentre and international back-bone network LU-CIX, a privately owned internet peering point established[75] EPT started to invest into Next Generation Network (NGN) and fibre to the home (FTTH) technologies	Soon to be merged with Restena
2010	Ultra-high broadband access strategy published LuxConnect opened second data centre and developed LuxCloud to start offering cloud services EPT opened its 3rd and 4th datacentre	EPT is charged with execution
2011	New EU "telecom package" transposed into Luxembourgish law EPT started to commercialise LuxFibre up to 100 Mbit/s Telindus (Belgacom) converted into a telecommunications operator	
2012	Orange and Tango start offering LTE 4G services Ministry announces its intention to build a TETRA network and publishes a call for a public-private partnership. EPT opens its 5th datacentre LuxConnect opens its 3rd datacentre	
2013	Telindus Telecom and EPT respond to the call of PPP for the Tetra Network EPT launches its 4G LTE network in May Ultra High Broadband Strategy is revised and potentially adapted	

Sources: (EC 1987), (EC 1990),(ILR 1997; ILR 1998; ILR 1999; ILR 2000; ILR 2001; ILR 2002; ILR 2003; ILR 2004a; ILR 2005a; ILR 2006a; ILR 2007a; ILR 2008b; ILR 2009a; ILR 2010a; ILR 2011a; ILR 2008a), (SMC 2010a), Author's interviews

1_ A pan-European media company, part of the German Bertelsman Group www.rtlgroup.com accessed 11.5.2013

2_ One of the world's largest satellite operators www.ses.com accessed 11.5.2013

3_ For the definition of the ICT ecosystem see e.g. (Fransman 2007)

4_ http://www.statistiques.public.lu/fr/acteurs/statec/index.html accessed 11.5.2013

5_ http://epp.eurostat.ec.europa.eu/portal/page/portal/eurostat/home/ accessed 11.5.2013

6_ Including OnLive Inc (which implemented a cloud gaming platform and chose Luxembourg to locate all its servers for the European distribution of its services), Big Fish Games, Agapier, Bigpoint, Kabam-Europe, Nexon Europe Sàrl and Innova.

7_ See http://ict.investinluxembourg.lu/ accessed 13.4.2013

8_ See http://wwwen.uni.lu/snt accessed 13.4.2013

9_ See http://ec.europa.eu/digital-agenda/en/scoreboard accessed 24.02.2012 and http://ec.europa.eu/information_society/policy/ecomm/library/communications_reports/index_en.htm accessed 24.2.2012

10_ Fixed and mobile together see http://www.ilr.public.lu/communications_electroniques/registrepublic/index.htm accessed 20.4.2013

11_ One of the authors is currently CEO of this organisation

12_ Author's interviews with representatives from EPT's middle management

13_ The world largest satellite operator who has its headquarter in Luxembourg, for more information see www.se

14_ See http://www.rtlgroup.com/www/htm/home.aspx accessed 9.3.2013

15_ See berec.europa.eu accessed 9.3.2013

16_ See http://www.mediacom.public.lu/ accessed 9.3.2013

17_ See http://en.filmfund.lu/ accessd 9.3.2013

18_ See http://ict.investinluxembourg.lu/ict/ accessed 9.3.2013

19_ See http://www.mediacom.public.lu/institutions/Institutions_nationales/cnp/index.html accessed 9.3.2013

20_ As required by EU's i2010 initiative

21_ See www.luxtrust.lu accessed 9.3.2013

22_ See www.luxconnect.lu accessed 11.5.2013

23_ Author's interviews with the CEO of LuxConnect

24_ See www.lu-cix.lu accessed on the 3.3.2013

25_ See www.LuxCloud.lu accessed on the 3.3.2013

26_ Which does still not exist as of today

27_ This does exist but is not updated regularly

28_ Internal report

29_ John Cordier, see a short bio in French on http://www.lalibre.be/economie/actualite/article/50111/telindus-orphelin-dejohn-cordier.html accessed 20.4.2013

30_ The world's largest steel producer – then called "ARBED"

31_ Author's interview with the CEO and CTO of Telindus and http://www.paperjam.lu/communique-de-presse/fr/croissancecontinue-confirmee-pour-telindus-telecom accessed 20.4.2013

32_ www.telecomluxembourg.com accessed on the 3.3.2013

33_ www.bce.lu accessed on the 3.3.2013

34_ www.datacentreluxembourg.com accessed on the 3.3.2013

35_ www.root.lu accessed on the 3.3.2013

36_ www.orange.lu accessed on the 3.3.2013

37_ www.cegecom.lu accessed on the 3.3.2013

38_ www.enovos.lu accessed on the 3.3.2013

39_ www.artelis.lu accessed on the 3.3.2013

40_ See section about Artelis

41_ See www.bce.lu accessed on the 8.3.2013

42_ www.tango.lu accessed on the 3.3.2013

43_ Jan Stenbeck see http://www.businessweek.com/stories/2001-06-10/jan-stenbeck accessed 20.4.2013

44_ See http://www.paperjam.lu/article/fr/tango-65-de-mieux-en-2012 accessed 20.4.2013

45_ www.telindus.lu accessed 11.5.2013

46_ See http://www.orange.lu/a-propos-de-nous/index.html accessed 3.3.2013

47_ A telecommunications subsidiairy of the local electricity board www.artelis.lu accessed 11.5.2013

48_ The satellite Operator www.ses.com accessed 11.5.2013

49_ See www.bce.lu accessed on the 8.3.2013

50_ www.aac.ul accesses 11.5.2013

52_ www.eltrona.lu accessed on 3.3.2013

53_ www.numericable.lu accessed on the 3.3.2013

54_ Source: interviews with Chairman and Board members of CATV operators' association

55_ For a broader Discussion about Smallness see (Symeou 2009).

56_ Sources author's interviews

57_ See www.aac.lu accessed 2.3.2013

58_ See www.ictluxembourg.lu accessed 2.3.2013

59_ See www.LuxConnect.lu accessed 2.3.2013

60_ 100 Mbit/s to every household

61_ For a full list see http://www.ilr.public.lu/communications_electroniques/registrepublic/index.html accessed on the 3.3.2013

62_ Interview of CEO of LuxConnect

63_ Discussions with CTO of LuxConnect

64_ For further historical information about EPT see http://www.pt.lu/portal/lang/en/Entreprise/about-us/pid/76 accessed 16.2.2013

65_ See www.restena.lu accessed 16.2.2013

66_ There is however until today a "Minister in charge of Communications" and a Service des Médias et de la Communication

67_ See www.millicom.lu accessed 16.2.2013

68_ For a comparison between different access technologies see (Fornefeld et al. 2008)

69_ www.LuxConnect.lu accessed 16.2.2013

70_ www.teralink.lu accessed 16.2.2013

71_ www.internet.lu accessed 16.2.2013

72_ www.artelis.lu accessed 16.2.2013

73_ See www.hotcity.lu accessed 16.2.2013

74_ www.telindus.lu accessed 16.2.2013

75_ See www.lu-cix.lu accessed 16.2.2013

References

Airoldi, M.-J., 2012. Le comportement des Luxembourgeois face aux nouvelles technologies de l'information et la communication depuis le début des années 60. , p.4. Available at: www.statec.public.lu.

Ben Aoun, L. & Dubrochard, A., 2010. TIC, innovation et effets perçus dans les entreprises luxembourgeoises. , (28375), p.28. Available at: http://mpra.ub.uni-muenchen.de/28375/.

Bauer, J.M., 2010. Learning from each other: promises and pitfalls of benchmarking in communications policy. Info, 12(6), pp.8–20. Available at: http://www.emeraldinsight.com/10.1108/14636691011086017 [Accessed November 8, 2012].

BooZ&Co, 2012. National Strategy for Very High Speed Networks, Luxembourg.

Bourgain, A., Pieretti, P. & Høj, J., 2009. Can the Financial Sector continue to be the Main Growth Engine in Luxembourg ? , (660), p.32. Available at: www.oecd.org.

Cave, M. & Martin, I., 2010. Motives and means for public investment in nationwide next generation networks. Telecommunications Policy, 34(9), pp.505–512. Available at: http://linkinghub.elsevier.com/retrieve/pii/S0308596110000807 [Accessed October 11, 2012].

Cave, M., Prosperetti, L. & Doyle, C., 2006. Where are we going? Technologies, markets and long-range public policy issues in European communications. Information Economics and Policy, 18(3), pp.242–255. Available at: http://linkinghub.elsevier.com/retrieve/pii/S0167624506000357 [Accessed October 25, 2012].

Curwen, P. & Whalley, Jason, 2011. Mobile telecommunications gives birth to a fourth generation: an analysis of technological, licensing and strategic implications. Info, 13(4), pp.42–60. Available at: http://www.emeraldinsight.com/10.1108/14636691111146145 [Accessed November 2, 2012].

Datamonitor, 2010. Luxembourg Country Analysis Report - In-Depth PESTLE Insights. , pp.11–27.

Deshpande, A., 2013. Broadband deployment and the bandwagon effect in the UK. Info, 15(1).

Dutta, S. & Lanvin, B., 2013. The Global Information Technology Report 2013 Growth and Jobs in a Hyperconnected World,

EC, 1990. Directive on competition in the markets for telecommunications services. , p.7. Available at: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:1990:192:0010:0016:EN:PDF.

EC, 1987. Towards a dynamic European Economy Green Paper on the Development of the Common Market for Telecommunications Services and Equipment. , (June), p.256. Available at: http://ec.europa.eu/green-papers/pdf/green_paper_telecom_services__common_market_com_87_290.pdf.

Elixmann, D., Schwab, R. & Stappen, C., 2003. Development of the telecommunications market in Germany since liberalisation. Info, 5(1), pp.41–51. Available at: http://www.emeraldinsight.com/10.1108/14636690310473881 [Accessed November 12, 2012].

EU, 2011. Broadband coverage in Europe in 2011, Brussels. Available at: http://ec.europa.eu/digital-agenda/.

Fayot, F. & Funck, L., 2012. Luxembourg's TMT Sector. The Technology Media and Telecommunications Review.

Fornefeld, M., Delaunay, G. & Dieter, E., 2008. The Impact of Broadband on Growth and Productivity, Brussels. Available at: http://ec.europa.eu/information_society/eeurope/i2010/docs/benchmarking/broadband_impact_2008.pdf.

Fransman, M., 2001. Evolution of the Telecommunications Industry into the Internet Age. Communications & Strategies, (43), pp.57–113.

Fransman, M., 2007. Innovation in the New ICT Ecosystem. International Journal of digital Economics, (68).

Fuentelsaz, L., Maícas, J.P. & Polo, Y., 2008. The evolution of mobile communications in Europe: The transition from the second to the third generation. Telecommunications Policy, 32(6), pp.436–449. Available at: http://linkinghub.elsevier.com/retrieve/pii/S0308596108000402 [Accessed October 11, 2012].

Galloway, L. & Mochrie, R., 2005. The use of ICT in rural firms: a policy-orientated literature review. Info, 7(3), pp.33–46. Available at: http://www.emeraldinsight.com/10.1108/14636690510596784 [Accessed November 12, 2012].

Gargano, L., 2012. L'essor du sector tertiaire au Luxembourg, Luxembourg.

Gómez-Barroso, J.L. & Feijóo, C., 2010a. A conceptual framework for public-private interplay in the telecommunications sector. Telecommunications Policy, 34(9), pp.487–495. Available at: http://linkinghub.elsevier.com/retrieve/pii/S0308596110000042 [Accessed October 11, 2012].

Gómez-Barroso, J.L. & Feijóo, C., 2010b. Unveiling the intricate public–private interplay in next generation communications. Telecommunications Policy, 34(9), pp.483–486. Available at: http://linkinghub.elsevier.com/retrieve/pii/S0308596110000613 [Accessed October 11, 2012].

Grajek, M., 2010. Estimating network effects and compatibility: Evidence from the Polish mobile market. Information Economics and Policy, 22(2), pp.130–143. Available at: http://linkinghub.elsevier.com/retrieve/pii/S016762450900050X [Accessed October 25, 2012].

Greenstein, S. & Mcdevitt, R., 2012. Measuring the Broadband Bonus in Thirty OECD Countries. OECD Digital Economy Papers, (197). Available at: www.oecd.org/sti/wokring-papers.

Howick, S & Whalley, J, 2007. Understanding the drivers of broadband adoption: the case of rural and remote Scotland. Journal of the Operational Research Society, 59(10), pp.1299–1311. Available at: http://www.palgrave-journals.com/doifinder/10.1057/palgrave.jors.2602486 [Accessed October 11, 2012].

Huigen, J. & Cave, M., 2008. Regulation and the promotion of investment in next generation networks—A European dilemma. Telecommunications Policy, 32(11), pp.713–721. Available at: http://linkinghub.elsevier.com/retrieve/pii/S0308596108000906 [Accessed October 11, 2012].

ILR, 2008a. 10 Years Institut Luxembourgeois de Régulation, Available at: www.public.ilr.lu.

ILR, 1997. Rapport annuel de l ' Institut Luxembourgeois des Télécommunications 1997, Available at: www.public.ilr.lu.

ILR, 1999. Rapport annuel de l ' Institut Luxembourgeois des Télécommunications 1999. Available at: www.public.ilr.lu.

ILR, 2001. Rapport Annuel de l'Institut Luxembourgeois de Régulation, Available at: www.public.ilr.lu.

ILR, 2002. Rapport Annuel de l'Institut Luxembourgeois de Régulation, Available at: www.public.ilr.lu.

ILR, 2003. Rapport Annuel de l'Institut Luxembourgeois de Régulation, Available at: www.public.ilr.lu.

ILR, 2008b. Rapport Annuel de l'Institut Luxembourgeois de Régulation, Available at: www.public.ilr.lu.

ILR, 2010a. Rapport Annuel de l'Institut Luxembourgeois de Régulation, Available at: www.public.ilr.lu.

ILR, 2011a. Rapport Annuel de l'Institut Luxembourgeois de Régulation, Available at: www.public.ilr.lu.

ILR, 2000. Rapport Annuel de l'Institut Luxembourgeois de Régulation 2000, Available at: www.public.ilr.lu.

ILR, 2004a. Rapport Annuel de l'Institut Luxembourgeois de Régulation 2004, Available at: www.public.ilr.lu.

ILR, 2005a. Rapport Annuel de l'Institut Luxembourgeois de Régulation 2005, Available at: www.public.ilr.lu.

ILR, 2006a. Rapport Annuel de l'Institut Luxembourgeois de Régulation 2006, Available at: www.public.ilr.lu.

ILR, 2007a. Rapport Annuel de l'Institut Luxembourgeois de Régulation 2007, Available at: www.public.ilr.lu.

ILR, 2009a. Rapport Annuel de l'Institut Luxembourgeois de Régulation 2009, Available at: www.public.ilr.lu.

ILR, 1998. Rapport Annuel de l'Institut Luxembourgeois des Télécommunications 1998. Available at: www.public.ilr.lu.

ILR, 2004b. Rapport statistique année 2003, Available at: www.public.ilr.lu.

ILR, 2005b. Rapport statistique des télécommunications au Luxembourg pour l ' année 2005, Available at: www.public.ilr.lu.

ILR, 2006b. Rapport statistique des télécommunications au Luxembourg pour l ' année 2006,

ILR, 2007b. Rapport statistique des télécommunications au Luxembourg pour l ' année 2007, Available at: www.public.ilr.lu.

ILR, 2010b. Rapport statistique des télécommunications au Luxembourg pour l ' année 2010, Available at: www.public.ilr.lu.

ILR, 2011b. Rapport statistique des télécommunications du Luxembourg de l ' année 2011, Available at: www.public.ilr.lu.

ILR, 2008c. Rapport statistique des télécommunications Luxembourg pour l ' année 2008, Available at: www.public.ilr.lu.

ILR, 2009b. Rapport statistique des télécommunications Luxembourg pour l ' année 2009, Available at: www.public.ilr.lu.

ILR, 2004c. Rapport statistique succinct Année 2004, Available at: www.public.ilr.lu.

ILR, 2012. Registre public des entreprises notifiées, Available at: www.public.ilr.lu.

ITU, 2012. Measuring the Information Society, Available at: www.itu.org.

Jakopin, N.M., 2008. Internationalisation in the telecommunications services industry: Literature review and research agenda. Telecommunications Policy, 32(8), pp.531–544. Available at: http://linkinghub.elsevier.com/retrieve/pii/S0308596108000682 [Accessed October 11, 2012].

Koski, H. a. & Majumdar, S.K., 2000. Convergence in telecommunications infrastructure development in OECD countries. Information Economics and Policy, 12(2), pp.111–131. Available at: http://linkinghub.elsevier.com/retrieve/pii/S0167624500000032.

KPMG, 2012a. Luxembourg Banks Insights 2012,

KPMG, 2012b. Luxembourg Platform for Business,

Leduc, K. & Poussing, N., 2003. ICT usage and the partner ' s location . The case of firms in Luxembourg,

Mahan, A.K., 2007. ICT indicators for advocacy. Comunica, pp.77–95. Available at: http://www.giswatch.org/sites/default/files/gisw_indicators_advocacy.pdf.

Martin, L., 2008. Understanding the implementation of e-business strategies: Evidence from Luxembourg. , (13645), p.26. Available at: http://mpra.ub.uni-muenchen.de/13645/.

Michaux, R., 2013. Le secteur bancaire au Luxembourg, Luxe,bourg. Available at: http://www.statistiques.public.lu/catalogue-publications/luxembourg/2013/PDF-05-13.pdf.

Nguyen Thi, T.U. & Martin, L., 2010. The Relationship between Innovation and Productivity conditional to R & D and ICT use . An empirical analysis for firms in Luxembourg. In 3rd Vietnam Economist Annual Meeting. pp. 1–27.

OECD, 2012. OECD Economic Surveys: Luxembourg 2012, Paris: OECD Publishing.

Parcu, P.L. et al., 2011. Study on Broadband Diffusion : Drivers and Policies, Available at: http://www.irg.eu/streaming/CN (11) 81_FSR_Study_on_BB_Promotion_FINAL.pdf?contentId=547201&field=ATTACHED_FILE.

Preston, P., Cawley, A. & Metykova, M., 2007. Broadband and rural areas in the EU: From technology to applications and use. Telecommunications Policy, 31(6-7), pp.389–400. Available at: http://linkinghub.elsevier.com/retrieve/pii/S0308596107000420 [Accessed October 11, 2012].

PWC, 2011. Luxembourg: an e-hub for Europe Opportunities and actions on the horizon 2015, Available at: http://www.pwc.lu/en/information-communication-technology/publications.jhtml.

Ragoobar, T., Whalley, Jason & Harle, D., 2011. Public and private intervention for next-generation access deployment: Possibilities for three European countries. Telecommunications Policy, 35(9-10), pp.827–841. Available at: http://linkinghub.elsevier.com/retrieve/pii/S0308596111001352 [Accessed October 11, 2012].

Rood, H. & Te Velde, R. a., 2003. Investment strategies in the Netherlands. Telecommunications Policy, 27(10-11), pp.701–715. Available at: http://linkinghub.elsevier.com/retrieve/pii/S030859610300079X [Accessed October 11, 2012].

Schneider, E., 2012. Top 10 : Luxembourg ICT assets by Etienne Schneider. In Eurocloud congress 2012. Luxembourg: Eurocloud. Available at: http://www.itone.lu/index.php?option=com_content&task=view&id=7196&Itemid=80.

SMC, 2009. Plan d 'action national en matière de TIC et de haut-débit, Luxembourg.

SMC, 2010a. Stratégie nationale pour les réseaux à « ultra-haut » débit. Available at: http://www.mediacom.public.lu/institutions/Institutions_nationales/smc/20100309_ngn/Strategie_nationale_pour_les_reseaux_a_ultra-haut_debit.pdf accessed 15th of January 2013.

SMC, 2010b. Why Luxembourg ? A Comprehensive Overview of the Regulatory, Economic and Lifestyle Advantges for ICT and Media Companies, Luxembourg. Available at: http://www.investinluxembourg.lu/ict/download-free-reports-page?sid=632.

Statec, 2012a. Annuaire statistique 2013th ed. STATEC, ed., Luxembourg. Available at: http://www.statistiques.public.lu/fr/publications/series/annuaire-stat-lux/index.html.

Statec, 2012b. Luxembourg in Figures, Luxembourg. Available at: http://www.statistiques.public.lu/catalogue-publications/luxembourg-en-chiffres/luxembourg-figures.pdf.

De Streel, A., 2008. Current and future European regulation of electronic communications: A critical assessment. Telecommunications Policy, 32(11), pp.722–734. Available at: http://linkinghub.elsevier.com/retrieve/pii/S0308596108000967 [Accessed October 11, 2012].

Symeou, P.C., 2009. Does smallness affect the liberalisation of telecommunications? The case of Cyprus. Telecommunications Policy, 33(3-4), pp.215–229. Available at: http://linkinghub.elsevier.com/retrieve/pii/S0308596108001304 [Accessed October 11, 2012].

Tintor, V., Jankovic, M. & Milicevic, V., 2010. The legal and economic framework of EU Telecom market regulation. Economic Annals, 55(185), pp.107–128. Available at: http://www.doiserbia.nb.rs/Article.aspx?ID=0013-32641085107T [Accessed October 11, 2012].

Tookey, A., Whalley, Jason & Howick, Susan, 2006. Broadband diffusion in remote and rural Scotland. Telecommunications Policy, 30(8-9), pp.481–495. Available at: http://linkinghub.elsevier.com/retrieve/pii/S0308596106000619 [Accessed October 11, 2012].

Whalley, Jason, 2006. Recent developments in the telecommunications industry of Nepal. Info, 8(1), pp.57–71. Available at: http://www.emeraldinsight.com/10.1108/14636690610643285 [Accessed November 12, 2012].

Whalley, Jason & Curwen, P., 2005. An investigation into internationalisation among mobile telecommunication companies in 2003. Info, 7(4), pp.21–29. Available at: http://www.emeraldinsight.com/10.1108/14636690510607277 [Accessed November 12, 2012].

Whalley, Jason & Curwen, P., 2012. Incumbency and market share within European mobile telecommunication networks. Telecommunications Policy, 36(3), pp.222–236. Available at: http://linkinghub.elsevier.com/retrieve/pii/S0308596111002138 [Accessed October 11, 2012].

Whalley, Jason & Curwen, P., 2003. Licence acquisition strategy in the European mobile communications industry. Info, 5(6), pp.45–57. Available at: http://www.emeraldinsight.com/10.1108/14636690310507216 [Accessed November 12, 2012].

Whalley, Jason & Curwen, P., 2006. Third generation new entrants in the European mobile telecommunications industry. Telecommunications Policy, 30(10-11), pp.622–632. Available at: http://linkinghub.elsevier.com/retrieve/pii/S0308596106000723 [Accessed October 11, 2012].

Yamakawa, P., Cadillo, G. & Tornero, R., 2012. Critical factors for the expansion of broadband in developing countries: The case of Peru. Telecommunications Policy, 36(7), pp.560–570. Available at: http://linkinghub.elsevier.com/retrieve/pii/S0308596112000468 [Accessed October 11, 2012].

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Academics and practitioners alike have given considerable attention to the measurement of "information" for policy, development and investment decisions. However, this is only possible if we can define what information is and how we can measure it. For the measurement many "proxies" or indicators have been developed using aggregate statistics and the application of largely quantitative methods to gain insights into e.g. e-Readiness, e-Leadership or the "digital divide".

Newcastle Business School (UK)

MEASURING LUXEMBOURG'S STATE OF ICT DEVELOPMENT_

Nico Binsfeld, Jason Whalley, Newcastle Business School

1_ Measuring information – a "grand challenge"?

Taylor (2006) provides an introduction into the history of these proxies starting in the early 1960s and the ongoing search for different information age indicators which were subsequently called information technology indicators including telecommunications, the internet, broadcasting and computing technology.

He notices that most of these indicators use statistical analytics to correlate multiple factors in order to identify relationships between information stocks, information flows and technology as well as other economic and social factors.

Most of these indicators use various national and international empirical data sources. A major concern is the question how to group these factors and how to define their relative weightings[1] and how to build combinations of these.

Taylor also discusses the essence of information and its characteristics and identifies information as a process, information as knowledge and information as a thing.

He moves on to discuss what it means to measure information comparing the process of measuring information to the evolution of physics from a Newtonian to a Quantum based approach.

He concludes that "the identification of approaches likely to yield meaningful data for developing an exploratory and predictive understanding of the interactions of key information proxies with other selected factors in the human environment" constitutes a "grand challenge" which involves some or all of the following:

_Development of some initial theories and models
_Identification of information indicators appropriate to the assigned goal(s)
_International standardization of data collection formats
_Establishment of uniform methods of data collection
_Creation of a public centralized and standardized data recording facility
_Making data conveniently and reasonably available to researchers
_Review and comparison of available statistical tools for data analysis to find those which can appropriately be used to test certain theories
_Generation of testable hypotheses regarding impacts and interactions of the information sector with economic, social, cultural and governmental factors
_Creation and testing of uniform instruments, research designs, and research data bases
_Development of multi-dimensional models which are empirically testable over time, in different places, and at different scales
_Continuous application and refinement of these models in real-world situations

He subsequently (Menou & Taylor, 2006), (Taylor & Zhang, 2007) argued for an organised collective effort and the development of a "coherent academic field of study" and in a first step to "establish mechanisms by which the relevant documents and data sets could be more easily accessed, the various approaches systematically mapped, those interested could meet and exchange ideas and develop cooperative ventures, and stakeholders could discuss their needs and appraisal of the instruments and findings".

The objective of this paper is to introduce elements of this field of study and their application in the specific case of Luxembourg.

2_ Research questions and methodology

The objective of the remainder of the document is to address the following two questions:

_How is Luxembourg positioning itself with regards to main international ICT related indicators?
_How has its position/situation evolved over time?

From the answers to these two questions, a summary assessment about the current state of development of the Luxembourgish ICT ecosystem will be provided and proposals will be made for further research[2].

In order to address these two questions, the authors will first identify the available national and international sources of information and ICT indices and discuss their underlying methodologies, their general limitations and their particular limitations in the specific context of Luxembourg.
When available, data will compiled into a time series and/or comparisons will be made with neighbouring countries as well as some countries that are generally considered to be successful in the ICT domain.
The analysis will rely entirely on secondary and publicly available data. There is also a wide range of commercial reports and analysis available on the subject, but these have been excluded due to access limitations.

1_E.g.by expert's opinions or some elaborate statistical methods like e.g. Structured Equation Modelling (Hair, Black, Babin, & Anderson, 2010).

2_Which the first author will undertake as part of his DBA project

3_ Indicators to assess Luxembourg's position

In this section, the authors will focus on a specific presentation of several relevant data sources and indices as well as their underlying methodology and discuss their advantages and potential limitations in the context of measuring Luxembourg's ICT developments.

3.1_ ICT Sector definition

In order to define the scope of the analysis, the 2007 OECD (OECD, 2011b) definition of the ICT sector will be used. OECD divides the sector into: ICT manufacturing, ICT trade and ICT services using revision 2 (NACE rev.2) of the statistical classification of economic activities in the European Union (Mas, Robledo, & Perez, 2012). This might lead to some potential inconsistencies when looking at time series including data older than 2007. It should also be noted that a different statistical classification is used by the United Nations[3] but methods exists to convert between the different classifications.

3.2_ National frameworks and data sources

3.2.1_ An initial ICT snapshot

Service des Médias et des Communications[4] together with the Ministry of Economy and Foreign Trade[5] and ICT Luxembourg[6] published a summary overview about Luxembourg and ICT (Service des Médias et des Communications, 2013).
This publication aims "to provide a snapshot of the ICT sector in Luxembourg based upon the latest statistics and benchmarks available at the time of publication, without pretending to be exhaustive. The data sources are key national and international organisations that were considered representative of Luxembourg's progress in the digital society. A voluntary choice was made in the selection of countries that Luxembourg is compared with. Besides Luxembourg's direct neighbours Belgium, France and Germany, the following countries have been chosen as they are considered the most competitive ICT nations worldwide: Ireland, Japan, the Netherlands, South Korea, Switzerland, the United Kingdom and the USA".

It contains a general overview of Luxembourg's geography, economy and society, detailed figures and comparisons on available infrastructure and connectivity, information and communication services, e-skills, innovation as well as Luxembourg's position on major ICT indices. The first author was part of the team in charge of elaborating this document[7] and it should be noted that while the information is factually correct, because the aim was to promote Luxembourg on an international scale, only those indicators have been included on which the country performs well and the publication does not claim academic rigour nor completeness or objectivity. It nevertheless provides a good starting point and contains a lot of useful information which will be referred to on several occasions below.

3.2.2_ National Regulatory Authority's annual statistical reports

Since 2003, the National Regulatory Authority (Institut Luxembourgeois de Regulation, ILR[8]) publishes every year an annual statistical report about the state of the telecommunications market in Luxembourg. It presents: the total size of the telecommunications market, the share fixed/mobile networks, the share between incumbent and alternative operators, state of internet and broadband access according to technologies any many other but purely telecommunications related factors. Due to space limitations and the lack of comparisons with other countries, the authors will only use the most recently available report (ILR, 2013).[9]
It should be noted that ILR collects the underlying information directly from the different telecommunications operators and service providers in the form of annual reports that they are legally forced to provide. Only the "regulated[10]" services are presented in ILR's reports so that the published annual accounts of the different operators may show different figures[11]. Information about satellite communications, broadcasting and other electronic media are excluded but these may represent an important element of the local market with large international players e.g. RTL Group[12] and Société Européenne des Satellites[13] operating out of Luxembourg.

3.2.3_ National Statistics Office' studies

The national statistical office[14] (STATEC) produces an annual review (Statec, 2012c) (Statec, 2012b) of the Luxembourgish economy which also contains (limited) information about the ICT sector focussing largely on the use of IT by individuals and enterprises. They also publish a complete repertoire of all enterprises active in the ICT sector as defined above (Statec, 2012a). In addition, they have published some specific studies about the evolution of the usage of ICT and the internet over time (Airoldi, 2012), (Frising & Niclou, 2012), (Frising, 2013).

They collect information for other organisations like Eurostat in regular annual surveys. A mandatory self-administered questionnaire is sent out to a population of about 3500 enterprises of more than 10 employees[15].

3.3_ Assessments at European Union level

EU member states are required to provide the outcomes of their local evaluations as mentioned above to Eurostat and different European Commission Units in order to establish on an annual basis a comparison of the state of development of ICT within the different member states.

3.3.1_ Eurostat

Eurostat[16], the European Statistical office, tracks the usage of ICT and more specifically, monitors the completion of a single European information space, innovation and investment in ICT research and the achievement of an inclusive European information society. These aspects correspond to the aims of i2010[17] – a European Information Society for growth and employment. This is an EU wide strategic framework for the information society and a key element of the renewed Lisbon Strategy[18], and it offers a comprehensive strategy for the ICT and media sector.

Eurostat provides EU member states with a standardised methodology (Eurostat, 2013), (Eurostat, 2011) for the collection and statistical treatment of the data in order to allow EU-wide comparisons. Data are collected on both households and enterprises and the framework is adapted on a regular basis in order to take into account the rapid pace of technological changes. The following main areas of indicators are published on a yearly basis: policy indicators for benchmarking digital Europe and the use of ICT by public services, telecommunications indicators focusing on mobile phones, E-commerce use by individuals and enterprises, the use of computers and the internet by individuals and business, E-skills of individuals and enterprises. They also provide a regional breakdown of these indicators. A summary of the main statistical findings, the data sources and availability, as well as the relevant publications and methodology (including links to the underlying databases) can be found in Eurostat (2012).

Initially the focus has been on access and connectivity but the scope has been extended over time to include socio-economic analysis such as gender and age specificities or educational and employment differences.

3.3.2_ European Commission

In 1990, the European Commission (EC) initiated a process of liberalisation of the telecommunications industry and the creation of a single European Market for such services with a first directive (European Commission, 1990) followed by several updates and adaptations[19]. Liberalisation actually started to happen as of 1997 and the European Commission produces since then an annual implementation report focusing on the evolution of the telecommunications market and the implementation of the EU directives in a given country e.g. (European Commission, 2010c), (European Commission, 2012b).

Contributing to the global effort to develop appropriate frameworks for measuring the information society, EC has sponsored different research programs over time that came up with several specific composite indices. Thus for example, the SIBIS[20] project (European Commission, 2003) (Empirica, 2002, 2003) proposed a set of 134 indicators on internet readiness

3_See http://unstats.un.org/unsd/cr/registry/isic-4.asp accessed 6.6.2013

4_See http://www.mediacom.public.lu/ accessed 6.6.2013

5_See http://www.eco.public.lu/ accessed 6.6.2013

6_See http://ictluxembourg.lu/ accessed 6.6.2013

7_Representing ICT Luxembourg

8_See http://www.ilr.public.lu/ accessed 6.6.2013

9_Further information can be found in (Binsfeld et al., 2013) a draft paper for presentation at the 24th European Regional Conference of the International Telecommunication Society in October 2013

10_Fixed, mobile voice, broadband and ultra high broadband accesss, cable TV

11_E.g. telecommunications figures shown in the incumbant operator's annual report http://www.pt.lu/portal/lang/en/Entreprise/pid/4980 accessed 10.6.2013

12_www.rtlgroup.com accessed 10.6.2013

13_www.ses-astra.com accessed 10.6.2013

14_http://www.statistiques.public.lu/en/index.html accessed 13.7.2013

15_For details see https://circabc.europa.eu/sd/d/fad1d595-f967-4bf9-9543-6ecfcb650f43/isoc_sdds_lu.htm accessed 13.7.2013

16_http://epp.eurostat.ec.europa.eu/portal/page/portal/eurostat/home accessed 13.7.2013

17_http://europa.eu/legislation_summaries/information_society/strategies/c11328_en.htm accessed 13.7.2013

18_http://www.europarl.europa.eu/summits/lis1_en.htm accessed 13.7.2013

19_See (Binsfeld et al., 2013)

20_http://www.sibis-eu.org/ accessed 13.7.2013

21_http://www.europarl.europa.eu/summits/lis1_en.htm accessed 13.7.2013 and digital divides, information security, perceptions and possible access barriers, digital literacy, learning and training, E-commerce, E-work, E-government, E-health and E-science. However, this index was only published twice in 2002 and 2003. It was followed by the so-called eEurope2005 index (INSEAD, 2005) which was developed as part of the overall assessment of the progress of the Lisbon[21] strategy (World Economic Forum, 2008, 2010).

In 2009, the High Level Group in charge of evaluating and reviewing the Lisbon strategy defined a new conceptual approach for the measurement of the information society and suggested new areas for investigation as well as a list of relevant key indicators (i2010 High Level Group, 2009). The proposal was to assess the development of ICT and its impact through a supply, use and impact framework measuring:

_efficiency gains in the production of ICTs that may translate into a growing contribution of the sector to economic growth and into falling prices of ICT goods and services (supply);
_decreasing prices to stimulate investment prompting the take-up of ICTs by individuals, businesses and the public sector: take-up can further be described through readiness and use of ICT services and content applications (use);
_diffusion of ICT contributes to the sustainable growth of the economy and to jobs, the efficiency of the public sector and the well-being of the population (impact).

It was proposed to use this model for a 2011-2015 benchmarking framework. Eurostat surveys represent the main source of statistical information, with additional data provided by the Communication Committee. The ICT use surveys kept the previously existing structure, including core indicators for tracking development over time. For specific policy needs, ad-hoc surveys/studies have been foreseen. It is based on this new framework that EC published the so-called digital competitiveness reports in 2009 and 2010 (European Commission, 2009), (European Commission, 2010b).

In March 2010, as a reaction to the economic and financial crisis in 2009 and acknowledging that the Lisbon strategy was not enough, EC launched the Europe 2020 Strategy to "exit the crisis and prepare the EU economy for the challenges of the next decade". An important part of this strategy was identified as the "digital agenda for Europe" (European Commission, 2010a) set out to define the "key enabling role that the use of ICT will have to play if Europe wants to succeed in its ambitions for 2020".

The declared objective of this "agenda" is to chart a course for maximising the social and economic potential of ICT, most notably the internet, a vital medium of economic and societal activity: for doing business, working, playing, communicating and free expression. A set of indicators, called digital agenda scoreboard was defined to measure progress on this agenda (European Commission, 2013d) (European Commission, 2013c) . Since then the scoreboard has been published in 2011, 2012 and 2013 (European Commission, 2011, 2012a),(European Commission, 2013b). It contains elements of the previously discussed indices as well as the implementation reports and addition ad-hoc special topics. It can be considered as the most comprehensive assessment of the state of ICT development in the European Union.
This scoreboard gives a lot of visibility to the different member states and respective governments will try to present their countries in the best possible way in order not be left behind or be on the "wrong" side of the digital divide within the EU. A lot of the underlying information is collected through Eurostat and the so-called communications committee[22] from national statistical offices and national regulatory authorities. Therefore care needs to take when interpreting these data.

3.3.3_ Digital divide within the EU?

With the extension of the EU towards Central and Eastern Europe, it became important to understand whether there were any differences in terms of ICT development between "old" and "new" member states. This lead initially to the so-called Digital Divide Index (DIDIX) (Selhofer & Hüsing, 2002) (Hüsing & Selhofer, 2004) (Hüsing, 2004).
More recently, Cruz-Jesus, Oliveira, & Bacao (2012) addressed this question for the period between 2008 and 2010 (during the economic crisis). They used underlying data from the digital agenda framework and multivariate statistical methods (factor and cluster analysis). They identified two latent variables (ICT infrastructure and adoption by population and e-business and internet access costs) and identified 5 different groups of countries (digital leaders, digital followers, digital laggards and firm-side low access focussed, individual side-focussed). Their analysis pointed out that the digital divide does actually exist even within the EU and is influenced by economic asymmetries but also by the year of entrance in the EU. In some countries the divide is narrowing but not for all. The analysis is based on only 16 underlying variables and does not take into account any regional differences within a country and is only available for a restricted period of time.

3.4_ International Organisations

Several international organisations or sub-organisation from United Nations also collect information about ICT development. Their main objectives are twofold: to establish a broad picture with almost all countries in the world in order to identify clusters of these in terms of developed or developing countries and to identify potential policies that governments or regulators might pursue in order to improve their countries' positions.

3.4.1_ World Economic Forum

In 2001, the World Economic Forum (WEF) published for the first time the so-called Networked Readiness Index, developed by Havard Business School with a survey of 75 countries. As of 2002 (Dutta, Lavin, & Fiona, 2003), this survey was extended and coordinated by INSEAD and is published on an annual basis along with comments and discussions of various topics in the so-called Global Information Technology Report (Bilbao-Osorio, Dutta, & Lavin, 2013). A set of variables is collected and divided in to 4 sub-indexes on the general political, regulatory, business and innovation environment, readiness defined in terms of infrastructure and digital content, affordability and skills, usage by individuals, businesses and government and since 2012 economic and social impacts (Dutta & Bilboa-Osoria, 2012).

The set of indicators is based on quantitative data from Eurostat, ITU, World Bank and others but also on qualitative surveys and interviews that are conducted on a global scale by local partner organisations. The exact number of indices as well as the split between survey and statistical sources varies from year to year as well as the number of countries included in the survey. A ranking is established based on the combination of the different sub-indexes not considering any specific weighting (other than the number of indicators per sub-index). WEF does not provide all of the details of their underlying methodology which makes it difficult to replicate the results and gives WEF a "competitive advantage".

The NRI is a very popular tool for policy and business decisions as well as comparisons between different countries. It is well documented in the media as it provides a single composite indicator to measure ICT performance and to establish a country ranking. Nevertheless it has received a lot of critiques. Thus Goswami, (2006a) questioned the relevance of some of the underlying indicators and identified some that are missing e.g. degree of competition in the market, performance of the NRA. Luyt (2006) questioned the whole idea of a competitive ranking between different countries and commented that the business aspects seem to be more prominent than individuals. The Austrian NRA (RTR, 2011) discusses the scaling between 1 and 7 of most of the indicators and the fact the category between 0 and 1 and between 6 and 7 is not achieved. They also questioned the "objectiveness" of the surveys conducted by the local partners as these can have an important impact on the outcome of the

22_https://ec.europa.eu/digital-agenda/en/communications-committee accessed 13.7.2013 study. On the other hand, some of the indicators are very difficult to influence by political or business decisions and some might take a long time before changes can actually be measured. The implicit weighting of the different indicators is also a matter of critiques, for example in the 2010 version only 3 indicators were used to measure usage of governments as opposed to 16 for businesses and 17 for individuals. For some indicators the measurement range varies from year to year as it is set by the lowest and the highest value achieved in a specific year. Additional problems arise with the ranking as a confidence interval (two standard deviations) has to be considered which is dependent on the actual sampling size. Sometimes the absolute differences between countries are very small and thus the ranking may not be statistically correct.

3.4.2_ International Telecommunications Union

The international telecommunications Union[23] as part of United Nations has a long history of measuring telecommunications in terms of the fixed phones lines, minutes of communications and their prices etc. With the technological evolution it had to develop these indicators into a more general of measures of the Information Society. In doing so it collaborated with many other UN and international organisations[24] and similarly to European Commission the indicator framework evolved over time. Much of this work was done within the framework of the World Summit on Information Society[25] (ITU, 2011c),(World Summit on the Information Society, 2005) and the Partnership on measuring ICT for development (Partnership on measuring ICT for development, 2012) that was set-up as part of the WSIS processes.

As part of these activities, the "Core ICT indicators" a common initiative by OECD, ITU and UN to harmonise indicators in order to allow international comparisons, were identified. A discussion about these is provided for example in Goswami (2006). This set contains 41 indicators in 4 categories namely: ICT infrastructure and Access, Access to and use of ICT by households and individuals, use of ICT by Business and indicators on the ICT sector and trade in ICT goods. He also highlights some of the major pitfalls when defining e.g. quality of service, defining what is meant by broadband, setting up price baskets, using or not purchasing power parity and identifying peer groups and illustrates some of the main challenges with data collection. Further details can be found in (UN, 2005a) and (UN, 2005b).

In 2009, ITU decided on a single index, the so-called ICT Development Index (IDI) measuring 11 Information and Communication Technologies indicators for over 150 countries, and calculating its value for 2002 and 2007, so that comparisons could be made. The ICT Development Index (IDI) is a merger of two previous indices: the Digital Opportunity Index and the ICT Opportunity Index. From the DOI it takes indicators related to households and broadband and the methodology and presentation, while from the ICT-OI it takes indicators related to skills, the normalization method and the digital divide analysis and methodology.

This merger responded to the proposal and need of the ITU and other international agencies to concentrate all efforts in just one multi-purpose measuring device, instead of having several complementing indices fostered by different organizations. But, while some consensus has been reached, the cost of is that the new index has evolved towards a lowest common denominator, losing for example the information that affordability brought to. This way, the new index is more polarized and is mainly intensive in infrastructures and just shyly on usage and skills, leaving a big void in all other aspects of digital life: the ICT sector, digital skills or the legal framework. In order to address this limitation, ITU has also defined an ICT price basked (IPB) that measures affordability of fixed, mobile and broadband internet services.

It is important to highlight that, unlike many other indices, the coefficients of the weights assigned to each indicator and sub-indices are calculated statistically, using principal components analysis. The index consists of 5 access indicators weighted 40%, 3 use indicators weighted 40% and 3 skills indicators weighted 20%. Detailed administrative and statistical procedures on the collection and treatment of the different indices can be found in (ITU, 2011a) Both IDI and IPB have since 2009 been published on an annual basis (ITU, 2009), (ITU, 2010), (ITU, 2011b), (ITU, 2012).

Critical comments have been made e.g.(RTR, 2011) about the fact ITU has not defined an absolute maximum value per index but calculates this on a rolling basis by taking the mean value plus twice the standard deviation. Thus countries' individual values may be higher than the "ideal" value. Unfortunately, ITU is not able to publish their index on an annual basis as in particular developing countries have difficulties to collect all of the underlying data. This implies that there may be a considerable delay (up to 2 years) between the collection of data and publication of IDI or IPB.

3.4.3_ Organisation for Economic Co-operation and Development

The Organisation for Economic Co-operation and Development (OECD) publishes a set of 15 key ICT indicators[26] which are updated at regular intervals and for which time-series may be available back to 1997. They also provide detailed indicators (OECD, 2011b) on the development of broadband in terms of penetration, usage (individuals, businesses), coverage and geography, prices, services and speeds[27]. The underlying methodologies are well documented in a series of so-called digital economy papers and two bi-annual publications, the communications outlook (OECD, 1999, 2001, 2003, 2005, 2007, 2009, 2011b, 2013) and the information technology outlook (OECD, 2000, 2002, 2004, 2006, 2008, 2010), since 2012 called the internet economy outlook (OECD, 2012b). While the first on focusses on infrastructure and access, the second discusses more the actual usage and socio-economical aspects of ICT. Both documents do also include a section on broadcasting and media infrastructures and include direct access to the underlying data. The statistics used and the methodology applied are well documented. The sources of information tend to be largely similar to the ones mentioned above ie Eurostat, ITU, World Bank and there is a large overlap with some of the publications by these organisations.

3.4.4_ World Bank

In addition to contributing to the above mentioned work (The World Bank, 2012b) and producing an annual update of the "World Development Indicators"[28], the World Band also produces an index to measure the so called "Knowledge Economy"(The World Bank, 2008), (Chen & Dahlman, 2005). The application of knowledge, as manifested in areas such as entrepreneurship and innovation, research and development, software and design, and in people's education and skills levels, is increasingly recognized to be one of the key sources of growth in the global economy.

The Knowledge Economy Assessment Method (KAM) was designed as a proxy for a country's preparedness to compete in the knowledge economy using 148 structural and qualitative variables. The comparison is undertaken for a group of 146 countries, which includes most of the OECD economies and more than 90 developing countries. The KAM methodology takes a cross-sectoral approach, allowing the user to take a holistic view of a wide range of relevant factors rather than just focusing on one area. The variables serve as proxies for the 4 pillars of the Knowledge Economy framework i.e. an economic and institutional regime to provide incentives for the efficient use of existing and new knowledge and the development of entrepreneurship; an educated and skilled population to create, share, and use knowledge well; an efficient innovation system of firms, research centres, universities, consultants and other organizations to tap into the growing stock of global knowledge, assimilate and adapt it to local needs, and create new technology and the underlying Information and communication technology to facilitate the effective creation, dissemination, and processing of information.

Included in the KAM are also several variables that track the overall performance of the economy. These variables help to illustrate how well an economy is actually using

23_http://www.itu.int/fr/Pages/default.aspx accessed 13.7.2013

24_For example http://www.orbicom.ca/en/ accessed 13.7.2013

25_http://www.itu.int/wsis/basic/about.html accessed 13.7.2013

26_http://www.oecd.org/internet/ accessed 13.7.2013

27_http://www.oecd.org/internet/oecdbroadbandportal.htm accessed 13.7.2013

28_http://data.worldbank.org/data-catalog/world-development-indicators accesed 13.7.2013 knowledge for its overall economic and social development. The KAM offers several pre-set display modes for simple visual representations of a country's Knowledge Economy readiness. A country can be assessed and compared with others on the aggregate performance on each of the KE pillars or the overall Knowledge Economy and Knowledge indexes for 1995, 2000 and the most recent available year. The KAM also makes possible customized country analysis and cross-country comparison on different indicators.

3.5_ Commercial organisations

In addition to the public sources mentioned above[29], there are many commercial initiatives and studies. These are mentioned here for completeness but most of these are either not accessible for academic purposes or do not contain information about Luxembourg.

3.5.1_ E-readiness rankings by the Economist Intelligence Unit

The Economist Intelligence Unit published up to 2010 an annual index (a bit similar to NRI) of e-readiness rankings (EIU, 2010). This was focussing on about 60 developed and large economies and used about 100 quantitative and qualitative measures organised into connectivity and technology infrastructure, business environment, consumer and business adoption, social and cultural environment, legal and policy environment and supporting e-services. Unfortunately there is not detailed description of the methodology available and its variables have changed a view times making historical comparisons very difficult.

3.5.2_ Nokia Siemens Networks' connectivity scorecard

Similarly the telecommunications equipment provider Nokia Siemens Networks[30] has published the so-called connectivity scorecard (Waverman, Dasgupta, & Rajala, 2011) focussing on the "useful connectivity", Whilst the underlying methodology has been well documented, it does unfortunately not include Luxembourg.

3.5.3_ Cisco Broadband Quality Score

CISCO[31] published, together with Oxford Business School, on 3 occasions (Cisco & Saïd Busines School, 2008, 2010) their "Broadband Quality Score" classifying countries into "ready for tomorrow, comfortably enjoying today's applications, meeting the needs of today's applications, below today's application threshold and basic apps". Whilst Luxembourg has been include in the studies, the underlying methodology has not be documented.

3.5.4_ The Digitisation Index

The consulting company Booz&Co[32] published on two occasions the "digitization index (DI)" focussing on 15 major economies in the world. The underlying methodology is similar to NRI and Luxembourg was not included in a first go (Sabbagh et al., 2012), (Friedrich, Stroh, & Vollmer, 2012).

Recently, this "DI" was extended and updated (Raúl L Katz, 2013), (R.L. Katz & Koutroumpis, 2013). The "new" digitization index "consists of six elements and twenty-three indicators measuring tangible parameters of perceived digitization metrics. Ubiquity, refers to the adoption of mobile and fixed broadband networks accounting for broadband accessibility and ownership of data devices, such as PCs. Affordability, is essential and derives from the relative access costs of providing such access. Reliability, of networks depends on the annual network investment per subscriber and the faults reported per line.

Speed, is measured by the performance of country level international links and the capacity of wireline 'last mile' offerings. Usage, is a key component of digitization and includes the utilization and adoption of all commercial activities, government services, social media adoption and data usage. Skills, contribute to digitization both in terms of development of local service offerings and usage capacities". The underlying databases are similar to IDI and NRI and the methodology has been well described in the literature. The assessment was extended to 150 countries over the period from 2004 to 2010 and Luxembourg has been included.

3.6_ Measuring the internet

With the evolution of broadband connectivity, the internet becomes more and more a critical part of the information society and many applications and services rely on it e.g. Voice over IP, IP-TV, Could storage, On-line gaming, Online applications etc. It is therefore necessary to develop new indicators and measurements to assess the development of the internet and the role of the different national economies on this respect.

Lehr (2012) discussed some of these issues in an OECD working paper and also presented the underlying problems in measuring broadband quality (Bauer, Clark, & Lehr, 2010). They also discuss some of the current approaches (Arbor Networks, 2012; Sandvine, 2013) providing some attempts to better understand internet traffic flows and security issues. OECD, in its most recent Communications Outlook, discusses this topic and proposes IP addresses, web servers, autonomous systems and domain names as measurement units (OECD, 2013).

3.6.1_ The web index

The World Wide Web Foundation published in 2012 the so called Web Index[33]. It covers 61 developed and developing countries, incorporating indicators that assess the political, economic and social impact of the Web, as well as indicators of Web connectivity and infrastructure. Much of the Web research that exists today measures quantifiable metrics, such as the number of Web users, speed of access to the Web, the number of broadband subscribers, or covers particular single-dimensions such as economic impact or censorship. However, it is also important to understand how the Web impacts social, developmental, economic and political dimensions as well. By compiling data across many different dimensions of Web health and making it freely available, the Web Index, covering a time period from 2007 to 2011, is intended deepen and broaden understanding of how countries can maximise the impact of the Web.

The Web Index assesses the use, utility and impact of the Web by measuring and ranking:

- _Web Readiness: The Index examines the quality and extent of Communications Infrastructure (facilitating connectivity to the Web) and Institutional Infrastructure (policies regulating Web access and skill and educational levels enabling the full benefit of the Web).
- _Web Use: The Index looks both at Web usage within countries (such as the percentage of individuals who use the Internet) and the content available to these Web users.
- _The Impact of the Web: The Index uses social, economic and political indicators to evaluate the impact of the Web on these dimensions. This includes measures of social networks, business internet use and e-participation.

The Web Index is based to a large extend (60%) on specifically collected primary data using surveys amongst local experts. The limitations and statistical issues of this approach are discussed in Annoni & Nardo (2012) who conclude that the index is a robust one but some questions need to be refined and some indicators are redundant. Unfortunately, Luxembourg is not (yet) included in the list of countries covered.

3.6.2_ The Netindex

Based on widely used speed testing tools[34], Ookla[35] calculates the so-called Netindex[36] which is freely available and constantly updated. It defines 5 different indices for upload, download, quality, promise and value and presents OECD, G8, APAC and EU averages as well as an individual country measurement and rank updated daily. This is a good example of how the development of the internet itself provides the tools to measure and assess its performance and more of such tools are likely to appear in the future.

3.6.3_ The Akamai - State of the internet report

Akamai[37] has set up a global content delivery network that replicates content of major internet sites in order to improve and speed-up access this content. Using

29_This list does not claim to be complete but focusses on the mäin indicators which are available for Luxembourg

30_http://www.nokiasiemensnetworks.com/ accessed on 13.7.2013

31_www.cisco.com accessed 13.7.2013

32_http://www.booz.com/uk/home accessed 13.7.2013

33_ http://thewebindex.org/ accessed 13.7.2013

34_http://www.speeedtest.net/ accessed 13.7.2013 and http://www.pingtest.net/ accessed 13.7.2013

35_https://www.ookla.com/ accessed 13.7.2013

36_http://www.netindex.com/about/ accessed 13.7.2013

37_http://www.akamai.com accessed 10.8.2013 this network, they do produce a quarterly "state of the internet" report including connection speeds, attack traffic, network connectivity, availability and latency problems, IPv6 transition as well as traffic patterns of leading web sites and digital content providers.

In its recent edition (Akamai, 2013), the report covers 177 countries including Luxembourg but it should be noted the due to a limited number of customers in Luxembourg, the results may not be representative and are not commented about by Akamai.

3.7_ Assessments of Telecommunications Regulations

In addition to ICT infrastructures, usage and skills, it can be interesting to identify how successful a country has been in "liberalising" its telecommunications markets. In that respect, some researchers have come up with assessment of the strengths of the respective national regulatory agencies.

3.7.1_ Polynomics regulation index

In order to study the effect to sector-specific regulations, Polynomics[38] proposes an index to measure the "density" of regulation (Polynomics, 2012a, 2012b; Zenhaeusern & Schneider, 2012; Zenhaeusern, 2012). It is based on coded answers to about 30 questions regarding telecommunications regulations. All questions were selected to relate to investment and innovation activity by telecommunications companies.

They either concern fixed, mobile or next generation access networks or multiple of these. This gives a total of about 40 indicators per country and per year. The indicators have so far been collected for all of the EU countries for period between 1997 and 2010 and give a good overview about how regulation processes have evolved over time.

3.7.2_ Telecommunications Governance Index

Waverman & Koutroumpis (2011) designed an index of the effectiveness of the institutional design of telecommunications regulators for 142 countries called "Telecommunications Governance Index" (TRGI) and compared this index to the transparency of the general political governance in the respective countries.

The index is made up of 5 equally weighted components: regulatory transparency, independence, resource availability, enforcement on licensees and per capita income.

All components except the GDP/capita are derived from ITU information about regulators either directly or using relevant proxies. The countries were plotted on a two-by-two matrix using TRGI and Political transparency as axis and grouped into 4 categories and analysed on a regional basis.

3.8_ Different purposes and objectives

As shown in the (necessarily incomplete) picture above, there is a wide range of indices and frameworks available. It is important to keep in mind the different and sometimes conflicting purposes and objectives of these different models as these will have influenced the number and choice of sub-indices, their respective weightings and statistical treatment and, therefore their overall relevance for the task at hand.

The summary table below provides an overview of the frameworks that will be used in section 6 for collecting information about Luxembourg, identifying their scope, their objectives and commenting on their underlying data and methodology.

4_ Luxembourg's ICT development from different viewpoints

The following section will present empirical evidence extracted from the different sources identified above. The intention is to present a broad coverage of the different aspects of ICT readiness, usage and impact. Due to space limitation, the chosen subset will necessarily be subjective but, by using different sources[39], the authors have tried to identify the major strengths and weaknesses of Luxembourg's current state of ICT development.

Organisation	Scope	Objectives	Comments
Service des Médias et de la Communication	National	Present Luxembourg to the "outside" world	Marketing oriented – only the positive aspects shown
Institut Luxembourgeois de Régulation	National	Assessment of the telecommunications market	Limited to figures about telecommunications market
STATEC	National	Establish the extent of ICT access and usage	Focus on equipment in households and enterprises
Eurostat	European Union	Compare EU members states in terms of ICT usage and access	Based on statistical information from Members
Digital Agenda Scoreboard	European Union	Measure progress on i2020 agenda	High political visibility
Digital Divide	European Union	Identify differences within EU between "old" and "new" members	Does not take into account gender, regions, skills….
World Economic Forum - Networked Readiness Index	144 countries in 2013	Global country rankings, advise to policy makers and managers	Varying set of indicators and countries, mixed qualitative and quantitative approach, methodology not completely transparent
International telecommunications Union - Price Basked	Global	Establish pricing level of standardized basket of ICT services	Not collected every year, information may be outdated
International telecommunications Union - Development Index	Global	Establishing development of ICTs on a global scale, measuring the digital divide	Variable underlying data quality, not published annually, information may be outdated
OECD Communications Outlook	Global	State of communications infrastructure and prices	Some information from earlier data collections
OECD Internet Economy Outlook	Global	Focus on use of the internet	Inconsistencies in inputs from countries
World Bank Knowledge Economy	146 countries	Focus on education, knowledge and skills	ICT as important underlying driver, limited time series available
CISCO Broadband Quality Score	Varied subset of countries	Broadband infrastructure only	Only available for 2008,2009 and 2010
Booz&Co Digitization Index	150 countries	Alternative country ranking focussing on infrastructures	Initial set only available for a limited set of countries, not updated on a regular basis
Webindex	61 countries	Limited to internet infrastructure and usage	Independent local experts provide underlying information (not yet available for Luxembourg)
Netindex	Internet	Direct collection of live traffic information	Changes almost on a daily basis, not clear what the underlying methodology is
Akamai State of the Internet	177 countries but limited to Akamai customers	Aggregated information collected within their content delivery network	Methodology not clear, limited number of customer sites
Polynomics Regulation Index	EU members, some OECD	For traditional and NGN networks	Based on qualitative interviews
Telecommunications Governance index	142 countries	Based country data from ITU	Derived from multivariate statistical analysis

_Table 1: Summary of different frameworks used in section 6 below

4.1_ Local Luxembourg evaluations

4.1.1_ Market overview according to the National Regulatory Authority

This section presents a general overview of the telecommunications market in Luxembourg in 2012 according to the National Regulatory Authority (ILR, 2013). For more information about the historical evolution of the market and a complete list of market participations see (Binsfeld, Whalley, & Pugalis, 2013) and (ILR, 2004a, 2004b, 2013, 2005, 2006, 2007, 2008, 2009, 2010, 2011, 2012).

4.1.1.1_ Market size in 2012 and investments

Total turnover was 513.3 million Euro with was almost identical for 2011 (+0.38%). Fixed services continued to decline by 5.77% to 227.1 million Euro. Mobile network services increased by 5.8% to 286.2 million Euro. In addition, CATV Networks generated about 34.8 million Euro. In absolute terms, this is a very small market in line with the small size of the country, but on a per capita basis OECD (OECD, 2013) ranks Luxembourg, with about 1400 USD/

38_http://www.polynomics.ch/en/welcome.php accessed 13.7.2013

39_Which may however rely very often on the same underlying data sets

	Number	Net floor space ft²	Net floor space m²	Data centre operators	Data centre service providers
Tier I	0	-	-	-	-
Tier II	5	26 910	2 500	Cegecom-Artelis, eBRC, SES, Sungard, Visual Online	Cegecom-Artelis, eBRC, SES, Sungard, Visual Online
Tier III	7	90 955	8 450	BCE, BT, Cetrel, eBRC, LAB data Vault PSF, SecureIT, Verizon	BCE, BT, Cetrel, eBRC, LAB data Vault PSF, SecureIT, Verizon, colocated: Datacenter Luxembourg
Tier IV	6	267 064	24 811	eBRC, EDH (European Data Hub) run by CSC, LuxConnect	eBRC, EDH (European Data Hub) run by CSC, LuxConnect, colocated: Cegecom-Artelis, Conostix, Datacenter Luxembourg, IBM, Iris, Netcore, Orange Business Services, SecureIT, Solido, Steria PSF Luxembourg, Systemat, Telecom Luxembourg Private Operator, Telindus Telecom, Visual Online
Multi-tier	1	51 128	4 750	LuxConnect	LuxConnect, colocated: Datacenter Luxembourg, IBM, Root, Systemat, Tech-IT PSF, Telecom Luxembourg Private Operator, Telindus Telecom
Total	19	436 057	40 511		

_Table 2: Data centres in Luxembourg (source: Luxembourg for Business)

Capita spend in telecommunications, 4th largest behind Switzerland, Australia and the United States.

Total fixed and mobile network investments grew substantially to 133.3 million Euro, the largest part 112.4 million Euro (+26.6%) in fixed networks. This is largely due (91.1%) to the deployment of the country's fibre to the home network (SMC, 2010) by the incumbent operator "Entreprise des Postes et Télécommunications" (EPT)[40], The 3 mobile networks[41] operators invested 20.98 million Euro (-18.3%) mainly in 4G LTE deployments. Thus a very high 25.9 % of the total turnover were invested and this ratio increased compared to previous years.

4.1.1.2_ Mobile networks

Mobile subscriptions (excluding pure data cards and machine to machine only (25100)) reached 762.000 (compared to a population of 520.000). Outgoing voice minutes grew by 8.13 % to 993.37 million, 982.3 million SMS were sent (+6.04%) and mobile data volume grew to 4673 TBytes, an increase of 149% compared to 2011. Mobile internet users also grew from 299300 in 2011 to 385100 in 2012. Apparently, customers are willing to use the full potential of their smartphones even though this generates higher costs and thus the average monthly revenue per user grew to 31.3 Euro.

4.1.1.3_ Fixed voice and leased lines

Subscriptions decreased from 280000 to 269000 and this confirmed a long-term trend. A large part of those being residential customers (66.7%). However, about 60% of the revenues in fixed voice services are generated by business users (voice and leased lines)

4.1.1.4_ Next Generation Access

Voice over Broadband services grew substantially to 31500 subscribers. Internet (broadband and ultra-high broadband) grew to 169000 (+4.26%). Ultra-High broadband (downstream higher than 30 Mbit/s). In total some 27000 households are now using either "fibre to the node", "fibre to the home" or "DOCSIS3.0[42] Cable TV" next generation broadband access. This represents an increase of 146.36% compared to 2011.

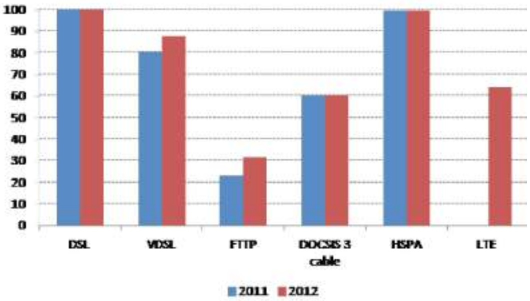

_Fig. 1: Percentage of Households covered by technology (source: ILR)

Broadband internet access is available in some form all over Luxembourg (see figure 1 above), fibre connectivity reaches about 32% of population and is growing rapidly. Cable TV subscriptions are decreasing due to a fierce competition from different IP-TV services[43], but internet over cable subscriptions have increased to 30.000 (+36.4%). Service bundles (triple and quadruple play) are becoming increasingly popular with a total of 223000 subscribers. Triple play (mobile and fixed voice plus internet access) grew by 36.6% to 112000 subscribers.

4.1.2_ Service des Médias et des Communications

As mentioned above, the Minister of Communications and together with the Ministry of Economy and Foreign Trade published a reference document "Luxembourg & ICT – a snapshot". This is largely based on information from

40_http://www.post.lu/fr/ and www.pt.lu accessed 14.7.2013

41_www.luxgsm.lu, www.tango.lu, www.orange.lu accessed 14.7.2013

42_http://www.cablelabs.com/cablemodem/ accessed 14.7.2013

43_http://www.tele.lu/ger, http://www.tangogeneration.lu/notre-tv/nos-offres, http://www.internet.lu/loltv_home.htm accessed 10.8.2013 secondary sources and presents Luxembourg according to its ICT development but also to several additional indices which are outside of the scope of this document. However, it also contains some original information mainly about Luxembourg's international connectivity and the underlying national and international carriers as well as round-trip times to the major European peering points. It argues that the central geographic location of Luxembourg makes it not just easy to access physically but also positions it well for on-line applications which need quick response e.g. gaming services.

There is also some information about datacentre capacity and quality (see table 3 below). There are different datacentres available in Luxembourg representing about 20% of the world's total high availability[44] datacentre capacity.
Overall, this document concludes that the ICT infrastructures are well developed in Luxembourg, that access and usage of ICT reaches almost 100% and the Government sees ICT as one of its "strategic" priorities for the development of the local economy.

4.1.3_ STATEC

Statec provides information on the usage of ICT by businesses and house-holds including time-series for some major indicators.

It can been seen that most business are using some form of IT but that collaborative tools other than emails are not widely used so far. Local area networks are present in all enterprises but Wireless Lan is only used in less than half of them. Indeed many of the financial institutions are still expressing security concerns when it comes to wireless access.

Almost all enterprises have some form of internet access and most of these broadband access. However, ISDN modems

Year	2005	2006	2007	2008	2009	2010	2011	2012
Entreprises using IT	97,5	98,1	97,3	97,9	97,3	98,0	98,4	98,4
Technologies used								
Intranet	45,7	44,8	45,0	54,7	41,0	35,2	48,7	48,5
Shared calendar	...	29,0	27,8	34,8	36,0	36,9	38,2	39,3
Extranet	27,5	25,0	25,8	28,7	34,0	33,9	35,4	32,3
Open Source	-	-	12,6	15,7	17,3	18,1	29,8	...
Project Management	...	12,5	13,4	16,6	16,0	18,9	19,3	19,5
Videoconferencing	...	5,7	6,8	10,1	9,2	11,4	13,8	16,3
Electronic Forums	...	7,4	8,4	12,0	12,8	14,5	13,4	15,3
Email	...	87,8	92,3	88,4	87,3	...	...	...
Local Area Network	93,4	96,8	98,1	98,7	98,8	100,0	...	...
Wireless Lan	15,3	22,9	27,2	35,3	41,5	42,9	...	...

_Table 3: ICT usage in Businesses over time (source: Statec)

Year	2005	2006	2007	2008	2009	2010	2011	2012
Business with Internet	95	95	97	98	98	98	98	99
Broadband connectivity	70	81	86	91	91	90	95	97
DSL (xDSL, ADSL, SDSL, etc.)	...	74	80	85	86	86	87	89
CableTV, Leased lines	...	16	16	19	20	18	28	34
ISDN Modem	50	49	40	34	33	29	26	30
Mobile	...	19	22	34	40	48	54	53
3G Mobile	...	...	...	...	...	21	28	41
Other mobile (WLAN)	...	...	...	...	...	44	49	40
Banking and Financial Services	75	76	79	79	83	85	...	...
Online Training	13	15	21	23	25	24	...	...
E-Government	...	...	...	94	91	94	91	91
Web based forms	...	84	86	90	88	90	89	86
Infrormation	...	77	80	85	86	88	86	84
Completed froms retrieval	...	35	38	43	43	50	59	63
Adminstrative procedures	...	...	...	29	30	39	40	49
Request for proposals	...	...	5	7	13	15	10	11

_Table 4: Web Access and Usage by Enterprises (source: Statec)

Année	2005	2006	2007	2008	2009	2010	2011	2012
Businesses with a web site	64	65	66	67	71	73	77	78
Price lists or catalogues	39	41	39	50	50	50	42	40
Job Offering	...	...	...	32	35	33	37	38
On-line ordering	...	...	...	21	19	20	21	22
Trust certifications	...	...	...	...	12	18	19	22
Personalised content	...	...	...	12	11	13	11	12
On-line delivery tracking	...	...	...	...	8	10	10	11
Product personalisation	...	...	...	17	11	12	9	9
Online ordering (at least 1% of orders)	22	30	34	35	34	35	33	36
Online sales (at least 1% of sales)	10	11	13	12	10	15	15	17

_Table 5: Web presence and E-commerce (source: Statec)

Year	2005	2006	2007	2008	2009	2010	2011	2012
HH with PC	74,5	77,1	80,0	82,8	87,9	90,0	91,7	92,0
HH with Internet Access	64,6	70,2	74,6	80,1	87,2	90,0	91,0	93,0
Broadband (DSL, Fibre, CATV)	51,7	62,8	77,5	76,2	81,5	78,0	75,0	73,0
Analogue/ISDN dial-up	51,0	36,3	25,7	24,1	19,5	30,0	27,0	22,0
DSL line	49,0	59,4	75,8	73,9	79,4	70,0	63,0	61,0

_Table 6: Households with a PC and Internet (source: Statec)

44_Tier IV according to http://uptimeinstitute.com/ accessed 14.7.2013 are also still use and mobile access specially over 3G and WLAN networks for smartphones and tablets is getting increasingly popular. Many organisations use the internet for banking and other financial transactions, most do also some government interactions and transactions over the web.

In terms of E-commerce, 78% of enterprises do operate a web site but these are not widely used for e-commerce transactions so far. E-commerce appears to be done more on an international than a local scale.

On the residential side, over 90% of households to own a personal computer and have access to the internet. Over 70% also have a broadband connection (mainly some form of xDSL or cable), both percentages have increased substantially since 2005.

Overvall, these indicators confirm that Luxembourg's population and entreprises have access to ICT and are using it widely.

4.2_ Luxembourg within the European Union

4.2.1_ Eurostat

Eurostat uses the statistics provided by Statec and compares Luxembourg with other EU member states. They also look more deeply into the actual usage characteristics and the level and skills of IT professionals. The following presents an extract of the wealth of information available based on Digital Agenda Scoreboard indicators.

In terms of actual internet usage Luxembourg scores amongst the top 3 performers in the EU with about 90% of households using the internet regularly. Only 6% never use the internet.

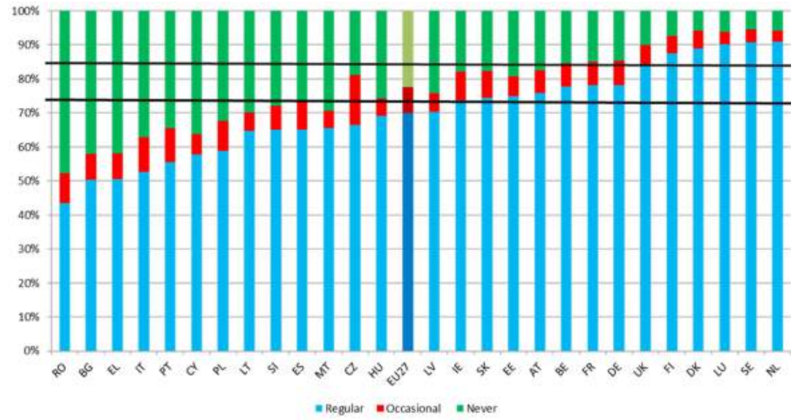

_Fig. 2: Internet usage (source: Eurostat)

About 40% of the working population claim to have reached a high level of computer skills and although this might be a very subjective assessment, it is substantially higher than the EU average. On the other hand, the amount of people admitting to have low IT skills is below the EU average. Obviously both indicators might be very subjective and therefore unreliable.

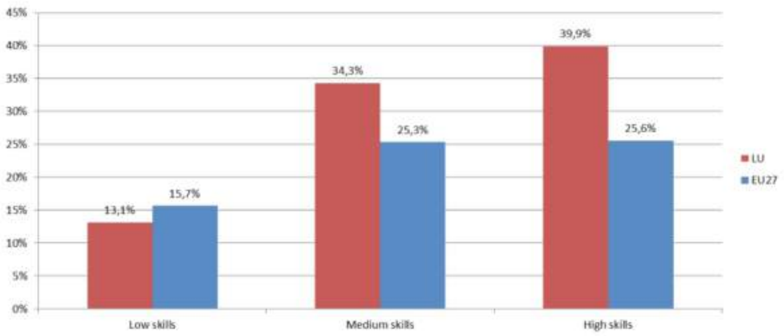

_Fig. 3: Levels of computer skills

In terms of ICT professionals Luxembourg is amongst the top 10 countries in the EU with about 4.8% of the working population active in ICT. It should however be considered that a large part of the working population comes from outside of Luxembourg (Schmitz, Drevon, & Gerber, 2012), (Service des Médias et des Communications, 2013) so that this figure needs to be treated with care.

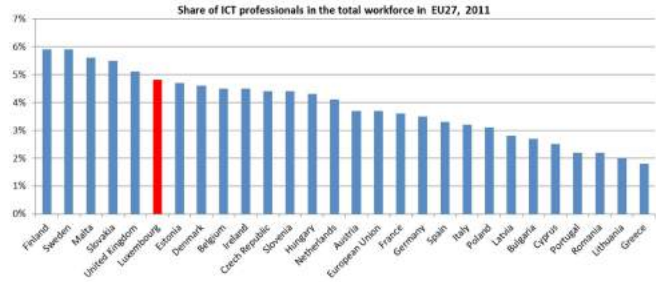

_Fig. 4: ICT Professionals

This seems to be confirmed with by the fact that Luxembourg is one of the countries that has most difficulties to recruit suitable ICT specialists and filling vacancies in this area as shown in the figure below.

_Fig. 5: Difficulties in recruiting ICT professionals

In terms of E-commerce it appears that most of it is done on a cross-border relationship with e-commerce providers like Amazon, Ebay and Itunes being very popular. This is not surprising given the small size of the country and the fact that local enterprises are not providing much e-commerce offerings so far (see table 5 above). In terms of Small and Medium size Enterprises (SME) selling online, Luxembourg reaches the EU average of about 14%.

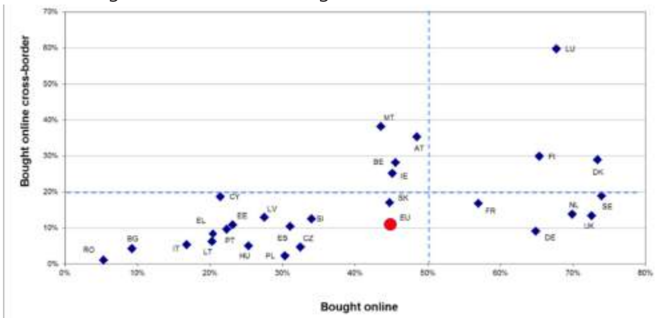

_Fig. 6: Citizens engaging in Ecommerce

In terms of E-government, a lot of efforts have been carried out recently and Luxembourg positions itself amongst the top 10 countries in the EU.

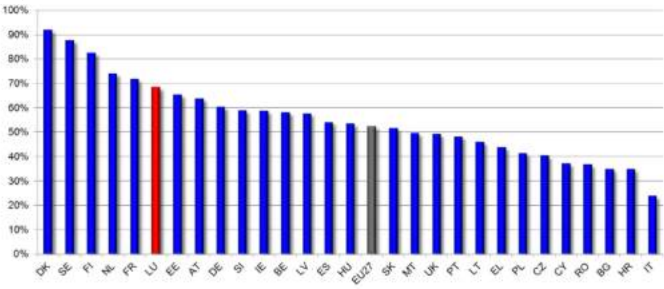

_Fig. 7: Electronic interaction by citizens with public authorities

However, on the use of ICT by public authorities themselves, whilst at a relatively high level, Luxembourg is outperformed by many EU members and even some of the new member states from Central Europe.

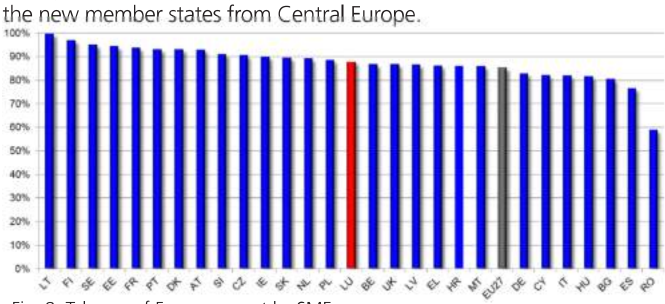

_Fig. 8: Take-up of E-government by SMEs

Overall, according to Eurostat, the share of gross value added by the ICT sector in Luxembourg is considerably more important than the EU average (second behind Ireland). This is not surprising as the local economy is to a large extend "services oriented" and dominated by the financial sector which needs a lot of ICT infrastructures and services as an underlying platform to offer their own products and services. It should be noted that there is nearly no ICT manufacturing[45] in Luxembourg so that the bulk of the value added comes from ICT services.

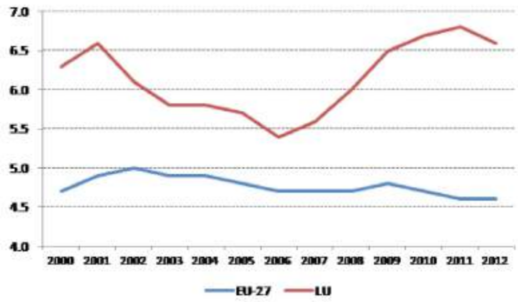

_Fig. 9: Share of Gross Value Added (%, at basic prices)

4.2.2_ Digital Agenda scoreboard

As part of the Digital Agenda for Europe scoreboard (DAE), the European Commission assesses the main telecommunications market and regulatory developments in the member states. The most recent report is not yet available but in 2011, Luxembourg was considered to be committed and well on track to make it "the first fully fibred country in Europe" (European Commission, 2012b).

This was confirmed by a special report on broadband availability in Europe (European Commission, 2013a) and in the latest DAE report (European Commission, 2013b). In the following, the authors present a comparison of Luxembourg in the main DAE indicators related to ICT infrastructure and access.

In terms of standard fixed broadband access defined as xDSL, Cable, FTTP and WiMAX[46], Luxembourg scores amongst the top 5 countries with an almost 100% availability.

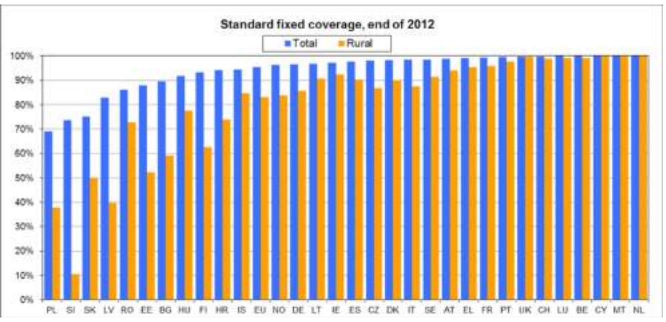

_Fig. 10: Fixed broadband availability (source: Point Topic)

The same applies for the so-called Next Generation Access (NGA) ie ultra-high broadband access including VDSL, Cable DOCSIS3.0, FTTH. The EU average is at about 54% of Households and Luxembourg is much higher amongst the top 5 countries of the EU and Switzerland. This confirms that the substantial investments made in FTTH infrastructure shown above are showing good results.

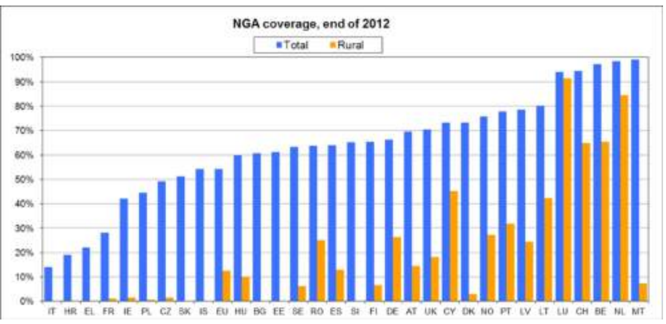

_Fig. 11: Next Generation Access (source: Point Topic)

However, take up and usage of NGA is a different story and by far the largest part of population still uses "standard broadband".

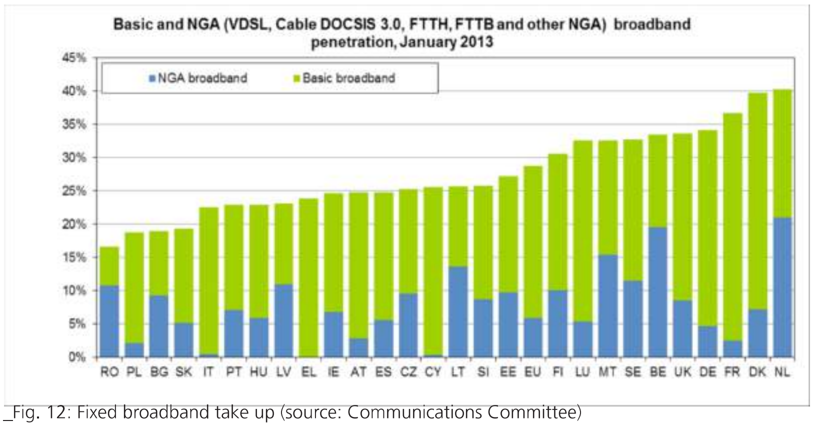

_Fig. 12: Fixed broadband take up (source: Communications Committee)

Luxembourg appears also to lack behind about 15 EU member states and EU average with only 17% of of households actually using either FTTH, VDSL or DOCSIS3.0 cable.

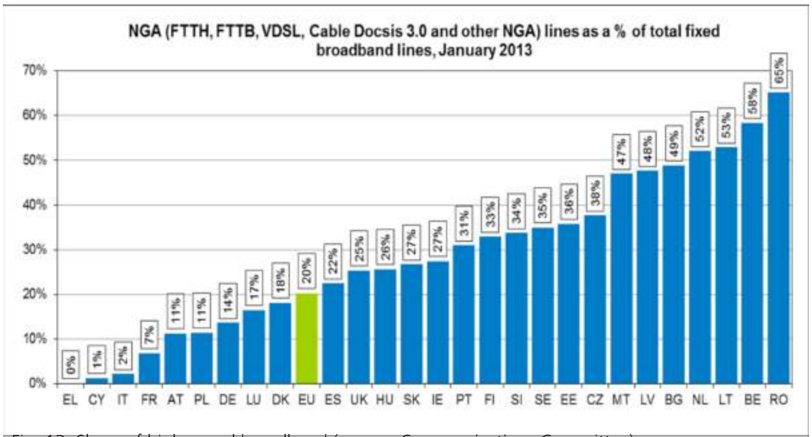

_Fig. 13: Share of high-speed broadband (source: Communications Committee)

Similarly in terms of the bandwidth actually offered, about 80% is below 30 Mbit/s. One possible explanation for this may be the dominance of the incumbent operator who has no interest to "cannibalise" its xDSL business and most importantly its leased line business for business customers.

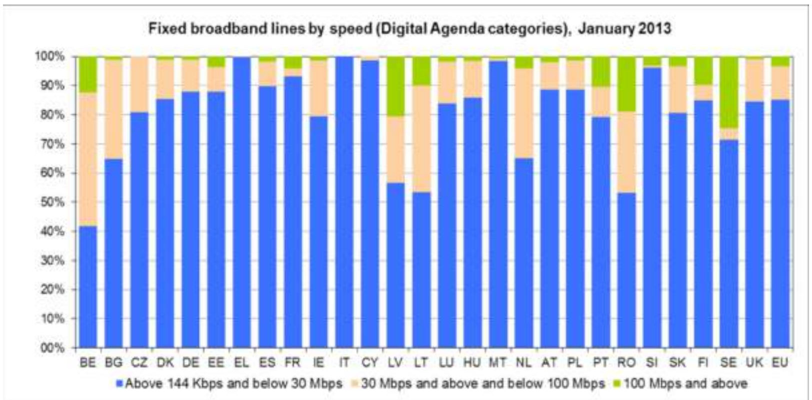

_Fig. 14: Fixed broadband lines by speed (source: Communications Committee)

From the assessments above it can be seen that the telecommunications infrastructure in Luxembourg is well developed and continues to be extended and upgraded. On the supply side, Luxembourg has a good chance to become the first "fully fibred" country in the EU, however on the demand side, take up of the new technologies is lagging behind.

4.2.3_ The digital divide within the EU

This study was carried out for 2008, 2009 and 2010 (Cruz-Jesus et al., 2012) and Luxembourg was classified for all 3 years of study into the "digital leaders" cluster together with Denmark, Finland, Sweden and the Netherlands. There appears to be an improvement over the years in terms for the "ICT infrastructure and adoption by population" dimension

45_According to OECD definition

46_A WiMAX licence has been awarded in Luxembourg but there are no services offered which is visible for many of the EU member states. On the "e-business and internet access cost dimension however – no real improvement is visible, the situation is more or less identical during the 3 years and Luxembourg, together with Finland scores less well than Denmark, Sweden and the Netherlands.

As an aside, the "digital laggards" are all coming from the new member states in CE and this suggests that there is indeed a "digital divide" apparent within the EU.

4.3_ International organisations

4.3.1_ World Economic Forum's "Networked Readiness Index"

The section below presents an analysis of the Networked Readiness Index (NRI) and its evolution over time for Luxembourg. It also presents an analysis of the major strengths (sub-indicators Luxembourg performed well) and weaknesses (sub-indicators it does not perform well). As mentioned above, the time series analysis needs to be treated with care as the methodology, the number of countries and the split between quantitative and qualitative measures has considerably evolved over time.

Table 8 and the figure 15 below show the actual value of the NRI and for the sub-indexes environment, readiness, usage and (since 2012) impact, as well as the rankings in the different categories. A percentage change has been calculated between 2003 and 2013 (intermediate values were difficult as even the scaling changed over time).

It can be concluded that on most indicators as well as on the so-called pillars, Luxembourg has improved over time and on some occasions even substantially. There are only 3 pillars for which this not the case: infrastructure environment (although this was dropped in 2011) which is surprising as a lot of the Government initiatives went into the development of the infrastructure, business readiness and skills. On "affordability" it almost stayed constant since 2003.

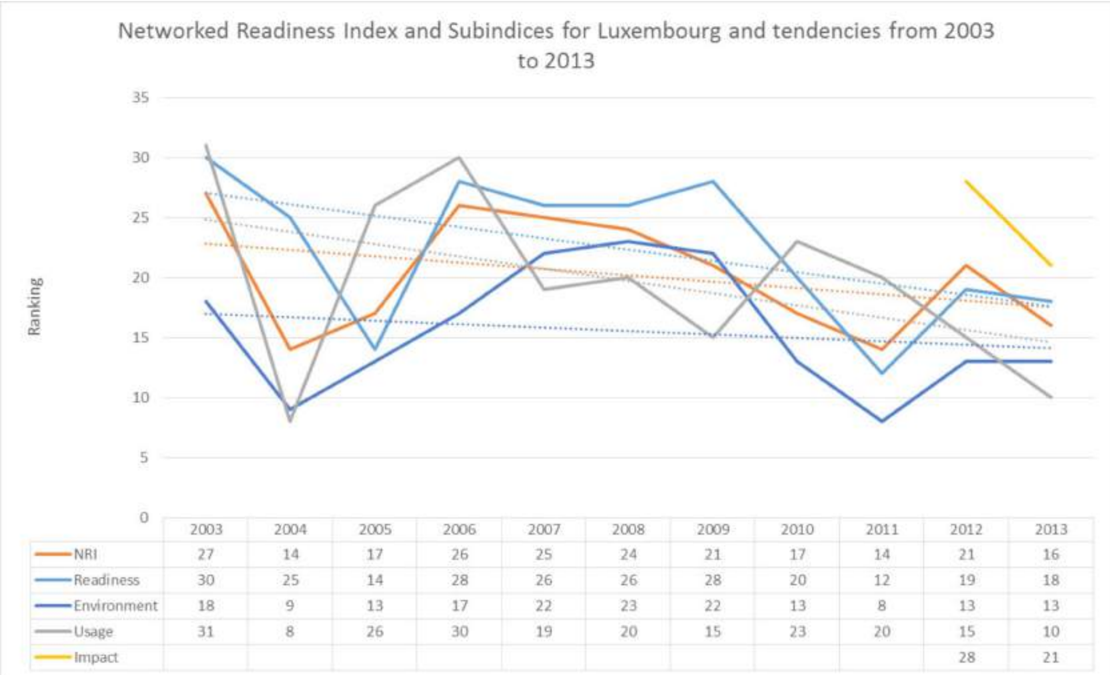

_Fig. 15: Evolution of NRI for Luxembourg (source: World Economic Forum)

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	% change 2003-2013 (or latest year)
NRI	**4,55**	**4,76**	**1,04**	**0,8**	**4,9**	**4,94**	**5,1**	**5,02**	**5,14**	**5,22**	**5,37**	18%
Rank	27	14	17	26	25	24	21	17	14	21	16	
Environment	**4,81**	**4,64**	**1,44**	**1,24**	**4,62**	**4,67**	**4,82**	**5,33**	**5,5**	**5,27**	**5,25**	9%
Rank	18	9	13	17	22	23	22	13	8	13	13	
Market Environment	3,79	4,27	1,14	0,86	4,46	4,86	5,02	5,4	5,41			43%
Rank	33	8	19	22	24	20	16	4	3			
Political and regulatory environment	5,03	5,17	1,4	1,19	5,31	5,44	5,39	5,99	6,06	5,79	5,77	15%
Rank	15	10	13	22	22	18	13	4	5	5	4	
Infrastructure environment	5,59	4,48	1,78	1,67	4,1	3,71	3,84	4,59	5,02			-10%
Rank	3	18	10	12	22	35	29	19	18			
Business and Innovation environment										4,75	4,73	0%
Rank										27	34	
Readiness	**4,93**	**4,96**	**0,94**	**0,51**	**5,05**	**5,29**	**5,26**	**5,09**	**5,17**	**5,86**	**5,79**	17%
Rank	30	25	14	28	26	26	28	20	12	19	18	
Individual readiness	5,07	5,04	0,85	0,83	6,05	6,07	5,95	5,22	5,44			7%
Rank	32	28	20	24	18	24	27	25	22			
Business readiness	5,12	5,19	0,54	0,29	4,82	4,79	4,78	4,82	4,76			-7%
Rank	22	25	27	35	29	38	39	30	22			
Goverment readiness	4,61	4,65	1,44	0,42	4,29	5,01	5,05	5,23	5,32			15%
Rank	28	28	7	33	32	21	18	10	7			
Infrastructure and digital content										6,17	6,43	4%
Rank										13	12	
Affordability										5,74	5,61	-2%
Rank										36	48	
Skills										5,66	5,33	-6%
Rank										31	33	
Usage	**3,9**	**4,67**	**0,75**	**0,66**	**5,02**	**4,87**	**5,21**	**4,65**	**4,74**	**5,26**	**5,62**	44%
Rank	31	8	26	30	19	20	15	23	20	15	10	
Individual usage	4,57	6	1,36	1,66	4,93	4,72	5,69	5,82	6,05	5,91	6,47	42%
Rank	8	1	13	13	9	9	4	5	3	7	4	
Business usage	3,56	4,62	0,8	0,74	5,38	5,18	5,29	3,94	4,16	5,03	4,97	40%
Rank	49	19	25	30	26	27	23	28	18	18	16	
Government usage	3,56	3,4	0,09	-0,42	4,76	4,7	4,64	4,19	4	4,83	5,41	52%
Rank	52	43	48	73	31	25	27	41	42	20	13	
Impact										**4,5**	**4,81**	7%
Rank										28	21	
Economic impacts										4,07	4,47	10%
Rank										30	25	
Social impacts										4,96	5,15	4%
Rank										34	20	

_Table 7: Networked Readiness changes (source: World Economic Forum)

Luxembourg, although improving in absolute terms, lost pace compared to its "competitors". It would appear that the efforts made by politicians and regulators have been able to compensate this and have put Luxembourg amongst the top 20 countries in the World. It is interesting to note as well that Luxembourg's position worsened in 2011 when the methodology was changed.

Looking into the details in the 2013 report, Luxembourg's main strengths seem to be related to its small size and its flexibility to adapt to market changes e.g. in terms of laws related to ICT, number of procedures, effectiveness of law making bodies and the fact that most households and businesses are using computers and the internet. The government's willingness and vision to develop ICT is also seen as a strength.

above, the country ranks extremely poor in terms of skills and this ranking has even worsened since 2002[47] which overall leads to a substantial reduction of the general IDI score and ranking.

4.3.3_ OECD Communications and Internet Economy Outlook

This section provides a summary of the main strengths and weaknesses of Luxembourg according to the latest OECD Communications (OECD, 2013) and Internet Economy Outlook (OECD, 2012b) reports.

OECD has defined a set of 15 key indicators[48], some of which, however, are not available for Luxembourg e.g. top 250 ICT firms, R&D in ICT because of the small size of the market and the fact that there is practically no ICT manufacturing in Luxembourg. Therefore, the authors have identified in the two publications mentioned above, all of the indicators which include Luxembourg and its respective ranking.

Strengths	Rank	Weaknesses	Rank
Laws relating to ICT	1	Tertiary education gross enrolment rate %	112
Internet & telephony competition	1	No. Days to start a business	81
Software piracy rate % software installed	2	Fixed broadband internet tariffs PPP USD/month	64
Households with Personal computer (%)	3	Quality of management schools	60
Impact of ICTs on access to basic services	3	Mobile cellular tariffs, PPP USD/min	59
Effectiveness of law making bodies	4	Intensity of location competition	58
Extent of staff training	4	No. Procedures to start a business	48
No. Procedures to enforce a contract	5	Quality of math&science education	46
Indivuduals using Internet (%)	5	E-Participation	38
Importance of ICT to government vision	5	Quality of educational system	36

_Table 8: Strengths and weaknesses according to NRI (source: World Economic Forum)

Several of the weaknesses appear to be linked to education in terms of tertiary education, management schools, math&science education and the overall quality of the educational system – all not directly related to ICT. Some of the tariffs which seem to be still relatively high and there appears to be a relatively low intensity of competition.

Price basket	2008	2009	2010	2011
GNI/capita USD	75880	84890	76710	77160
IPB	0,4	0,47	0,5	0,5
Rank	3	5	7	5
Fixed PB	0,5	0,42	0,4	0,4
Rank	11	15	14	13
Mobile PB	0,2	0,18	0,4	0,4
Rank	7	7	13	12
Broadband PB	0,7	0,59	0,6	0,6
Rank	5	7	7	6

_Table 9: ITU Price Basket (source: ITU)

In terms of IPB, Luxembourg ranks amongst the top 10 countries in the world, which is not surprising given the country's very high Gross National Income per Capita. However, no major changes can be seen over time, except for mobile communications which appear to have become more expensive. This could be due to increased importance of data services and smartphones bundles. It should also be born in mind that due to the small size of the country, a substantial part of the mobile costs arises from roaming charges. Although EU is pushing all operators to reduce these charges, this was not visible yet in 2011.

Development index	2002	2007	2008	2010	2011
IDI	4,62	7,03	7,71	7,78	7,76
Rank	21	7	2	7	7
Access	6,68	8,6	8,8	8,8	8,87
Rank	11	2	2	3	3
Use	1,4	5,56	7,09	7,24	7,07
Rank	22	2	1	3	7
Skills	6,91	6,84	6,77	6,79	6,9
Rank	62	75	82	87	81

_Table 10: ITU Development Index (source: ITU)

In terms of IDI, major improvements have been made improvements between 2002 and 2008 mainly in terms of Access and Use and the country ranks amongst the top 10 in the world and even in the top 3 in terms of Access. This can be explained by the development of the underlying telecommunications infrastructure and international connectivity (Binsfeld et al., 2013) and by the development of usage of PCs and internet by Households as seen above. However, in line with the NRI findings

Indicator	Value	Rank	Year
Ind. Portable devices to access internet	60%	1	2010
Supply chain management	27%	3	2010
HH health information	66,3%	3	2010
HH Internet for Learning	73%	4	2010
HH Internet for communications	85%	5	2010
Households Internet Access	90,60%	6	2011
HH Internet for gaming	38%	6	2010
Receiving invoices	33%	6	2010
HH Web pages	18%	7	2011
Employees using computers	57%	7	2011
HH Internet for E-commerce	53%	8	2011
HH Internet for Banking	58%	8	2011
ICT specialists	4,50%	8	2010
Wireless Broadband	66,10%	10	2011
Senior 55-64 using the internet	73%	10	2011
Intranet	35%	12	2010
Internal file sharing	56%	12	2010
Share of ICT sector employment	6%	13	2009
Businesses using the internet	97%	13	2011
HH Social Networking	52%	14	2011
B with BB connection	95%	14	2011
B Web sites	75%	15	2011
HH Internet for information from public authoritie	40%	17	2011
HH Peer-to-peer file sharing	18%	18	2011
Buying online	30%	18	2010
HH Internet for Job search	13%	20	2011
Ind. Social Networking	44%	20	2010
Awareness of security obligations	36%	21	2010
Fibre Broadband Penetration	0,80%	25	2011
Forms to authorities	63%	25	2011
Ind. Gender gap	8%	28	2011

_Table 11: Indicators for Luxembourg (source: OECD Internet Economy Outlook 2012)

As the number of countries included in these indicators is not always the same, the absolute ranking positions may not be comparable. Therefore, only a general classification was used – ranks 1-10 are defined as "amongst the top 10 OECD countries", 11-20 as "around OCED average", rank 21 and higher as "lagging behind".

In terms of Internet Economy, it can be seen that Luxembourg shows relatively little awareness of security issues which is surprising given the importance of the financial sector and the

47_The 2002 values have been recalculated by ITU from previous indices to allow for comparisons on the IDI.

48_http://www.oecd.org/internet/broadband/oecdkeyictindicators.htm accessed 17.7.2013 fact that many ICT providers need to have the "Professionnel du Secteur Financier (PSF)[49]" status to be allowed to offer services to the financial sector, that the Government has issued a national e-security plan (SMC, 2011) and that Luxembourg has set up its own certification authority[50].

Luxembourg also did lack behind on "fibre connectivity" – however this issue has been addressed (SMC, 2010), (SMC, 2009) and future assessments should show significant improvements in this area. The two other weak points are, a relatively important gender gap – women are far less present in ICT roles and appear to be less fluent as well and finally e-Government as many administrations seem still to have issues with e-forms.

The share of ICT specialists appears to be higher than average and this might, yet again be linked to the importance of ICT for the financial sector and confirms findings presented above. According to OECD, Luxembourg is considered "average" on many indicators related to internet and e-commerce usage by individuals and business. However, Luxembourg does also rank amongst the top 10 in several other indicators related to internet usage and in particular mobile internet usage. It can be argued, that access to the internet and its usage is in line with many other OECD countries. Having a deeper look into a set of different price baskets, it appears prices for most services are towards the higher end or, at best, average. Often these values are expressed as a ratio of GNI or GDP and Luxembourg appears to score well. This, however is due to the very high GDP[51] rather than to low prices for communication services. Overall, telecommunications price levels for both businesses and individuals, according to OCED price basked, appear to be less attractive than in most other OECD countries.

Indicator	Value	Rank	Year
Total paths per 100 inhabitants	235	1	2011
Net additions fixed phones	6%	1	2009-2011
IP v6 users	2,60%	2	2012
Data only 2 GB	9 USD/PPP	2	2012
Investment per capita	300 USD	3	2011
Routed AS numbers/100.000 inh.	9,20%	3	2012
Share of ASN IPv6 ready	47%	3	2012
Content available over Ipv6	55%	3	2012
Use of Smartphones to access Inet	34%	3	2011
Telecom revenue/capital	1400 USD	4	2011
Leased Lines 34Mbit/	3000 USD/PPP	4	2012
Tablet 2 GB	10 USD/PPP	4	2012
Investment per path	130 USD	5	2011
Mobile sucriptions per 100 inh.	150	5	2011
CableTV	68%	5	2011
Data only 1GB	9 USD/PPP	5	2012
Country relatad ccTLD reg.	140	6	2012
Secure Web server /100000 inh	220	6	2012
Bundles	56%	6	2011
Share of mobile	52%	8	2011
ARPU	40 USD	8	2011
Routed IPv4 addresses per capita	1,9	9	2012
Data only 500 MB	9 USD/PPP	9	2012
Data only 10 GB	25 USD/PPP	9	2012
Penetration of digital TV	92%	10	2011
Tablet 1GB	10 USD/PPP	10	2012
Wireless Broadband	68%	11	2012
IPTV	13%	11	2011
30 Calls plus 100 MB mobile	17 USD/PPP	11	2012
900 Calls plus 2 GB mobile	45 USD/PPP	11	2012
Fixed broadband	33%	12	2012
Telecom revenues per access path	580 USD	13	2011
Data only 5 GB	25 USD/PPP	14	2012
Tablet 500 MB	10 USD/PPP	14	2012
Tablet 250 MB	10 USD/PPP	15	2012
Tablet 5 GB	20 USD/PPP	15	2012
300 Calls plus 1 GB mobile	40 USD/PPP	16	2012
100 Calls plus 2 GB mobile	45 USD/PPP	17	2012
Broadband fixed low basket 2GB	28 USD/PPP	18	2012
100 Calls plus 500 MB mobile	32 USD/PPP	18	2012
Digital terrestrial television	8%	20	2011
Monthly HH expenditure	140 USD/PPP	20	2011
Broadband fixed low basket 14GB	45 USD/PPP	22	2012
Broadband fixed high basket 42 GB	55 USD/PPP	24	2012
Fibre connections	2,00%	25	2012
Dial up	4%	25	2011
Broadband fxed low basket 18 GB	60 USD/PPP	25	2012
Broadband fixed high basket 54GB	60 USD/PPP	25	2012
Bit/data caps	45%	27	2012
Broadband fixed low basket 6GB	35 USD/PPP	28	2012
Annual growth .lu domain names	15%	29	2000-2012
Broadband fixed low basket 11GB	55 USD/PPP	29	2012
Broadband fixed high basket 18 GB	46 USD/PPP	30	2012
Broadband fixed high basket 33 GB	55 USD/PPP	30	2012
Broadband fixed high basket 6GB	37 USD/PPP	31	2012
Mobile Termination rates	0.12 USD	34	2012

_Table 12: Indicators for Luxembourg (source: OECD Communications Outlook 2013)

There are however, some products and services for which Luxembourg scores well, again these appear to be more on the mobile side. Mobile devices, smartphones and tablets seem to be appreciated by local customers, average monthly revenue per user is amongst the highest in OECD, just as the total revenue as well as the total spending per capita. Mobile subscriptions, digital TV and cable TV networks are amongst the highest countries as well and service bundles appear to be very popular again confirming previous findings.

On the other hand, according to OECD, Luxembourg has a well-developed internet infrastructure, it ranks second behind France in terms of IPv4[52] addresses per capita, IPv6[53] networks and content delivery and scores well on autonomous systems[54] (ASN), and country-code top level domains[55] (ccTLD). Domain .lu names[56] grow scores far less well and this might be explained by relatively high costs to register such a local domain name.

4.3.4_ The World Bank Knowledge Economy Index

The Knowledge Economy Index framework of the World Bank allows to explore further the issues around education identified above, bearing in mind however, that the KEI is only available for 1995, 2000 and 2012.

In ranking terms (The World Bank, 2012a), Luxembourg has achieved an improvement from 2000 to 2012 and has made it into the top 20 countries. However, in absolute terms the KEI has decreased from 8.51 in 2000 to 8.37 in 2012. Looking into the 4 constituents of the KEI: economic and institutional regime, education, ICT and innovation the following scores can be identified and it can be seen that Luxembourg scores badly on the education indicator.

	KEI	Ranking	Economic Incentive Regime	Rank	Innovation	Rank	Education	Rank	ICT	Rank
1995	8,42	10	9,23	8	8,92	13	6,08	39	9,45	7
2000	8,52	22	9,6	2	8,92	11	6,38	34	9,14	9
2012	8,37	20	9,45	6	8,94	11	5,61	40	9,47	2

_Table 13: KEI evolution (source: World Bank)

Dwelling deeper into the underlying variables, it turns out that, just as for NRI above, it is "tertiary" enrolment rate, collected from an UNESCO database, that the country scores worst and this leads to very low rank on this sub-index. Unfortunately, the situation does not seem to have improved over time.

Adult Literacy Rate (% age 15 and above), 2007	10.00
Average Years of Schooling, 2010	7.24
Average Years of Schooling, female, 2010	6.69
Gross Secondary Enrollment rate, 2009	7.31
Gross Tertiary Enrollment rate, 2009	2.27
Life Expectancy at Birth, 2009	8.97
Internet Access in Schools (1-7), 2010	8.85
Public Spending on Education as % of GDP, 2009	n/a
4th Grade Achievement in Math(TIMSS), 2007	n/a
4th Grade Achievement in Science(TIMSS), 2007	n/a
8th Grade Achievement in Math(TIMSS), 2007	n/a
8th Grade Achievement in Science(TIMSS), 2007	n/a
Quality of Science and Math Education (1-7), 2010	6.87
Quality of Management Schools (1-7), 2010	5.57
15-year-olds' math literacy (PISA), 2009	5.74
15-year-olds' science literacy (PISA), 2009	4.43
School Enrollment, Secondary, Female (% gross), 2009	7.29
School Enrollment, Tertiary, Female (% gross), 2009	2.11
No Schooling, total, 2010	5.04
No Schooling, female, 2010	5.20
Secondary School completion ,total (% of pop 15+), 2010	6.93
Secondary School completion ,female (% of pop 15+), 2010	7.09
Tertiary School completion ,total (% of pop 15+), 2010	6.69
Tertiary School completion ,female (% of pop 15+), 2010	6.69

_Table 14: Educational Assessment Variables and scores (source: World Bank)

49_http://www.luxembourgforfinance.lu/psf accessed 17.7.2013

50_https://www.luxtrust.lu/en accessed 17.7.2013

51_http://epp.eurostat.ec.europa.eu/statistics_explained/index.php/GDP_per_capita,_consumption_per_capita_and_price_level_indices accessed 17.7.2013

52_http://www.ripe.net/ripe/docs/ripe-592 accessed 17.7.2013

53_http://www.worldipv6launch.org/ accessed 17.7.2013

54_http://www.apnic.net/services/services-apnic-provides/helpdesk/faqs/asn-faqs accessed 17.7.2013

55_http://www.iana.org/domains/root/db accessed 17.7.2013

56_http://www.dns.lu/ accessed 17.7.2013

On the other hand, the country scores world-wide second in terms of ICT access and infrastructures, which is in line with the findings from WEF and ITU and almost stable on the other two sub-indexes.

4.4_ Commercial organisations

4.4.1_ The "Booz&Co" Digitisation Index

A first set of results has been presented recently at the EURO-CRP 2013[57] conference. This puts Luxembourg amongst the top performers – the so-called "advanced" countries

Unfortunately, the breakdown according to the different sub-indices is not publicly available. In particular it would have been useful to have access to the "skills" subindex.

When looking at the correlation between GDP/capita and DI, however, it can be seen that Luxembourg does actually score below what would be expected given its top position in terms of GDP per capita.

4.4.2_ Cisco Broadband Quality Score

Luxembourg was included in this assessment from 2008 to 2010. In 2008 and 2009, Luxembourg was classified into

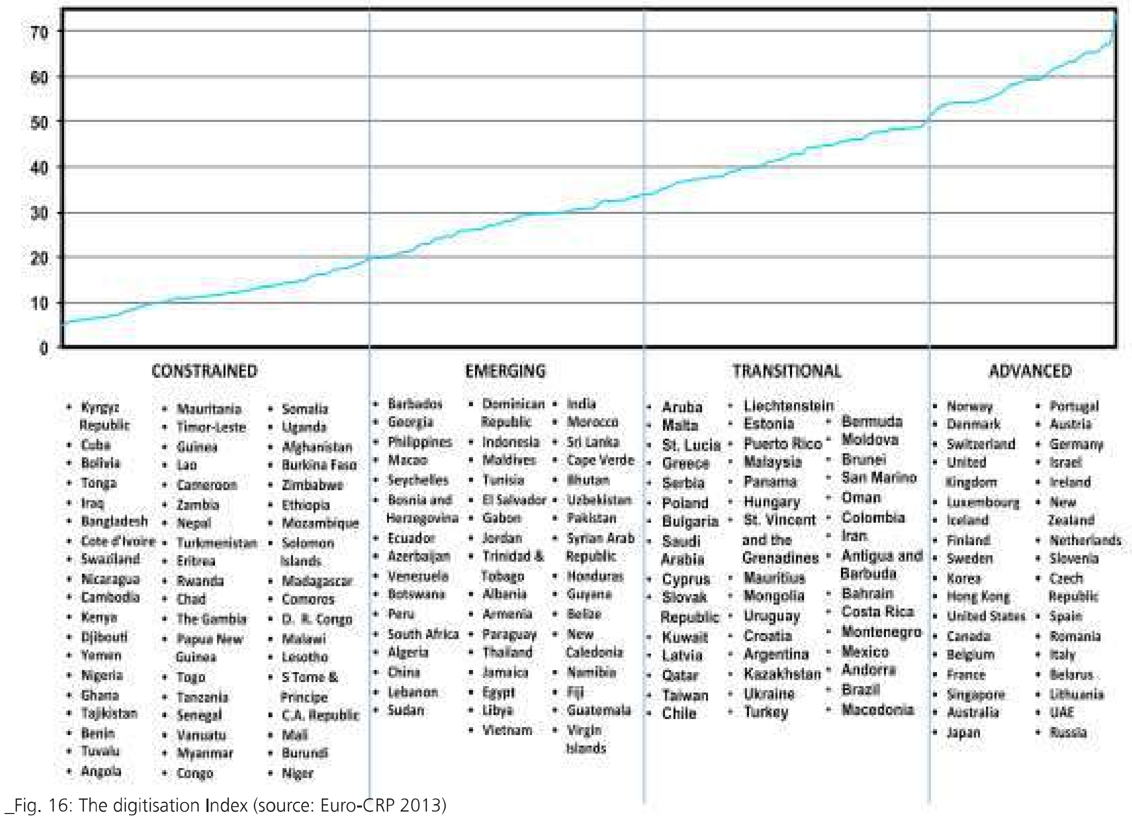

_Fig. 16: The digitisation Index (source: Euro-CRP 2013)

In 2011, Luxembourg scored third amongst the EU27 countries just behind Denmark and the UK. It scored 7th on a global scale with a score of 65 which is 10 above the EU27 average. Looking at the development between 2004 and 2010, its score has improved by 224% which shows that the initiatives that have been taken in terms of infrastructure have been successful.

"ready for today's applications" countries with ranks 30 and 24 respectively – a good improvement in only one year. In 2010, Luxembourg was classified into "ready for today's applications" but qualified as a "broadband leader" with rank 7 amongst "innovation economies" and rank 16 in terms of mobile broadband. Again this seems to indicate a good improvement. However, it should be noted that about 14

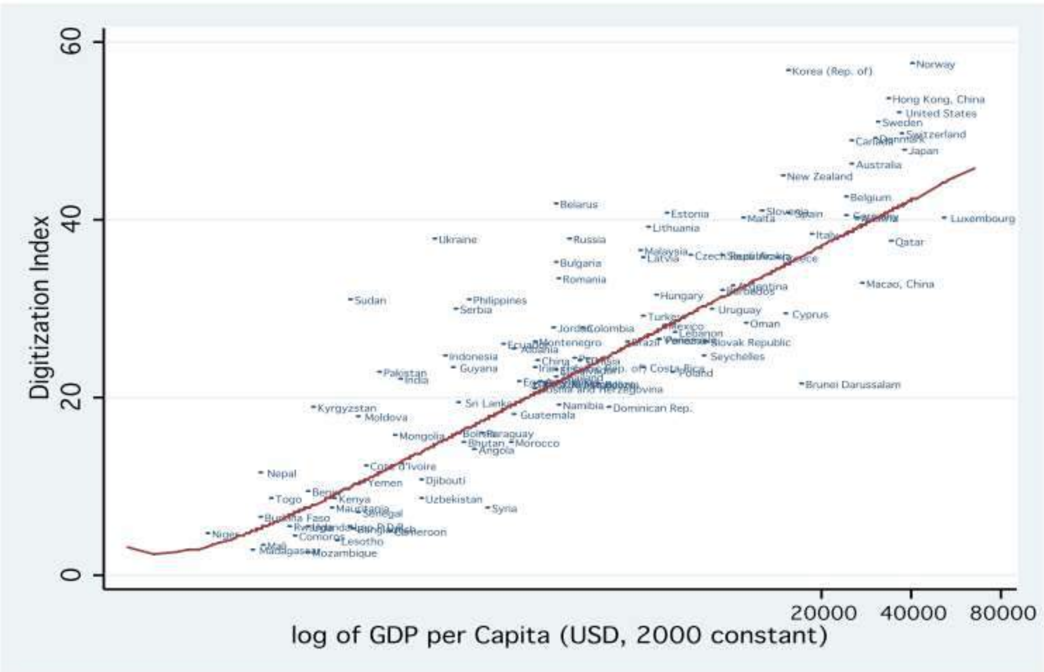

_Fig. 17: Correlation GDP-Capita/DI (source: Euro-CRP 2013)

57_http://www.eurocpr.org/ accessed 18.7.2013 countries were classified into "ready for tomorrow's applications" as opposed to only 1 in 2008 which suggests an overall improvements amongst many countries. The BQS therefore suggests some improvements but it is not clear whether these did actually happen or whether it was just a change in the methodology. Unfortunately, there is not enough information available about the underlying methodology to come up with a more precise view.

4.5_ Measuring the internet

In addition to these ad-hoc indicators, it is also interesting to look at Netindex values which are collected on a rolling yearly basis. No information is available for Luxembourg in terms of quality index. All other indicators are available with about 550 samples collected over the last year. This gives in indication for the overall available downlink and uplink speed, the relative costs of services and the so-called "promise", meaning the ratio between speed advertised by operators and those actually achieved. As expected, Luxembourg, because of its high GDP/capita, ranks very well on the cost indicators and ranks amongst the top 10 countries for uplink and 12th for downlink speeds. In terms of the promise index, there is still room for improvement with rank 44. Of course, these values need to be treated with care as they can change on a daily basis – but they give a good, almost online indication about the broadband traffics actually achieved.

Download (Mbit/s)	31,5
Ranking	12
Upload (Mbit/s)	20,04
Raking	7
Relative cost of Broadband (% of GDP/Capita)	0,589
Ranking	1
Relative cost of Mbit/s	0,05%
Ranking	2
Household Promise Index (%)	83,21
Ranking	44

_Table 15: Netindex values for Luxembourg on the 14.7.2013 (source: Netindex)

In terms of the Akamai – state of the internet 2013 report, Luxembourg appears to score badly on the average available connection speed and even more so on the peak connection speed. This is surprising given the fact the underlying technical infrastructures are well developed and not in line with the Netindex assessment above. However, Akamai states in its comments that it only considers countries with more than 25.000 IP addresses that made request for content on their platforms. Therefore the figures might not be completely reliable as a lot depends on the actual web sites accessed. It should also be noted that the global average connection speed was identified as 3.1 Mbps and the global average peak connection speed at 18.4 Mbps both values being far lower that the results for Luxembourg.

Country	Average connection speed (Mbps)	Country	Peak Connection Speed (Mbps)
Switzerland	10,1	Romania	47,9
Netherlands	9,9	Switzerland	40,3
Czech Republic	9,6	Netherlands	38,2
Sweden	8,9	Belgium	38
Denmark	8,3	United Kingdom	36,3
Austria	7,9	Hungary	35,9
United Kingdom	7,9	Czech Republic	35,5
Finland	7,7	Sweden	34,9
Romania	7,5	Portugal	34,5
Belgium	7,4	Poland	32,2
Norway	7,4	Spain	31,3
Ireland	7,3	Ireland	30,9
Germany	6,9	Germany	30,8
Hungary	6,6	Austria	30,6
Slovakia	6,4	Denmark	29,5
Iceland	6,3	Iceland	29,3
Poland	6,2	Russia	29,3
Russia	6	Finland	29,2
Luxembourg	5,3	Slovakia	29,1
Portugal	5,3	Norway	28,7
France	5,2	Greece	25,5
Spain	5,2	Turkey	25
Greece	4,7	France	23,5
Italy	4,4	Italy	21,8
Turkey	3,1	Luxembourg	21,5

_Table 16: Average and peak connection speeds to the Internet (source: Akamai)

4.6_ The efficiency of the national regulatory authority

4.6.1_ Telecommunications Regulation Index

Finally, it can be useful to have a look at the performance of the NRA according to the Polynomics Telecommunications Regulation Index. There are two versions of this index. The first, called RDI24, is focusing on "traditional fixed and mobile services", the second, called RDI37, also includes additional aspects for next generation networks.

The RDI24 is available as a time series starting in 1997 (Zenhäusern, Schneider, Berner, & Vaterlaus, 2012). Luxembourg presents a very low so called "regulation density"; actually it is the lowest (0.32) in the overall sample which includes all EU member states but also the US and Australia. This density has not evolved over the last 5 years. Cyprus, Slovenia and Spain present the highest regulator densities in the EU with a value of around (0.70).

On the RDI37, a time series is only available down to 2008 and it is again Luxembourg that presents the lowest regulatory density (0.26) of all of the countries considered in the study. Overall, it can also be seen, that the values for all of the NRAs are lower on the RDI37 as they have less experience in regulating NGA.

This could indicate that ILR takes an overall quite "laid-back" approach to its regulatory task and does not intervene very much in the market. More information would be needed in order to understand whether this due to a lack of resources or an intentional political approach to leave space market forces.

4.6.2_ Telecommunications Regulatory Governance Index

In terms of the Telecommunication Regulatory Governance Index (TRGI) (Waverman & Koutroumpis, 2011), Luxembourg scored 34 in the Global ranking and 19 for the regional rank in 2008. Only the new EU member states from Central and Eastern Europe performed less well.

This seems to confirm the findings in the Polynomics approach above although the underlying methodology is a completely different one. It can also be noted that compared to a relatively high "overall political transparency", Luxembourg scores poorly which could suggest that the regulator does less well than other Government agencies and the general economic governance in the country. Obviously, one would need to have access to more recent data and a time series in order to be able to draw more definite conclusions. It is also not clear which underlying factor (regulatory transparency, independence, resource availability or enforcement on licensees) contributes most to this low ranking.

5_ Summary of the major findings

In this chapter, the authors will summarise the main findings as they appear through the different indicators assessed above.

Not surprisingly, the telecommunications of Luxembourg is a very small one in absolute terms but the share of ICT both in terms of value added and jobs created is higher than in most other EU or OECD countries. Having said this, there is close to none ICT manufacturing, very little ICT R&D and the bulk of the revenues in the sector are generated through services. This might be linked to the importance of the financial sector (KPMG, 2012), (Bourgain, Pieretti, & Høj, 2009) for Luxembourg's economy overall (OECD, 2012a), a financial sector which is relying extensively on ICT.

The mobile telecommunications market is more important than the fixed network one and the gap between the two is continuing to grow. Internet access and broadband internet access are playing a major role and are well developed, consumers are attracted by triple and quadruple play service bundles, average monthly revenue per user is high, just as the overall telecommunications revenues (on a per capita basis), and they continue to grow.
In the mobile market, there is competition with 3 mobile 2G/3G/LTE operators, the fixed residential market is largely in the hand of the incumbent operator. For enterprise

customers, there is a growing competition in recent years but the incumbent also is the largest player this sector. 100% of the population has access to the internet, almost all homes are using a personal computer and wireless broadband using 2G/3G. Wireless Lan is present in the main population areas. Internet infrastructure is well developed in Luxembourg. Luxembourg scores very well on IPv6 deployment (Tadayoni & Henten, 2012), autonomous systems and country code Top Level Domains as well as on several "on-line" performance measures. Cable TV networks are also well developed in Luxembourg but they face a fierce competition by different IPTV services.

In line with Europe's 2020 goals, Luxembourg has defined an ultra-high broadband strategy based on fibre to the home roll-out and the incumbent has been given the mandate and the resources to build the underlying infrastructures. Recently, these resources have even been extended in an effort to stimulate the local economy with a so-called "Marshall Plan" (Di Pillo, 2013), (Cortey, 2013).

In the period between 2005 and 2009, Luxembourg did lose out in terms of its position in international rankings as can be documented by the NRI and IDI. The Government did put in place several actions to develop Luxembourg's international connectivity and create datacentre capacity (Binsfeld et al., 2013). This has positioned Luxembourg as one of the world's largest providers of TierIV datacentre capacity and has led to excellent broadband connectivity to the main European Peering Hubs.

Considerable improvements can be noted on both indices in recent years as a consequence. This is confirmed also by the DAE scoreboard, by the digitisation index and by regular measurements directly on the internet. Access to the internet and the underlying infrastructure is not a problem in Luxembourg anymore, the technological issues have been addressed successfully.

In terms of affordability, the situation is less positive as prices for many ICT services are still towards the higher range compared to other EU or OECD countries. In many indicators, this does not become visible because prices are often measured as a percentage of GDP/capita or GNI/capita. On an absolute basis however, the situation is not so favourable and ITU's IPB also shows that no substantial improvements have been made over time.

One reason behind these relatively high prices might be the very high investments that operators (mainly the incumbent) have made for a relatively small market. However, it could also be argued that it might be the lack of active competition that has allowed operators to keep their pricing levels high. This hypothesis might be confirmed by the very low ranking achieved by the national regulatory authority, in fact the lowest of all countries considered. This shows that the regulator has not been able or willing to intervene very much with the market forces.

Whilst almost all businesses and households make good use of the internet, e-commerce is not very well developed within Luxembourg and a large part of it is buying from international e-commerce providers. This could be explained by the small size of the country and the limited size of the market. However, Luxembourg does still have room for improvement in order to fully exploit its legal environment allowing it to set up e-commerce operations out of Luxembourg, other than offering an attractive "tax haven" to some international e-commerce players (Binsfeld et al., 2013).

More generally, Luxembourg appears to take some advantage out of its role as founding member of the EU, its geographical location and its small size that leads to a certain flexibility and as WEF calls it – its "vision for ICT". Thus it ranks world-wide first on the indicator "laws related to ICT". However, there are also some issues identified in terms of the number of processes to set up a company, the accessibility of authorities via the internet, the usage of electronic forms which appear to restrict somewhat these potential advantages.

A major issue identified in several indicators appears to be an inappropriate educational system and in particular a very low "tertiary enrolment rate". This has a major effect on both NRI and IDI rankings and is confirmed by the studies from World Bank.

It might well be that all 3 organisations are using the same underlying databases (from Unesco?) but nevertheless the issue appears to be serious one as shown for example by the several weaknesses that WEF has identified for Luxembourg's educational system, the very low rank on this specific sub-index in the IDI and in the KEI from World Bank. Even worse, no improvements seem to have been made over time in this respect but according to IDI the situation even got worse.

As a consequence, ICT skills need to be imported from neighbouring countries or even from abroad which gets increasingly more difficult and companies appear to have substantial difficulties to recruit skilled ICT workers.

6_ Conclusions and future work

Despite the many different limitations and methodological problems of measuring the information society, it was possible, using a wide range of different indicators and indices, to conduct an assessment of Luxembourg's ICT state of development, to gain a good understanding of its strengths and weaknesses and to answer the two research questions identified above:

_Luxembourg does position itself amongst the top performers in the EU and worldwide with regard to ICT. Its ICT sector is well developed and constitutes and important part of its economy.

_Luxembourg has been able, over the last decade or so, to improve this position and in particular was able to extend the underlying technical infrastructures and to develop the use of ICT and therefore overall its e-Readiness. It has not been successful, however, in improving the skills and educational aspects related to ICT.

However, the combined indicators above also have allowed to identify many additional important questions for which they do not provide the answers and which require additional work:

_Is the country's focus on TierIV datacentre capacity really appropriate, why does it have 20% of the world's overall capacity? Is there a deliberate decision by other countries not to focus on this category?

_Is it really necessary and economically sensible to roll-out a nationwide fibre to the home network given the fact that there is substantial cable TV network coverage in place already?

_Why is the regulation density so low in comparison with other OECD countries? Is this a lack of resources or a political decision?

_Why are businesses and individuals and the government not more actively using e-transactions and local e-commerce offerings?

_Is the country taking appropriate advantage from its "flexibility" ,small size and political vision?

_Is the country taking appropriate advantage from its relative "richness" with one of the highest GDP/capita in the world?

_What exactly is the issue with regards to education and skills? Are the country's university and research centres focussing on the "right" areas of competences? Is there a deeper underlying problem with the country's educational system? Or is it just a matter of reporting the "right" figures

Clearly these questions can't be addressed on a purely technical or ICT level. They have to be looked at from the wider socio-economic perspective.

Whilst this might be achieved on a purely quantitative basis by making use of a wider range of indices and assessment framework as presented for example in Bandura (2008) or Taylor & Cui (2011), the authors' believe it will also be necessary to collect qualitative information directly from the different stakeholders involved in order to gain a deeper understanding and to be able to address at least some of issues which might be essential for Luxembourg's long-term well-being.

Bibliography

Airoldi, M.-J. (2012). Le comportement des Luxembourgeois face aux nouvelles technologies de l'information et la communication depuis le début des années 60 (Le Luxembourg 1960-2010). Luxembourg. Retrieved from www.statec.public.lu

Akamai. (2013). The State of the Internet 2013 (Vol. 6).

Annoni, P., Weziak-Bialowolska, D., & Nardo, M. (2012). Assessment of the Web Index uncertainty analysis. JRC Scientific and Policy Reports (Vol. EUR 25476).

Arbor Networks. (2012). Infrastructure Security Report 2012 Volume VIII (Vol. VIII).

Bandura, R. (2008). A Survey of Composite Indices Measuring Country Performance : 2008 Update. New York. Retrieved from http://web.undp.org/developmentstudies/docs/indices_2008_bandura.pdf

Bauer, S., Clark, D., & Lehr, W. (2010). Understanding broadband speed measurements (MITAS Working Paper).

Bilbao-Osorio, B., Dutta, S., & Lavin, B. (Eds.). (2013). The Global Information Technology Report 2013 Growth and Jobs in a Hyperconnected World (2013th ed.). Geneva: World Economic Forum.

Binsfeld, N., Whalley, J., & Pugalis, L. (2013). Luxembourg – a bastion of state-ownership in Europe. International Telecommunications Society Regional Conference. Brussels.

Bourgain, A., Pieretti, P., & Høj, J. (2009). Can the Financial Sector continue to be the Main Growth Engine in Luxembourg ? (OECD Economics Department Working Papers No. 660). Paris. Retrieved from www.oecd.org

Chen, D. H. C., & Dahlman, C. J. (2005). The Knowledge Economy , the KAM Methodology and World Bank Operations.

Cisco & Saïd Busines School. (2008). Broadband Quality Score A global study of broadband quality 2009.

Cisco & Saïd Busines School. (2010). Broadband quality score 2010.

Cortey, L. (2013, June 20). Le Luxembourg monte en puissance. Luxemburger Wort, p. 49. Luxembourg.

Cruz-Jesus, F., Oliveira, T., & Bacao, F. (2012). Digital divide across the European Union. Information & Management, 49(6), 278–291. http://doi.org/10.1016/j.im.2012.09.003

Di Pillo, N. (2013, May 10). 2,5 milliards d'euros à investir. Luxemburger Wort, p. 69. Luxembourg.

Dutta, S., & Bilboa-Osoria, B. (2012). The Global Information Technology Report 2012 Living in a Hyperconnected World. (S. Dutta & B. Bilbao-Osorio, Eds.). World Economic forum.

Dutta, S., Lavin, B., & Fiona, P. (2003). Global Information Technology Report 2002-2003: Readiness for the Networked World. Oxford University Press. Retrieved from http://ictlogy.net/bibliography/reports/projects.php?idp=401

EIU. (2010). Digital economy rankings 2010 Beyond e-readiness. Retrieved from http://www.eiu.com/site_info.asp?info_name=digitaleconomy_2010

Empirica. (2002). SIBIS Highlights 2002.

Empirica. (2003). SIBIS Pocket Book 2002/03.

European Commission. (1990). Directive on competition in the markets for telecommunications services. Brussels: EC. Retrieved from http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:1990:192:0010:0016:EN:PDF

European Commission. (2003). SIBIS New eEurope Indicator Handbook.

European Commission. (2009). Europe's Digital Competitivenss Report i2010 - ICT country profiles (Vol. 2).

European Commission. (2010a). A Digital Agenda for Europe. EU.

European Commission. (2010b). Europe's Digital Competitiveness Report 2010.

European Commission. (2010c). Implementation Reports. Retrieved from http://ec.europa.eu/information_society/policy/ecomm/library/communications_reports/index_en.htm

European Commission. (2011). Digital Agenda Scoreboard 2011.

European Commission. (2012a). Digital Agenda Scoreboard 2012.

European Commission. (2012b). Telecommunication Market and Regulatory Developments Luxembourg 2011.

European Commission. (2013a). Broadband coverage in Europe in 2011. Brussels. Retrieved from http://point-topic.com/wp-content/uploads/2013/11/Point-Topic-Broadband-Coverage-in-Europe-in-2012-Final-Report-20130813.pdf?utm_campaign=EU_publishes_Broadband_Coverage_in_Europe_study&utm_medium=Email&utm_source=CM_pointtopic

European Commission. (2013b). Digital Agenda Scoreboard 2013.

European Commission. (2013c). Digital Agenda Scoreboard 2013 Electronic communications market indicators : Definitions , methodology and footnotes on Member States. Brussels.

European Commission. (2013d). Digital Agenda Scoreboard key indicators. Retrieved from http://digital-agenda-data.eu/datasets/digital_agenda_scoreboard_key_indicators/indicators

Eurostat. (2011). Implementing core variable in EU social survey - methodological guidelines (Vol. 12).

Eurostat. (2012). Information society statistics. Retrieved from http://epp.eurostat.ec.europa.eu/statistics_explained/index.php/Information_society_statistics

Eurostat. (2013). Methodological Manual for statistics on the information society. Retrieved from http://epp.eurostat.ec.europa.eu/portal/page/portal/information_society/introduction

Friedrich, R., Stroh, S., & Vollmer, C. (2012). The 2012 Industry Digitization Index.

Frising, A. (2013). Regards sur les internautes au Luxembourg et dans l'UE27 (Regards No. Mai 2013). Luxembourg. Retrieved from http://www.statistiques.public.lu/fr/actualites/conditions-sociales/conditions-vie/2013/05/20130515/index.html?from=rss

Frising, A., & Niclou, P. (2012). Regards sur les technologies de l ' information et de la communication dans les ménages. Luxembourg. Retrieved from www.statistiques.lu

Goswami, D. (2006a). A review of the Network Readiness Index. Retrieved from www.regulateonline.org

Goswami, D. (2006b). Report on Workshop on ICT Indicators for Benchmarking Performance in Network and Services Development.

Hair, J. F., Black, W. C., Babin, B. J., & Anderson, R. E. (2010). Multivariate Data Analysis - a global perspective (7th ed.). Upper Saddle River, New Jersey: Pearson Education.

Hüsing, T. (2004). THE IMPACT OF ICT ON SOCIAL COHESION : LOOKING BEYOND THE DIGITAL DIVIDE.

Hüsing, T., & Selhofer, H. (2004). DIDIX : A D IGITAL D IVIDE I NDEX FOR M EASURING I NEQUALITY IN IT D IFFUSION. IT&Society, 1(7), 21–38. Retrieved from www.itandsociety.org

i2010 High Level Group. (2009). Benchmarking Digital Europe 2011-2015.

ILR. (2004a). Rapport statistique année 2003. Luxembourg. Retrieved from www.public.ilr.lu

ILR. (2004b). Rapport statistique succinct Année 2004. Luxembourg. Retrieved from www.public.ilr.lu

ILR. (2005). Rapport statistique des télécommunications au Luxembourg pour l'année 2005. Luxembourg. Retrieved from www.public.ilr.lu

ILR. (2006). Rapport statistique des télécommunications au Luxembourg pour l ' année 2006. Luxembourg. Retrieved from www.public.ilr.lu

ILR. (2007). Rapport statistique des télécommunications au Luxembourg pour l'année 2007. Luxembourg. Retrieved from www.public.ilr.lu

ILR. (2008). Rapport statistique des télécommunications Luxembourg pour l ' année 2008. Luxembourg. Retrieved from www.public.ilr.lu

ILR. (2009). Rapport statistique des télécommunications Luxembourg pour l'année 2009. Luxembourg. Retrieved from www.public.ilr.lu

ILR. (2010). Rapport statistique des télécommunications au Luxembourg pour l ' année 2010. Luxembourg. Retrieved from www.public.ilr.lu

ILR. (2011). Rapport statistique des télécommunications du Luxembourg de l'année 2011. Luxembourg. Retrieved from www.public.ilr.lu

ILR. (2012). Registre public des entreprises notifiées fournissant des services aux consommateurs. Luxembourg.

ILR. (2013). Rapport statistique des télécommunications du Luxembourg de l'année 2012. Luxembourg. Retrieved from http://www.ilr.public.lu/communications_electroniques/statistiques/rapp_statistiques_ILR/2012_rapport_statistique_final1.pdf

INSEAD. (2005). eEurope2005 A study of the degree of alignment of the new member states and the candidate countries. (INSEAD, Ed.). SAP. Retrieved from http://www.umic.pt/images/stories/publicacoes/Misc_ eEurope_2005.pdf

ITU. (2009). Measuring the Information Society 2009. Retrieved from http://www.itu.int/ITU-D/ict/publications/idi/

ITU. (2010). Measuring the Information Society 2010. Retrieved from http://www.itu.int/ITU-D/ict/publications/idi/

ITU. (2011a). Handbook for the collection of administrative data on Telecommunications/ICT (2011th ed.). Geneva. Retrieved from http://www.itu.int/dms_pub/itu-d/opb/ind/D-IND-ITC_IND_HBK-2011-PDF-E.pdf

ITU. (2011b). Measuring the Information Society 2011. Retrieved from http://www.itu.int/ITU-D/ict/publications/idi/

ITU. (2011c). Measuring the WSIS targets - a statistical framework. Geneva.

ITU. (2012). Measuring the Information Society 2012. Retrieved from http://www.itu.int/ITU-D/ict/publications/idi/

Katz, R. L. (2013). Using a Digitization Index to measure the Economic and Social Impact of Digital Agendas. In Euro CRP 2013 A digital agenda in search of evidence: Issues and Trends Brussels, Belgium March 21 (Vol. 2013).

Katz, R. L., & Koutroumpis, P. (2013). Measuring digitization: A growth and welfare multiplier. Technovation, 0–5. http://doi.org/10.1016/j.technovation.2013.06.004

KPMG. (2012). Luxembourg Banks Insights 2012. Luxembourg.

Lehr, W. (2012). Measuring the Internet THE DATA CHALLENGE (OECD Digital Economy Papers No. 194). Paris. Retrieved from http://dx.doi.

org/10.1787/5k9bhk5fzvzx-en

Luyt, B. (2006). Defining the digital divide: the role of e-readiness indicators. Asib Proceedings, 58(4), 276–291. http://doi.org/10.1108/00012530610687669

Mas, M., Robledo, J. C., & Perez, J. (2012). ICT Sector Definition Transition from NACE Rev . 1 . 1 to NACE Rev . 2 A Methodological Note. Luxembourg. Retrieved from http://ipts.jrc.ec.europa.eu/publications/pub.cfm?id=5919

Menou, M. J., & Taylor, R. D. (2006). A "Grand Challenge": Measuring Information Societies. The Information Society, 22(5), 261–267. http://doi.org/10.1080/01972240600903904

OECD. (1999). Communications Outlook 1999.

OECD. (2000). Information Technology Outlook 2000.

OECD. (2001). Communications Outlook 2001.

OECD. (2002). Information Technology Outlook 2002.

OECD. (2003). Communications Outlook 2003.

OECD. (2004). Information Technology Outlook 2004 (Information Technology Outlook). OECD Publishing. Retrieved from http://www.oecd-ilibrary.org/science-and-technology/information-technology-outlook-2004_it_outlook-2004-en

OECD. (2005). Communications Outlook 2005.

OECD. (2006). Information Technology Outlook 2006 (Information Technology Outlook). OECD Publishing. Retrieved from http://www.oecd-ilibrary.org/science-and-technology/oecd-information-technology-outlook-2006_it_outlook-2006-en

OECD. (2007). Communications Outlook 2007.

OECD. (2008). Information Technology Outlook 2008 (Information Technology Outlook). OECD Publishing. Retrieved from http://www.oecd-ilibrary.org/science-and-technology/oecd-information-technology-outlook-2008_it_outlook-2008-en

OECD. (2009). Communications Outlook 2009 (OECD Communications Outlook). OECD Publishing. Retrieved from http://www.oecd-ilibrary.org/science-and-technology/oecd-communications-outlook-2009_comms_outlook-2009-en

OECD. (2010). Information Technology Outlook 2010. OECD Publishing. http://doi.org/10.1787/it_outlook-2010-en

OECD. (2011a). OECD Communications Outlook 2011. Paris: OECD Publishing. Retrieved from http://dwmw.files.wordpress.com/2011/06/oecd-commoutlook-2011.pdf

OECD. (2011b). OECD Guide to Measuring the Information Society 2011. OECD Publishing. http://doi.org/10.1787/9789264113541-en

OECD. (2012a). OECD Economic Surveys: Luxembourg 2012. Paris, Paris: OECD Publishing. http://doi.org/http://dx.doi.org/10.1787/eco_surveys-lux-2015-en

OECD. (2012b). OECD Internet Economy Outlook 2012. OECD Publishing. http://doi.org/10.1787/9789264086463-en

OECD. (2013). Communications Outlook 2013 (OECD Communications Outlook). OECD Publishing. Retrieved from http://www.oecd-ilibrary.org/science-and-technology/oecd-communications-outlook-2013_comms_outlook-2013-en

Partnership on measuring ICT for development. (2012). PARTNERSHIP ON MEASURING ICT FOR DEVELOPMENT.

Polynomics. (2012a). Management Summary of the Study Report Polynomics Regulation Index 2012.

Polynomics. (2012b). Manual for the Polynomics Regulation Index 2012 Data Set.

RTR. (2011). Messung von informatorischer und technologischer Reife. Schriftenreihe Der Rundfunk and Telekom Regulierungs GmbH, 1, 156. Retrieved from www.kig.gv.at/Portal.Node/kig/public/Content/files/berichte/NRI.pdf

Sabbagh, K., Pattheeuws, S., Moe, T., Peterson, M., Gillies, S., & Vollmer, C. (2012). Maximizing the Impact of Digitization. Retrieved from www.booz.com

Sandvine. (2013). Global Internet Phenomena Report. Retrieved from www.sandvine.com

Schmitz, F., Drevon, G., & Gerber, P. (2012). La mobilité des frontaliers du Luxembourg : dynamiques et perspectives. LES CAHIERS DU CEPS / INSTEAD. Luxembourg.

Selhofer, H., & Hüsing, T. (2002). THE DIGITAL DIVIDE INDEX – A MEASURE OF SOCIAL INEQUALITIES IN THE ADOPTION OF ICT. In International Telecommunications Society Regional Confernce Copenhagen.

Service des Médias et des Communications. (2013). Luxembourg & ICT - a snapshot. Luxembourg. Retrieved from http://ict.investinluxembourg.lu/ict/luxembourg-and-ict-a-snapshot

SMC. (2009). Plan d'action national en matière de TIC et de haut-débit. Luxembourg.

SMC. (2010). Stratégie nationale pour les réseaux à « ultra-haut » débit. Luxembourg. Retrieved from http://www.mediacom.public.lu/institutions/Institutions_nationales/smc/20100309_ngn/Strategie_nationale_pour_les_reseaux_a_ultra-haut_debit.pdf accessed 15th of January 2013

SMC. (2011). Stratégie nationale en matière de cyber sécurité. Retrieved from http://www.mediacom.public.lu/cybersecurity/Strat__gieCybersecurity_122011.pdf

Statec. (2012a). 2012 Répertoire systématique: Les entreprises luxembourgeoises. Luxembourg.

Statec. (2012b). Annuaire statistique. (STATEC, Ed.) (2013th ed.). Luxembourg. Retrieved from http://www.statistiques.public.lu/fr/publications/series/annuaire-stat-lux/index.html

Statec. (2012c). Luxembourg in Figures. Luxembourg. Retrieved from http://www.statistiques.public.lu/catalogue-publications/luxembourg-en-chiffres/luxembourg-figures.pdf

Tadayoni, R., & Henten, A. (2012). Transition from IPv4 to IPv6. In 23rd European Regional International Telecommunication Society conference; Vienna (pp. 1–19).

Taylor, R. D. (2006). The Nature and Measurement of Information: Two "Grand Challenges" for the field. In 16th Biennial Conference of the International Telecommunications Society. Beijing.

Taylor, R. D., & Cui, J. (2011). Does Happiness Matter ? What do We Want from the National Broadband Plan And How Will We Know if We Get It ? In Telecommunications Policy Research Conference Washington, D.C. (pp. 1–36).

Taylor, R. D., & Zhang, B. (2007). Measuring the Impact of ICT: theories of information and development. In Telecommunications Policy Research Conference, September 26-28, Washington DC (pp. 1–39).

The World Bank. (2008). Measuring knowledge in the world's economies.

The World Bank. (2012a). Knowledge Economy Index (KEI) 2012 Rankings.

The World Bank. (2012b). The Little Data Book on Information and Communication Technology 2012 (2012th ed.). World Bank Publications. http://doi.org/10.1596/978-0-8213-6973-9

UN. (2005a). Core ICT Indicators.

UN. (2005b). Measuring ICT: the global status of ICT indicators.

Waverman, L., Dasgupta, K., & Rajala, J. (2011). Connectivity Scorecard 2011. Retrieved from http://www.connectivityscorecard.org/images/uploads/media/TheConnectivityReport2011.pdf

Waverman, L., & Koutroumpis, P. (2011). Benchmarking telecoms regulation – The Telecommunications Regulatory Governance Index (TRGI). Telecommunications Policy, 35(5), 450–468. http://doi.org/10.1016/j.telpol.2011.03.006

World Economic Forum. (2008). The Lisbon Review 2008 Measuring Europe ' s Progress in Reform.

World Economic Forum. (2010). The Lisbon Review 2010 Towards a More Competitive Europe ?

World Summit on the Information Society. (2005). WSIS Thematic Meeting on " Measuring the Information Society ." Geneva-Tunis. Retrieved from http://www.itu.int/wsis/docs2/thematic/unctad/final-conclusions.PDF

Zenhaeusern, P. (2012). Scope of the Polynomics Regulation Index 2012.

Zenhaeusern, P., & Schneider, Y. (2012). Polynomics Telecommunication Regulation Index 2012. In 23rd European Regional International Telecommunication Society conference; Vienna (pp. 1–13). Vienna.

Zenhäusern, P., Schneider, Y., Berner, S., & Vaterlaus, S. (2012). Polynomics Regulation Index 2012. Olten (CH).

Ant, M., Goetzinger, P., & Binsfeld, N. (2016).

E-Skills Study - Strategies for the creation of a virtual e-skills training centre in Luxembourg. Luxembourg.

E-Skills Study

Strategies for the creation of a Virtual e-Skills Training Centre in Luxembourg

Marc Ant
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Final Report
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Partners

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1 Introduction

1.1 Context

The field of ICT (Information and Communication Technologies)[1] has become a very crucial and profoundly important element in our society. ICT has grown tremendously over recent decades and will continue to do so.[2] The reasons behind this progress are manifold and certainly due to an increasing competitiveness between companies, the beneficial effect of scientific research, as well as to technological innovations and advances, in conjunction with a political climate aiming at technological progress, economic development and job creation.

In the meantime, the Internet has become the cornerstone of the new ICT age, allowing communication not only between people, but also between devices or machines and people. As a consequence, we are nowadays living in a competitive and globalised world, in which everything is speeding up, and becoming more and more interrelated and complex.

In parallel, ICT has become the basic job creator in the European industry, as the digital economy is growing at seven times the rate of the rest of the economy.[3]

ICT is ubiquitous, supporting every industry and services sector, supporting and improving the capabilities and productivity of every economic activity, and potentially providing benefits to every home and individual.

But despite the tremendous progress the ICT industry has seen over the last several decades, expanding from plain old telephone services to advanced optical fibre and wireless technologies, the ICT industry remains immature with regard to its structure and self-concept, but with even more significant opportunities for innovation and growth in both the near and the distant future.

That is why not only companies but also more and more national governments as well as regional authorities are conceiving ICT strategies in order to facilitate innovation and development within their respective range of responsibility and activity. For any modern institution or organization, the presence of a robust ICT ecosystem is absolutely crucial and that is why direct and continuous public and private investment in ICT infrastructure, in market regulation, in ICT product commercialisation, and of course in research and development are essential for the development of future advanced products and services.

Gaining leadership of some sort in parts of the ICT sector will require active engagement and intensive collaboration between government administrations, research institutions and innovative enterprises and their representative bodies in order to create and animate an appropriate technological, legal and social framework as well as a positive climate to direct funds and initiatives into the right direction and to better coordinate and account for efforts across all actors.

However, all these developments and evolutions are based to a very large extend upon one particular factor: the ICT skilled human being.

Therefore, to create, develop and use this myriad of new technologies to their full potential, a large number of highly skilled workforce is required in order to take advantage of these new technologies efficiently.

Economic growth and development is in the meantime depending largely upon ICT (and much less on finance, as in previous years), which is by itself depending upon a highly skilled workforce.

A double issue thus confronts us: First, the demand for ICT professionals that prospers continuously, is facing an ever increasing shortage of skilled ICT workers. The biggest problem is therefore that professionals are missing in quantity and in quality. Despite the fact that the number

[1] Throughout this document, we will use the term ICT in its plural form, as we consider that ICT is made out of more than one technology.

[2] IDC (2014). *ICT trends 2020 – Main trends for information and communication technologies (ICT) and their implications for e-Leadership skills*. http://eskills-lead.eu/fileadmin/lead/reports/lead_-_technology_trends_-_august_2014_rev_sep1.pdf

[3] European Commission. (2014). *Digital agenda for Europe*. Luxembourg: Publications Office of the European Union. http://europa.eu/pol/pdf/flipbook/en/digital_agenda_en.pdf

of ICT practitioners has been growing in the past and will still continue to grow in the future, and despite the fact that the number of computer science graduates has again increased in the recent past, a significant decline has nevertheless been noticeable on the whole within Europe since 2005.[4]

We are facing a fundamental problem between offer and demand on the ICT job market, which has to be dealt with urgently in order to ensure the necessary economic growth.

But we must not forget that the issue is also to be seen from the qualitative point of view, as the active ICT workers are themselves confronted with the so-called half-life of knowledge (*Halbwertszeit des Wissens*), which is following Fullers[5] or Moore's[6] laws: Our knowledge of the world is constantly increasing and changing more and more rapidly, so that yesterdays innovation is todays out fashioned gadget.

This insight is particularly true for the world of ICT. Knowledge becomes more and more sophisticated and complex, and therefore obsolete faster and faster. It must therefore constantly be created and kept up to date, to avoid the risk of losing competitiveness, innovation, creativity and jobs.[7]

The question therefore is: What can we do about it in general, and in Luxembourg in particular.

1.2 Origin of the study: Skills centres of the crafts sector

The present study has emerged from a project initiated by the Luxembourg confederation of the crafts sector (*Fédération des Artisans*)[8] and which had as an objective to create the so-called skills centres of the crafts sector (*Centres de Compétences de l'Artisanat*).

The idea for the skills centres of the crafts sector is based on the insight that the quality of training is a key to the employability of the employees and, by extension, to the competitiveness of businesses. Faced with the significant shortcomings in this area, the crafts confederation, together with the craft federations, have decided in 2014 to launch new skills centres for continuing vocational training in the field of technical engineering of buildings and building completion.

With increased transborder competition, unprecedented technical and technological evolutions, skilled labour shortages, the crafts sector is facing enormous challenges that require responses that are quick, comprehensive and structured. However, the continuing vocational training system in place in Luxembourg does not fully meet the needs of the crafts sector and does not offer sufficient opportunities for the personnel development of its employees.

Given this situation, the *Federation des Artisans* has decided to react in order to enrich, supplement and professionalize the existing continuing training activities in the crafts sector.

The goal of this initiative is therefore to create skills centres for continuing vocational training in the crafts sector.

These centres are intended to provide companies with collaborators through training that continuously responds to new technological, managerial and economic realities. They are in line with the governmental declaration and European programmes on sustainable construction and intelligent energy management. The centres focus on the trades of technical building engineering[9] and building completion[10].

The skills centres are in pursuit of three objectives: first creating a coherent and comprehensive sectorial continuing vocational training system, second ensuring an innovation monitoring system, and third investing in the solidarity economy.

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[4] Hüsing, T., & Korte, W.B. (2010). *Evaluation of the implementation of the communication of the European Commission E-skills for the 21st century.* Bonn: Empirica.

[5] Buckminster Fuller, R. (1981). *Critical Path*. New York: St Martin's Press.

[6] Moore, G.E. (1965). Cramming more components onto integrated circuits. *Electronics*, 38, 8, p. 114–117.

[7] Arbesman, S. (2013). *The Half-Life of Facts.* London: Aurum.

[8] www.fda.lu

[9] www.cdc-gtb.lu

[10] www.cdc-par.lu

The training system is intended for employees of small crafts businesses and includes basic sectorial training, vocational development and high-level specialization. The structure of this system complies with the European Qualifications Framework (EQF) and allows a continuous progression of the employees throughout their career, that is to say from the base level (EQF 1) to the mastery of knowledge and to advanced and specialized skills (EQF 5-7).

Focused on a triad knowledge-skills-attitudes, a skills reference system has been put into place for some thirty crafts professions in technical building engineering and completion. This system represents a structured and consistent framework to the employer, while providing increased vertical and horizontal mobility opportunities for employees.

The part related to innovation is not limited to the analysis of trends or to the dissemination of innovative knowledge, but also integrates the tools to implement the most advanced technical and technological developments in the crafts enterprises of the country.

Finally, the solidarity dimension is to enhance the professional integration of people excluded from the labour market or youth attracted to crafts.

To ensure the financing of the skills centres, an unprecedented alliance for an innovative project has been achieved, foreseeing that the crafts enterprises of the two sectors technical building engineering and building completion will invest annually 0,5% of their total payroll in training measures in favour of their employees.

To generalize this principle of shared financing of training in the artisanal sector, the *Federation des Artisans* has concluded with the representative unions OGB-L and LCGB on the 3rd of July 2015 an interprofessional agreement, which is establishing and structuring a coherent sectorial vocational training system.

Based on an equitable partnership, a joint management committee was set up to provide institutional support to the skills centres.

With the support from the Ministry of Economy, it is planned to build a new training centre for the crafts sector at Krakelshaff in Bettembourg.

By the fact of creating structured training programmes though vertical and horizontal channels (from beginner to master), it then becomes possible to establish a genuine system of lifelong learning. The vision is here to set up an open, flexible and permeable training system that meets the expectations of both crafts businesses and their employees.

1.3 Extension to the ICT sector

Originally, it was foreseen to include the professions and companies that are active in the following businesses: electronics in communications and IT, installation of alarm, surveillance and security systems, telephony systems and applications, computer network architecture, low-voltage systems, ... This sector is represented by the crafts federation called *Fédération des Intégrateurs.*[11]

But as the concept of the skills centres evolved, the responsible actors of the *Fédération des Intégrateurs*, in conjunction with the project team, had increasingly difficulties to add the specificities of this particular sector to the intended skills centres.

As no satisfying solution could be found on this level and as the model of the skills centres had been conceived as an open system applicable to other vocational areas, it has been decided by the committee of the *Fédération des Intégrateurs* to reflect upon the opportunity to create a specific skills centre for ICT professions and to extend at the same time the project to other actors within the Luxembourg ICT sector, as for instance the association *ICT Luxembourg*[12], which works as a coordination platform for the trade associations representing the ICT sector in Luxembourg, and the newly created *House of Training*[13] as the training institution for the industrial, services and banking sectors.

[11] www.fdi.lu
[12] www.ictluxembourg.lu
[13] www.houseoftraining.lu

More or less at the same time (second half 2014), the Luxembourg Government had launched its *Digital Lëtzebuerg*[14] initiative, whose aim it is to strengthen and consolidate in the long term the country's position in the ICT field, while the guiding principle behind this initiative is to diversify the economy to the benefit of the citizens and of all socio-economic sectors.

Finally, the four actors, *Fédération des Intégrateurs, ICT Luxembourg*, the Ministry of Communication and Media and the Ministry of the Economy, had agreed to support technically and financially this study in order to fathom the opportunity to create a distinct skills centre for ICT or e-skills in Luxembourg. The Ministry of Labour expressed their demand of streamlining the training offer in the ICT sector in Luxembourg by applying the newly developed EQF-framework to existing und upcoming suppliers of training. The Agency for Employment (ADEM) supported the study with data input and invited the ICT centre to design a specific Fit for ICT programme for unemployed people in Luxembourg.

1.4 Objectives of the study

As a result of the interactions between the above mentioned partners and ICT actors, it has been decided to reflect upon the opportunities to create a specific ICT skills centre in order to structure the training offer and demand in the ICT sector in Luxembourg and beyond. For this reason, the present ICT study has been commissioned by the *Fédération des Intégrateurs, ICT Luxembourg*, the Ministry of the Economy and the Ministry of Communication and Media.

The study was realised on the behalf of these partners by *Sustain SA* and *Centre de compétences GTB*.

The precise objectives of this study are the following:

Module 1:
To identify the fields of opportunities within ICT in the framework of the horizon 2020.

Module 2:
To identify, describe and analyse relevant ICT professions and their associated skills

Module 3:
To elaborate a model for an e-Skills training centre

Module 4:
To define an action plan concerning the creation of an e-Skills training centre

The beneficiaries of this study are first its sponsors, i.e. the *Fédération des Intégrateurs*, the Ministry of Communication and Media and the Ministry of the Economy, second the professional associations active in the field of ICT, and third the companies in the field of ICT themselves.

The study was supervised by a steering committee composed of the following members:

Claudine Kariger
Laurent Solazzi
Gerard Hoffmann
Vincent Lekens
Romain Schmit
Eric Busch

[14] www.gouvernement.lu/4103901/20-digital-letzebuerg

As a methodological framework, the study referred to desk research, interviews and several workshops, inviting representatives from the following associations: Ministère de l'Etat, Ministère de l'Economie, Ministère du Travail, FdI, ICT Luxembourg, Fedil ICT, Luxinnovation, APSI, ABBL, ADEM, ...

1.5 Structure

In this report, we are first analysing the remarkable global trends and developments in the field of ICT, followed by an analysis of the ICT situation in Luxembourg and the carving out of potential best strategies in this field for the country.

In a second part, we will develop and recommend an ICT job profile and competence reference system describing the requested skills for each identified ICT profession.

In a third part we develop and recommend a concept and structure for a virtual ICT skills centre in Luxembourg.

The final structure of this report therefore pursues the following route:

1. Identification, description and analysis of general trends and future developments in the field of ICT and of e-skills.
2. Identification, description and analysis of ICT job families and skills reference systems.
3. Extraction of appropriate skill profiles.
4. Elaboration of a model of a virtual e-skills training system.
5. Definition of an action plan for the implementation of the virtual e-skills training system.

1.6 Project team

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2 ICT in the world

2.1 The age of the information and communication technologies

Eric Schmidt[15], chairman of Google, proclaimed in his 2015 World Economic Forum blog that the best inventions are never finished. And indeed, who would have thought in the 1870ties that the invention of a combustion engine automobile by Karl Benz would lead to a global industry, selling millions of cars a year. Or were the contemporaries of the Wright brothers at the beginning of the 20th century able to foresee that the consequence of their first human flight of 12 seconds would lead today to the hopping on and off of millions of passengers on airplanes to fly around the world for vacation or for business - as easy almost as taking a bus or a metro? Did the German mathematician-philosopher Gottfried Wilhelm von Leibniz think about the information society when he designed his calculating machine - the Step Reckoner - in 1671? Or, could Lady Ada Lovelace[16], the English mathematician who identified the first algorithm, together with Charles Babbage's analytical machine[17], have imagined that today the world without computers and programmes would not work anymore? And what about the pre-emption of our present cloud and big data society by Alan Turing[18] and John von Neumann[19], despite their extraordinary intellectual capabilities?

In any case, the contributions of all these pioneers could not have had this major effect upon our societies, if there had not been other inventors and innovators that had been striving over years to further develop and expand their original ideas, to add new features, new techniques and lately new technologies. In terms of innovation, these basic techniques and technologies have led to the rise of the latest long-run macroeconomic wave of technological revolutions, described as the latest Kondratieff-cycle[20], named after this Soviet economist of one hundred years ago, and subsequent to the following predecessors:

1. the age of the first industrial revolution (late 18th century);
2. the age of steam and railways (early 19th century);
3. the age of steel and heavy engineering (late 19th century);
4. the age of oil, electricity, automobile industry (early 20th century);
5. until finally the present age of the information and telecommunications industry (late 20th, early 21st century).

This evolution corresponds to an iterative process, which can be characterised as being complex, emergent, contingent, dynamic, changing, accelerated, relative, probable and competitive. It is driven by the instalment of add-ons and improvements, by expansion and development, by disruption, by research, innovation and application, and of course also by marketing and sales, as the economic dimension of these processes should not be forgotten.

In the end, these new technologies aim at helping to make life simpler or more viable for people, businesses and communities, and they contribute to increase the availability of things in terms of volume, velocity, variety or even veracity.

In that sense, the history of technical and technological development is and will still be an endless story, a venture with almost no limits.

Today, the latest Kondratieff-cycle is mainly associated with the terms digital revolution, Internet, cloud computing, big data, smart services, industry 4.0, Internet of things, innovative ecosystems, ...,

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[15] agenda.weforum.org/2015/01/why-the-best-inventions-are-never-finished/

[16] Lethbridge, L. (2001). *Ada Lovelace - The computer wizard of the victorian England*. London: Faber&Faber.

[17] Swade, D. (2001). *The Difference Engine: Charles Babbage and the Quest to Build the First Computer*. New York: Viking.

[18] Turing, A. (1937). On Computable Numbers, with an Application to the Entscheidungsproblem. In *Proceedings of the London Mathematical Society*. 42, 230–265.[19] Neumann, J.v. (1958/2000). *The computer and the brain*. New Haven: Yale University Press.

[19] Neumann, J.v. (1958/2000). *The computer and the brain*. New Haven: Yale University Press.

[20] Händeler, E. (2011). *Kondratieffs Gedankenwelt - Die Chancen im Wandel zur Wissensgesellschaft*. 5. vollst. überar. Aufl. Moers: Marlon.

and some protagonists of this discourse profess their conviction that this evolution could be regarded upon as the solution to all our global and local problems - under the condition to grant full access to broadband Internet to everyone, of course.

This very optimistic setting is counterbalanced by a more pessimistic viewpoint, denying the generalisation of the blessings of the broadband Internet, its associated technologies and applications. It is indeed unlikely that the emergent changes will not create a darker side of things, as referred to by the economists Brynjolfsson & McAfee[21] or the Nobel-Prize winner Robert. J. Schiller[22], as it is feared that the social gap between those who have knowledge and access to these tools and those who don't, will ever increase.

In any case, the computer and Internet age has changed our ways of life more fundamentally and more rapidly than any other revolution before and we are far from solving all our problems through this. On the contrary, the digital revolution will create both winners - those who will be able to adapt rapidly, those who are in the right business and in the right professions, those who are able and willing to ensure a permanent updating of their knowledge and skills - and losers. What about those workers whose jobs will be permanently replaced by computers and robots, such as professional drivers through self driving car und trucks, or even teachers through MOOCs?

We are in a phase of total disruption: old settings are wiped away, long-standing traditions in society and business models in economy are made obsolete and replaced by intellectually demanding alternatives, only understood by experts any longer. And by the time we have learned a new application, f.ex. Facebook, we need to move on to the next one, f.ex. Whatsapp, and so on. It seems as if algorithms were supplanting people - we are anxiously waiting for the moment of singularity to occur, i.e. the moment when machines such as computers, networks or robots will start to become intelligent and able to ensure an iterative self-improvement by designing and building their own and improved spring-offs.[23]

This unprecedented disruption of the world must be faced. But how? Adrian Wooldridge[24], Management Editor of the Economist Research and Innovation, describes disruption as being driven ever faster by a host of forces - from the digital revolution to the rise of Asia to financial innovation - and going to grip constantly new industries such as education and healthcare, the way we work and live, and the way politicians have to lead their politics and policies. These changes are extremely profound, fast and simultaneous, different in substance from any previous technological revolution and they will evidently not only lead to new production and management techniques, but also to completely new ways of living and thinking.

The worlds of people's public management, participative politics, CSR, sustainability, frugal innovation or engineering, social and recurrent economies, etc., will clash even more with the demands of growth, profitability or return on investment. Whether we want it or not, whether we are able or not, the occurring revolutionary innovations will make us run faster even to stay in the same place, they will make us remain flexible, changeable, adaptable and adoptable in multi-facetted, permanent and iterative loops.

What is the solution? Of course, it is certainly no use and counterproductive to ignore the current evolution, but to let the current overrun us like a Tsunami would be equally fatal. It is therefore highly recommendable to accompany and to shape this process strategically. We have to live in local contexts on the basis of a global background, and we have to seek for compensations for the potential losers of the digital revolution - as it will nevertheless be improbable that a former truck driver will be transformed into a programming expert in logistics easily. The art and wisdom of dealing in the new age will be to reinforce the advantages of the digital revolution and to reduce its drawbacks to a minimum, while drawing appropriate lines through strategic thinking and acting, and

[21] Brynjolfsson, E. & McAfee, A. (2014). *A Second Machine Age: Work, Progress, and Prosperity in a Time of Brilliant Technologies*. New York: Norton.
[22] Schiller, R. (2015). *Irrational Exuberance.* 3rd ed. Princeton: Princeton University Press.
[23] Kurzweil, R. (2005). *The Singularity Is Near*. New York: Viking.
[24] Wooldridge, A. (2015). *The Great Disruption: How business is coping with turbulent times*. London: The Economist.

opportunistic, unreflected and blind use of gadgets that fill our lives with irrelevant and random information.

2.2 Definition of ICT

Ever since its existence, the human species has used tools and techniques to communicate and to exchange information. Maybe the recent ICT revolution of exchanging information and enhancing communication using sophisticated tools and instruments is therefore nothing more than a further step in the ongoing human evolution that started 500.000 years ago, when human beings invented speech, or when they introduced symbols 30.000 or writing 5.000 years ago. Albeit primitive in the beginning, such as signalling messages with metal mirrors to reflect the sun, using smoke signals or doves, until the first mail system in the 6th century or the first telegraphic tools in the early and the telephone in the late 19th century, it is to be concluded that the human beings' tools and instruments to communicate have become more and more complex and sophisticated, thus eventually leading to the new information and communication society.

By opposition to the archaic societies of the primitive man, the premodern society of the dark middle ages and the modern societies since the age of enlightment, the new information and communication society is submitted to tremendously rapid and radical social and economic changes or disruptions due to the advances in information and communication technologies.

Today, ICT profoundly influence the ways organizations seek to transform work, services, and management, or the ways in which households domesticate new media and how public policy and regulation shape the impact of technology on employment, media concentration, privacy, and access in an information society.

In 1998, OECD member countries agreed to define on the basis oft he international standard classification of activities (ISIC Rev. 3) the ICT sector as a combination of manufacturing and services industries that capture, transmit and display data and information electronically.[25]

The 2011 OECD Guide to Measuring the Information Society, however, provided a narrower definition of the ICT sector, whilst removing the second element for the manufacturing industries. It states:

> The production (goods and services) of a candidate industry must primarily be intended to fulfil or enable the function of information processing and communication by electronic means, including transmission and display.[26]

In general, ICT could therefore be defined as a large set of highly performant electronical tools, instruments, applications and programmes that generally integrate several devices, such as television, telephone, computer, network, satellite, which are driven and operated by specific software or programmes, and which are linked to electronically based services, such as Internet, email, social networks, videoconferencing, chats, etc.

ICT, which constitutes a so-called umbrella term, is certainly characterised by the convergence or merging of several technologies and the abundant use of diverse transmission lines carrying rapidly large amounts of data of different types and formats.

Similar to a suitcase in which anything can be stored, the term and concept of ICT stands for an amalgam of things, all following the same objective: based on a large panoply of sophisticated and highly performant technologically based devices, ICT produces, processes, stores and retrieves more quantities (big data) and different qualities (data, voice, image) of information, which is made available faster and better, enabling people and organizations to work, transform and change this information, and to disseminate it to more people at a faster rate on a global and immediate scale - a situation unprecedented by anything in human history.

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[25] OECD. (2002). *Measuring the Information Economy*. Paris : OECD. p. 81. http://www.oecd.org/sti/ieconomy/1835738.pdf

[26] OECD. (2011). *OECD Guide to Measuring the Information Society 2011*. Paris : OECD. p. 59. http://www.oecd.org/sti/ieconomy/oecdguidetomeasuringtheinformationsociety2011.htm

As ICT is available (almost) anytime and anywhere, and the concept and technologies behind can therefore be related to as a potential to transcend time and space. ICT makes a simultaneous, asynchronous, geographically dispersed and punctual living and thinking possible - an option not achieved by any other device or resource before in the history of mankind.

2.3 Reasons for success

The examples in history indicating that the availability of information represents a strategic advantage are numerous. As for example, the legend of Nathan Mayer Rothschild relates to his early knowledge of the outcome of the Battle of Waterloo and his efficient communication ways, which enabled him to speculate on the London stock exchange and make a vast fortune.

In general, it is acknowledged today that the availability and mastery of ICT not only represents a major strategic advantage for companies, but also for individuals.

2.3.1 For the company

ICT systems promote business innovation and improve internal and external operational efficiency, enable the conception and production of new competitive products and services, providing those who master it with a strategic and sustainable advantage over those who don't, reinforcing thus the so-called digital divide.[27] The ICT related businesses reinforce their agility as they are able to realize competitive performances and to prosper in rapidly changing and permanently fragmenting global markets, to adopt to model lifetimes which are getting shorter and shorter, to ensure high quality, high volume and highly customized products and services without long foreruns and which are based on intelligent cooperation.

A company's ICT strategy is therefore strongly related to its general strategy, in terms of competitive advantage and differentiation, growth and costs, revenue and profitability, efficiency and effectiveness, product innovation and differentiation, cooperation and alliance, business operations, organizational setting and people management techniques, customer, supplier and competition management, reach and brand image, ...

The fact remains that modern technologies provide far more and far better options.

2.3.2 For the individual

It seems as if ICT have taken over nowadays nearly every aspect of an individual's daily life from work to leisure and even culture, in health, education or mobility. Mobile phones, desktop computers, hand held devices, emails and the use of Internet have become a central part of our existence and play a vital role in our day to day activities.

ICT has rendered the global and interdependent village possible, where people can constantly interact, without having to consider space or time boundaries. Information can be caught through ICT devices and transmitted almost instantly, information exchange can happen over long distances (f.ex. a university lecture via Skype where the professor sits in South-Korea and the students follow the course in a lecture hall in Germany), with a quality that would make a naive observer think that the person sits right next door.

Without ICT, the modern most efficient medical diagnosis and therapies would not be possible or the current highly complex mobility systems (road, railways, air traffic) would never have occurred. ICT in education opens new forms and larger access to knowledge and qualifications and it is at the source of sustainable smart buildings, smart cities or even smart countries.

In any case, ICT has opened vast new realms of possibilities and opportunities: the efficient and highly performant processing of information and data with the help of ICT devices has opened new facets, it makes things easier, faster, more available, accurate and reliable, the output quality remains the same over time as computers don't get tired and unconcentrated as human beings, the data storage and retrieval capacities are almost without any limits (although the quality of computer

[27] Bauerlein, M. (2011). *The digital divide*. New York: Tarcher/Penguin.

data processing is not even close to the capacities of the human brain), and the input and output material of computers can be achieved in a large variety of different formats.

2.4 Drawbacks

However, despite all these advantages, it must not be forgotten that the ICT revolution also includes major drawbacks such as the issue of the digital divide.

The euphoria induced by the ICT revolution has to face the fact that not all persons or societies can take part in this new evolution and are not able to take advantage of the available technologies. This may be due to age, working status, poverty or geographical location, and will thus have an effect on people's health, or their economical and social development due to lesser opportunities or missed chances.

And here, despite the technology’s fast pace, remedies are slow and resources intensive, as it is difficult to train an unemployed person with low initial training into a high ICT performer, or to bring Internet in the remote, underdeveloped areas on earth.

Furthermore, today's technological revolution will become tomorrow's commodity, as all new ICT functions will soon become ubiquitous and available to all, so that they represent no longer a strategic advantage.[28]

And, one must not forget, that the fact that we have more and more channels to communicate does not automatically mean that we have more interesting or intelligent things to say or to do.

[28] Carr, N. (2004). *Does IT Matter? Information Technology and the Corrosion of Competitive Advantage*. Cambridge (MASS): HBS Publishing Corporation.

Insert: History of ICT in a nutshell[29]

ancient times:	invention of the abacus as a calculating device used for many centuries by many ancient societies (Egyptian, Persian, Chinese, Native American, ...) and which are still in use today in many parts of the world
1671:	design of a calculating machine by Leibniz - the Step Reckoner (Staffelwalze) - as the first mechanical machine able to perform the four arithmetic operations
1822:	invention and unfinished construction of the first mechanical computer (analytical/difference engine) by Charles Babbage
1843:	invention of the first computer programme (algorithm) by Lady Ada Lovelace
1930s:	emergence of first programmable computers
1936:	fundamental publication by Alan Turing *On computable numbers*, setting the foundation for the upcoming computer science, in which the construction of a hypothetical machine that can solve any solvable problem using simple rules is suggested
1939:	David Packard and Bill Hewlett found Hewlett-Packard in a Palo Alto, California garage with their first product, the HP 200A Audio Oscillator
1941:	construction of the early computer Z3 by Konrad Zuse
1940-45:	construction of a first computer at Bletchley Park to decipher the German Enigma
1944:	completion of the Harvard Mark-1 by Harvard professor Howard Aiken
1945:	outlining of the first architecture of a stored-program computer by John von Neumann in *First Draft of a Report on the EDVAC*"
1946:	launching of the ENIAC by John Mauchly and J. Presper Eckert enabling 5.000 operations per second
1947:	first testing of a point-contact transistor, setting off the semiconductor revolution, by William Shockley, Walter Brattain and John Bardeen
1948:	publication of *Cybernetics* by Norbert Wiener and *The Mathematical Theory of Communication* by Claude Shannon
1949:	development of the Mark I computer using the Williams tube for memory
1950:	launching of the first commercially produced computer, the ERA 1101, produced by Engineering Research Associates
1951:	commercialisation of the UNIVAC I by the U.S. Census Bureau as the first commercial computer gaining high notoriety
1950s:	first high level programming languages (f.ex. FORTRAN)
1953:	completion of the first commercial IBM computer 701
1955/60:	appearance of first large computer companies: Burroughs, Digital Equipment Corp., NEC
1960:	design of the first commercial modem, the Data phone by AT&T
1963:	publication of the ASCII Code for Information Interchange enabling the exchange data between machines of different manufacturers
1964:	design of the first supercomputer, the CDC 6600 by Seymour Cray
1965:	foundation of Commodore Business Machines by Jack Tramiel
1967:	design of the LOGO computer language for children by Seymour Papert
1969:	appearance of the original Internet (ARPANet)
	development of the UNIX operating system by Kenneth Thompson and Dennis Ritchie
1971:	sending of the first e-mail by Ray Tomlinson
1972:	commercialisation of the Hewlett-Packard HP-35 as a fast and accurate electronic calculator with a memory
	foundation of Atari Inc. by Nolan Bushnell und Ted Dabney
1974:	design of the first working station with a built-in mouse by Researchers of the Xerox Palo Alto Research Centre

[29] Campbellkelly, M. et al. (2013). *Computer: A History of the Information Machine*. 3rd ed. Oulder: Westview.
Ceruzzi, P.E. (2003). *A History of Modern Computing*. 2nd ed. Boston (Mass.): MIT Press.

1976:	design of the Apple 1 and foundation of Apple computer company by Steve Wozniak and Steve Jobs
1976/77:	completion of the first personal computers (Apple, TRS-89 and Commodore).
1978:	introduction of the 5 1/4" flexible disk drive and diskette by Shugart Associates
1980:	creation of the first hard disk drive for microcomputers, the ST506 by Seagate Technology
1981:	introduction of the IBM PC completion of the first portable computer, the Osborne I by Adam Osborne introduction of MS-DOS by Microsoft introduction of the first 3 1/2" floppy drives and diskettes by Sony
1982:	development of Lotus 1-2-3 by Mitch Kapor
1983:	launching of Word and Windows by Microsoft
1984:	commercialisation of the Macintosh, the first mouse-driven computer with a graphic user interface by Apple
1985:	development by the C++ object-oriented programming language by Bjarne Stroustrup
1990:	launching of the World Wide Web (www) by Tim Berners-Lee et al. at the CERN through the development of the Hyper Text Markup Language (HTML), the Uniform Resource Locator (URL) and the Hyper Text Transfer Protocol (HTTP)
1991:	release of the open source Linux programming language by Linus Torvalds
1993:	first graphical browser for the World Wide Web
1994:	foundation of Netscape by Marc Andreessen, Jim Clark and of Yahoo by Jerry Yang and David Filo
2000:	commercialisation of a plethora of applications and services being added in the Internet and the Web
2010:	convergence of computing and communication devices, connectivity of computing devices, digital social networks, sensor technologies, Internet as a layered system, Semantic Web, security issues

2.5 Global trends within ICT

With regards to the statistics published by the International Telecommunication Union (ITU)[30], a specialized agency of the United Nations (UN) responsible for issues that concern information and communication technologies, the tendency seems to be confirmed: over the past 15 years, the information and communication technologies (ICT) have grown in an unprecedented way, providing huge opportunities for social and economic development.

As ITU reports, today in 2015, there are more than 7 billion mobile subscriptions worldwide, up from 738 million in 2000. Globally, 3,2 billion people are using the Internet, of which two billion live in developing countries. Internet user penetration increased seven-fold since 2000 from 6,5 to 43 per cent of the global population, whereas the proportion of households with Internet access at home advanced from 18 per cent in 2005 to 46 per cent in 2015. Similarly, 3G mobile-broadband coverage is rapidly extending, reaching globally 47 per cent in 2015 (12-fold since 2007). In 2015, 69 per cent of the global population is apparently covered by 3G mobile broadband, with an increase of 45 per cent since 2011 (with an estimate of 29 per cent of the global population living in rural areas 89 per cent in urban areas).

Furthermore, ITU findings indicate that broadband is now available and affordable in more then 110 countries, with the cost of a basic (fixed or mobile) broadband plan corresponding to less than five per cent of Gross National Income (GNI) per capita. The global average cost of a basic fixed-broadband plan, as measured in PPP$ (or purchasing power parity $), is 1,7 times higher than the average cost of a comparable mobile-broadband plan.

2.6 Specific trends within ICT

Based on a summary review of literature, we identify the following major global trends in ICT with strategic impact on individuals and organizations, with a high potential of disruption, i.e. displacing earlier technologies by unexpected quantum leaps of innovation and by merging the real world more and more with the virtual one.[31]

2.6.1 Ubiquity

ICT will continue to proliferate at a very high rate and will evolve at a very fast pace with a profound impact on all kinds of living and working spaces (manufacturing halls, hospitals, universities, schools, houses, cars, ...).

ICT will continue to enhance **vertical integration and inter-connection** of all aspects of the living and working spaces: industry will seek to respond to ever newer demands (f.ex. industry, medicine, care taking of elderly people, ...) and it will look for unexploited opportunities and new markets by offering new products and services. Hence, not only ICT devices will be inter-connected, but the

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[30] http://www.itu.int/en/ITU-D/Statistics/Pages/facts/default.aspx

[31] http://www.itbusinessedge.com/slideshows/top-10-strategic-technology-trends-for-2014.html
http://eskills-lead.eu/fileadmin/lead/reports/lead_-_technology_trends_-_august_2014_rev_sep1.pdf
http://www.gartner.com/smarterwithgartner/gartners-top-10-strategic-technology-trends-for-2015/
http://www.gartner.com/newsroom/id/2867917
http://www.slideshare.net/denisreimer/gartner-top-10-technologytrends2015Analysts Examine Top Industry Trends at Gartner Symposium/ITxpo 2014, October 5-9 in Orlando
David Cearley, vice president & Gartner Fellow; Gartner: technology research and advisory corporation
http://gblogs.cisco.com/asiapacific/top-10-ict-trends-in-2015-are-you-ready-for-digital-transformation/
http://wwwen.zte.com.cn/en/products/bearer/201401/P020140103420890268179.pdf
ICT Development Trends (2014): Embracing the Era of Mobile-ICT ZTE COPORATION
McKinsey & Company's assessment of worldwide trends over the period 2006 - 2015
https://www.fit.fraunhofer.de/content/dam/fit/de/documents/composite_d41.pdf
http://www.projinit.com/ict-trends-for-2015/
http://unpan1.un.org/intradoc/groups/public/documents/un/unpan014026.pdf
http://unctad.org/en/PublicationsLibrary/ier2015overview_en.pdf

myriads of **smart issues** (such as smart houses or smart cars) are arising rapidly in volume and importance.

The trend is to turn away from a single focus on technological feasibility, possibilities and potential, towards a view of the user as being equipped with real social, cognitive and physical expectations and needs in diverse contexts and environments. The user's expectations and needs relate to the permanent, immediate and omnipresent availability, reliability and workability of devices, applications and information that work right away and are available, anytime, everywhere, and under any circumstances.

This ubiquitous access to information is changing the economics of knowledge and its associated meanings. Not only is knowledge increasingly available and, at the same time, increasingly specialised, but its production is moving from its creation by individual specialists to its creation by communities of practice in an open source manner.

The trend will be seconded by a **ubiquitous availability and embeddedness of computers** that will regulate our lives everywhere, on every issue imaginable (or not yet imagined) and at any time and everywhere. As context-aware devices, computers will understand and interact more and more independently with their surroundings, taking initiatives autonomously and responding appropriately to changes and expectations (expressed or unexpressed).

This evolution will be extended by a growing **service ubiquity** through smart and mobile terminals in conjunction with large mobile broadband networks that make all kinds of services available by simply touching and swiping: booking travels, ordering over online shopping, socialization and entertainment, or even business activities. In this new ICT era, we are changing our ways of thinking as we do not any longer retrieve information (whether necessary or unnecessary) with the help of the memory part of our brain, but through a slight gesture upon our mobile device.

These knowing and interacting services and devices, referred to as the **Semantic Web**, will not only respond to expressed wills and demands of people from and through the World Wide Web, but they will automatically and independently assess needs and demands, and report on the best fit solutions. It will automate and self-initiate tasks of the knowledge based person and further enhance network intelligence in our lives.

Furthermore, these knowing services and devices will be connected to the Internet and able to communicate with each other or with other devices, external data basis, and of course human beings. This computing concept, referred to as the **Internet of Things** (IoT)[32], whose initial description has been attributed to Kevin Ashton in 1999, describes the scenario of data being created by the things or devices themselves, and not necessarily by human beings as under the first Internet, thus creating new added-value. Here again, the old Aristotelian saying reveals to be accurate once more: The whole will be greater than the sum of its parts.

> If we had computers that knew everything there was to know about things - using data they gathered without any help from us - we would be able to track and count everything, and greatly reduce waste, loss and cost. We would know when things needed replacing, repairing or recalling, and whether they were fresh or past their best.[33]

IoT stands for a world in which not only computers, tablets and smartphones are connected, but in which any kind of physical thing or device is connected and communicating with another one in a highly sophisticated way, creating on the basis of the physical world a new virtual world of information.

Thus, through network availability and interconnectivity, devices have become ubiquitous and the information has become equally ubiquitous, waiting and looking up things in a reflected and goal oriented way are no longer an option - changing thus radically the way we live and work - and also the way we think.

2.6.2 Mobility

[32] Greengard, S. (2015). *The Internet of Things*. Boston: MIT Press.

[33] http://www.rfidjournal.com/articles/view?4986

As people practice a more and more mobile lifestyle, they expect to be able to take their virtual existence along with themselves on their mobility path. That is why integrated mobile communications devices will become even more essential, reduced in size and increased in performance and options. Mobile devices and mobile apps become merged instruments with which one can operate all kinds and variations of communication (telephone, Internet telephony), operate steering activities, such as regulate a house (alarm system, air conditioning regulation, garage opening, or an audio/video system) or just simply work by accessing company data and software, thus changing the nexus of location and of work. Through the mobile devices, it has become possible to stay connected with any other interlocutor anytime, anywhere, through any device, and we will have our data available on-the-go and in real-time.

The trend is furthermore to overcome the gap between mobile devices and laptop computers, and to integrate all options onto one single device with very large storage capacities. We will continue to move on towards the era of **mobile-ICT**, which is characterised through a ubiquitous service availability, the consideration of the user experience, the emergence of disruptive technologies, the formation of more innovative business patterns and the advent of new industry production processes.

This trend will be endorsed by further significant developments in the framework of the **last mile access technology**, seamlessly integrating 3G/4G/WLAN technologies, replacing broadband wireline access and delivering ever higher wireless bandwidths, providing thus access points to Internet based communication almost anywhere: in homes, in offices, while travelling in cars, trains or airplanes. In conjunction with the issues of security and the associated technologies as well as the Internet of Things (IoT), companies and their employees will become even more mobile as they will be able to use both external services and internal applications in a more or less safeguarded way, contributing this way to radically new work- and life-styles.

2.6.3 Portability

People will still use different devices at different places and therefore they will be in need of a great portability option, taking their information with them and therefore needing to synchronize their devices automatically and immediately. Therefore, applications will need to address the issue of supporting a simultaneous use of multiple devices, in order to make available the same information at any moment and on any device, hence the future importance of clouding services.

As an extension, the **second screen or cross screen phenomenon**, standing for the coordination of television viewing with the use of mobile device, will increase in importance as all kinds of applications (games as well as company software) will use multiple screens and exploit wearables or other devices to deliver an enhanced experience. It seems that every surface is potentially turning into a screen and surfacing with some kind of video application. And, it seems that the classic linear television system is bound to disappear and being replaced by streaming (cf. Netflix, ...), having even repercussions on the production and dissemination methods of TV series (cf. House of Cards).

2.6.4 Velocity

Due to the large amounts of information to be processed, computers need to become ever more performant, hence faster. Distributed computing, supercomputing, parallel computing and quantum computing will continue to evolve, although some of the related issues are still at an experimental stage of research.

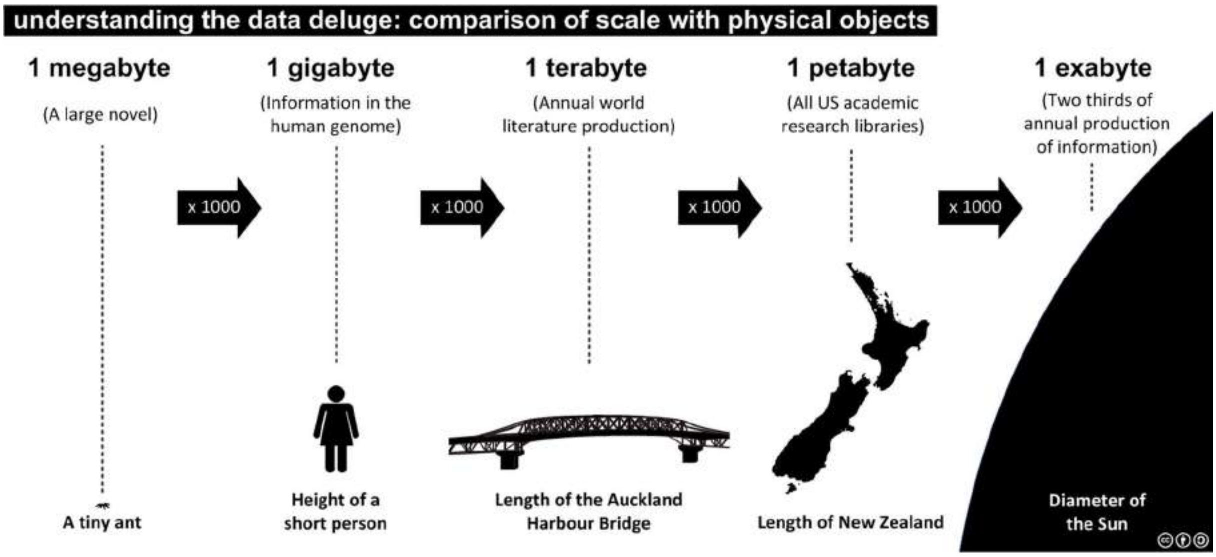
It seems as if in application and computer architecture the concepts of networking and parallelism will continue to spread and spill over from supercomputers to individual workstations. The different and faster processors within a single computer will be used with external processors in parallel in order to perform a myriad of operations and tasks at the same time.

For his purpose, new algorithms will be needed that will be able to execute numerous computations in parallel and simultaneously on the same processor or on physically separated processors (**Concurrency**) and that permit to be extended in line with a growing amount operations (**Scalability**).

2.6.5 Obesity

The American systems theorist Buckminster Fuller stated in his *Knowledge Doubling Curve*[34] that until 1900 the human knowledge has doubled approximately every century. This curve however changed to an exponential rate, as by the end of World War II the human knowledge had already been doubling every 25 years. Today, depending of course on the fields of interest, human knowledge is generally doubling every one to two years, and it will be only a question of a little bit more time to conclude that knowledge is doubling at a daily or even, why not in some not too distant future, at an hourly rate.[35]

Figure 1: Understanding the data deluge: Comparison of scale with physical objects[36]



This evolution has of course a large effect upon the required faculties of computers to collect, process, store and retrieve these amounts of data. The challenge will be to find intelligent and efficient ways to analyse and process the knowledge associated to the data.

On a similar scale as the previous Kondratieff-cycles, where for example the oil had become the motor of the industrial revolution, the acquisition, processing, storing and retrieving of data have become the motor of the digital age. But data as such is like crude oil: little can be done with it by itself. It needs to be refined to change into a useful product and commodity. Similarly, the vast amounts of data processed on myriads of computers remain superfluous or meaningless, unless they are ordered, structured and associated to knowledge and meaning - the difference from previous eras being that the new data needs to be processed almost in real-time in order to contribute to solving complex issues.

Therefore, this new age of **datafication** will be based on performant and secure computers and networks as well as elaborate analytical capacities. For that reason, the processing of **Big Data**[37] will need to rely upon **advanced and automated analytics** in order to filter, structure and analyse the vast amounts of data generated and exploited by embedded systems in order to be able to deliver that the right information is delivered to the right person, device or system, at the right time. But for

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[34] Buckminster Fuller, R. (1981). *Critical Path*. New York: St Martin's Press.

[35] http://www-935.ibm.com/services/no/cio/leverage/levinfo_wp_gts_thetoxic.pdf

[36] Infographic created by Julian Carver of Seradigm in New Zealand http://seradigm.co.nz/2010/07/10/the-data-deluge.html

[37] Mayer-Schönberger, V. & Cukier, K. (2013). *Big Data: A Revolution That Will Transform How We Live, Work and Think*. New York: Houghton, Mifflin, Harcourt.

this accomplishment to be successful, this process will also need a pronounced capability of humans to evaluate the results provided - thus eventually merging the physical, analytical and cognitive worlds. This activity is being referred to as **Data Mining**[38], which consists of identifying patterns within the raw data in order to extract meaningful, understandable and usable information clusters. For example, data mining can be used to individualise offers, prices and services, to profile customers, to enhance customer insight or to increase the forecast of customer behaviour patterns.

2.6.6 Miniaturisation, integration and sophistication

New technologies (applications, devices, tools, instruments) will become more and more pervasive (vertically and horizontally), integrated, smarter, smaller, with the trend to produce wearable computers that will consume less energy, store more data, provide a wider range of new options and which are linked to almost anything.

Following Moore's Law[39] that processing power and storage capacity is doubling every eighteen months (although currently slowing down), the rapidly increasing performance levels of these wearable mobile devices, such as Smartphones, the Apple watch, the Google glass or the flexible screens and batteries, will be based on quad and even octa core technologies, opening new and still unexploited opportunities, making for many the dream of personal multitasking come true.

All of these will contribute to constitute the **quantified self** and enable high-precision measurements, new payment methods, more attractive and powerful technical options (tiny projectors inside handsets, virtual keyboards on flat surfaces, data entering by speech or even direct links to the brain), or location based services and apps.

Furthermore, new cost-effective technologies such as **3D Printing** will rapidly expand and open new industrial and commercial applications in industry, medicine or consumer goods, enabling producers to respond to individual and short-run requests from manufacturers.

2.6.7 Cyber-industrialisation

The new and very fast developing model of the **Industry 4.0**[40] has recently occurred and relates to a customized and flexible mass production, which is highly automized and permanently optimized. It stands for the concept of smart machines and factories, which are based on cyber-physical systems (CPS) and which constitute systems of collaborative computational elements controlling physical entities. This new industry is relying on the management of big data in an energy efficient, sensorised, virtual and decentralized way, while the Internet represents the cornerstone of this new industry, allowing communication between devices, machines and people.

As the the Coordinator of the *Industry 4.0 Digital Factory Division* of Siemens AG, Prof. Dr.-Ing. Dieter Wegener, states:

> The essence of the Industry 4.0 vision, the "Internet of Things", is the ubiquitous connection of people, things and machines. This connection is intended to produce a variety of new goods and services. Products, means of transport or tools are expected to "negotiate" within a virtual marketplace regarding which production elements could best accomplish the next production step. This would create a seamless link between the virtual world and the physical objects within the real world.[41]

The industry 4.0 will lead to new **Smart Manufacturing** models that will function on the basis of a performance oriented and demand driven dynamic of technological innovation and intelligent and aware customers. It will be fully integrated, energy and resource efficient, using advanced data

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[38] Brown, M. (2014). *Data Mining For Dummies*. Hoboken, NJ : Wiley.

[39] Moore, G.E. (1965). Cramming more components onto integrated circuits. *Electronics*, 38, 8, p. 114–117.

[40] Roland Berger Strategy Consultants. (2014). *Industry 4.0. The new industrial revolution. How Europe will succeed.* https://www.rolandberger.com/media/pdf/Roland_Berger_TAB_Industry_4_0_20140403.pdf

[41] PWC. (2014). *Industry 4.0. Opportunities and challenges of the industrial internet*. p. 5. http://www.strategyand.pwc.com/media/file/Industry-4-0.pdf

analytics, modelling and simulation to produce new, improved or advanced products in flexible and adaptive factories, thus changing entirely the roles and functions of its collaborators.

2.6.8 Cloudification

ICT will increasingly be transferred to hybrid clouds and therefore, new technologies will be needed to regulate and manage fast access to large cloud disposals. This cloudification will have as an effect that the focus will no longer be on the individual computer or on the local systems, but on the associated workload, resp. its management, thus shifting cost issues form the unit of a computer to costs per workload. This trend is advantageous for companies, as they can delegate a large part of their ICT development and maintenance activities to cloud service providers and focus on their primary businesses focus and their essential on core-competencies.

A first associated trend will be in the direction of **Intelligent Cloud-based Networks**, linking smart mobile devices with highly efficient cloud applications, enabling a larger and faster amount of data traffic. This trend will significantly reduce the network equipment and operation costs for companies, whereas the providers of Intelligent Cloud-based Networks will have to come up with new business models, as they are confronted with increased operating costs that the user will not necessarily want to allocate for.

A second associated trend concerns the concept of **Web-Scale IT**, being defined as the activities of large cloud service companies, like Google, Amazon, Facebook, Uber, etc., that are based on new IT processes and architectures, as well as agile programming of everything in order to be able to handle large amounts of data in a flexible and efficient way.

2.6.9 Autonomy

With the support of sophisticated software, advanced algorithms and large data management tools, machines will become ever more autonomous or smart: self-parking or even self-driving cars, smart robots or machine helpers will continue to evolve rapidly and replace tedious, dangerous or repetitive tasks.

These **Smart Machines** will be able to understand the contexts in which they operate, they will respond appropriately and automatically, and eventually learn from their experiences.

2.6.10 Convergence

The convergence of cloud and mobile computing will continue to expand while delivering applications and services to remote devices from centrally coordinated and managed computers and applications: 3G mobiles + Social Networking + Video + VoIP + GPS = **Impressive Mobile Devices**.

Computing will become an **elastic self-service activity**, where services such as software are made available and billed when needed and synchronized across multiple devices, as most users relate to more than one device.

In the end, both the physical and the digital worlds will converge by a permanent and systemic information exchange between people, between people and things, and between things, into a new virtual one with an augmented reality. The interactions in the virtual world will thus become alike to the interactions in the physical world.

2.6.11 Security

Due to numerous threats and menaces in the world of Internet (spams, worms, viruses, cyber attacks, ...) the issue of security has been becoming crucial for a long time. As the Internet-based virtual society is open and interactive, with quick information dissemination, **Cybercrimes** have become omnipresent and are proliferating at a remarkable speed. They have become more and more common and intrusive, and menace especially private and financial point-to-point communication.

Of course, this development will need increased efforts in the future with additional costs to resolve this scourge. From a reactive and preventive approach, the focus has shifted towards integration, as a *before - during - after* attitude. For that reason, Governments are increasing regulations and enforcements, and companies will consider cybersecurization as an integral part of their business processes, as digital security should neither be considered as a roadblock, nor should it lead to the false belief that a 100 percent secured environment could be created. Through more elaborated and sophisticated risk assessments, as well as appropriate preventive measures, companies will necessarily have to consider security aspects on all levels, as the classical approach of perimeter protection and firewalls are no longer enough: the tendency will be to move from a security-conscious design of self-protecting applications towards an integrated, dynamic and permanent security testing and to context-aware devices and applications, including highly performant access controls, to only quote a few.

The most eminent future challenge will be to address efficiently the increasingly fatal challenges on network security as we all rely more and more network services and activities to run our lives, while at the same time more and more highly qualified specialists try to break into or even destroy our security intervals.

2.6.12 Socialising

As it seems, the general social networks such as Facebook, twitter, etc., seem to have reached certain limits, or at least will most likely not continue to expand as rapidly as in the recent past.

The consumer lead social networks will be facilitated through the **Web 2.0** and its expansion will be in terms of diversification and specialisation. The virtual communities will organise themselves around a series of special interest groups or thematic niches - while relying on the same integrated applications, such as chats, e-mails, disclosure of video and photos, and services offered by the mobile video and multimedia market, in conjunction with high or even ultrahigh quality standards, will be at the fore-front of an increased datafication of things.

Furthermore, social media will increase in social acceptance, as they will more and more integrate the business, commercial, scientific and political levels of interaction.

Therefore, besides purely personal aspects, social media will tend to become a complement, if not a replacement of the so-called classical media. Information provided by the actors or the observers themselves are faster and more up-to-date than information that has to be processed through the logics of professional media players. Direct and immediate online information will be the future key of information dissemination. Social media will be replacing mass media, the narrowcast will be the future broadcast. Actors and observers will create and disseminate their own news in a completely autonomous way - with a lot of questions linked to such a new approach that need to be addressed (f.ex. information biases).

2.6.13 Consumerizing

A further trend is to be noted concerning the proliferation of ICT over social and sectorial borders. In more and more cases, the new technologies and the linked applications that have emerged successfully within the consumer markets, have the tendency to spread beyond their original target groups to engage within the business, schools and public administration communities. What people are used to use at home, they also request from their outside-of-home interlocutors.

2.6.14 User experiencing

In times of mobile ICT, voice and data services will become combined and will not be evaluated with the help of traditional ICT product performance indicators but by the so-called **User Experience**. Here, the user and not the technology will constitute the foremost interest, as the design of these devices and applications will be more and more user centred, they will be based on advanced graphical norms and take into consideration psychological (ergonomic and cognitive) aspects of the human-machine-interaction. The attached criteria will not be the usability of a device or of an application, but the criterion of user experience will be concerned with all aspects of the user's experience, personality, physical and cognitive abilities, when interacting with the device, commodity, product, facility or service.

2.7 Conclusion

Without any doubt, the ICT revolution has continued its pathways since the year 2000 and driven the global development to new unprecedented heights. The ever increasing variety of instruments, tools, devices, gadgets programmes and applications generated by ICT has achieved a degree of maturity and connectivity between people and things around the globe never achieved or even imagined before. In our fast-growing global information or digital society, ICT have had and will continue to have a profound impact on every aspect of our societies and of each individual's life, and hopefully this evolution will be of an inclusive nature.

From now on, technology tools will accompany us from the cradle to the grave, from dusk to dawn, in virtually all areas of our lives, until the age of pervasive and ubiquitous computing finally dawns. And aren't we all waiting anxiously for the singularity to occur finally, when at last computers and robots will be able to rebuild and improve themselves?

In general, these technological tools have ever since their uprising become smaller, cheaper, more powerful, more user-friendly and very much integrated into almost all facets of our daily life. They profoundly affect our ways of living and working, of spending our leisure time, of communicating and socialising, of learning and thinking.

Through this integration of information technology (IT) with communication technology (CT), a new form of technology gradually has merged: ICT - information and communication technology or technologies, as they are made out of more than one technology.

This technology itself has in the meanwhile been integrated into the world-wide-web and the mobile Internet, so that our societies have undoubtedly and irrevocably been boosted into the age of fast and smart ICT. This evolution has brought about a tremendous array of new opportunities and challenges, which are not limited to the ICT industry itself, but which are impacting all our societies and all individuals as a whole in their present existence and their future development.

The new ICT evolutions are much more radical then any previous new technique or technology, as they represent far more than just one more layer over existing systems and structures: they will profoundly, permanently and iteratively alter the existing systems and structures themselves.

Nowadays, it is commonly acknowledged that ICT have become and are continuing to become utterly ubiquitous, mobile and perfectly embedded in all kinds of economic and social activities, processes, production methods, devices and products. Converging technologies will lead to new products and services, as well as new behaviours and attitudes, they will change the scope and structure of our economic and social demeanour, while the current skilled users are the mothers and fathers of the next generation of producers of ICT.

The slogan is: fast, massive, anytime, anywhere and on any device. Internet based services and activities such as information seeking and sharing, working, businessing, socializing, gaming, will be available without limits and used without hesitation. The access of smart products to diverse points will be seamless, fast, flexible and in the cloud. The underlying intention is to create innovation and added-value, financial results and eventually a better life.

From the purely **economic angle**, the competitiveness of States, the productivity of companies and the self-development of individuals are closely related to their capacity of mastery of ICT. ICT are their driver, in the hope that radical innovation is produced, progress and evolution guaranteed, jobs created and the costs induced by ICT counterbalanced more and more quickly by a significant gain in productivity. As a consequence, similarly to ICT themselves, the world's economic activities will equally converge and realign towards a common ground of understanding and following similar activities. Especially emerging economies will grow their share in the ICT market, first as consumers, then as producers and operators, while having increasingly the same information and the same access to the same products, commodities and services at their disposal.

In terms of economic development, the growth and opportunities of the ICT market will not only benefit to large ICT companies, but also create a myriad of opportunities for small start-up companies, the real creators of innovation in ICT.

Inter- and intra-firm linkages will create new sorts of networks, alliances and collaborations between all kinds of companies, large and small, ICT with industry or services, general provider or niche player, traditional and online production systems. In any case, ICT will contribute to economic growth either as an enhancer of innovation or a facilitator of cost reduction and of productivity increase. In any case, the major change related to ICT is that boundaries between ICT and other industries or services are blurring (cf. FinTech).

At he same time, the global **ICT economy** is restructuring, as the ICT market will be dominated by a few up-above world wide active giants in hardware and software, occupying the major parts of the business, seconded by a plethora of down-below very small firms and start-ups, that largely contribute to invention and innovation - the middle level companies being the one encountering the most difficulties in the future, as both their economic and their innovation capacities might become too limited.

The business model for the future will therefore be to establish non-traditional, flexible, interlinked and fast acting networks of specialists, by filling the gaps by experimenting new trajectories, and by stimulating the communities of ICT producers and of open sources activists themselves, leading eventually to fully fledged ecosystems, within which it is no longer possible to distinguish between the producer, the operator, the supplier or the client: all will be one. This development will have as an effect that all innovation in industry, finance, transportation, energy, education, healthcare etc. will be directly linked to any kind of ICT.

As a consequence, high-level ICT practitioner skills are increasingly in demand, coupled with a lower demand for traditional ICT technical skills, particularly in the infrastructure and traditional IT management areas. Furthermore, a revival of hardware innovation is to be noticed, stimulating also a fresh demand for highly specific hardware-related and systems management skills. It can also be noticed that the demand for highly specialized resources tends to move away from the ICT users towards the ICT vendors, while the profiles required by ICT users is becoming more and more business- and project-oriented, with a strong focus on the design of new services and applications, while relying on standardized platforms and services.

But still, the area of applications skills remains the most dynamic, in line with the emergence of the so-called apps economy. This builds not only on software skills but also on the ability to manage very innovative and demanding customer requests.

This whole evolution is paralleled by the emergence of highly integrated, automated and scalable infrastructures, which are driving a new demand for an appropriate standardization and interoperability of skills within the ICT industry.

Furthermore, beyond falling in love with its own technological achievements, the ICT sector has recently discovered the individual, the ICT user with its needs and demands, and acts upon its life not only through the vast array of ICT devices and applications, but by embedding itself in all kinds of daily commodities. Thus, ICT is changing profoundly our way of living, thinking, working and leisuring. The social networks will play an ever more important role in all aspects of our social interaction - be it for the better or the worse.

As a side effect, the way we work is also unprecedented, as with the ubiquitous ICT, the mobile, polyactive and time/space independent worker has occurred.

We are quite actively working on a new **systemic digital ecosystem** of the 21st century, in which everything is connected and networked with everything, leading to new non-linear and emergent realities, and with the Internet as the forum where actors meet. In that sense, as stated by the **Actor-Network-Theory** (**ANT**), developed originally by Michel Callon and Bruno Latour, objects, devices, concepts and humans become integral and equivalent parts of social networks, as highly digitalised nonhumans also become able to act or participate in systems or networks.[42]

[42] Latour, B. (2005). *Reassembling the Social: An Introduction to Actor-Network-Theory*. Oxford: Oxford Univerity Press.

Any participant or actor sends and receives vast amounts of structured information, creating in an endless loop new information and thus new states within the hyper complex Internet system. There is no owner of the forum, but only technological, mechanical and human contributors that share information and influence each other in unpredictable and emergent ways. The change will be permanent and it will induce improvement and amelioration, performance and profitability, efficiency and operability, safety and security, and also crime, ...

As we are directing ourselves towards a world of connected devices, processes and people, it is likely and hoped that this evolution will make our political, economic, social and personal lives better and more comfortable in general (information availability, socialising, freedom of expression, healthcare, education, creativity, business development, leisure time, ...).

But this evolution will also have drawbacks (cybercrimes, misbehaviour, depersonalisation, ...), with which has to be dealt as well, as these changes not only open doors, behind which can be found marvels, but also abysses of unwanted realities and abuses.

In any case, the **emerging complexities and uncertainties** associated to the recent trends and developments in the field of ICT will deeply impact upon our societal, social, economic, psychological and personal life, they will induce radical and unpredictable consequences in our ways of living.

The question therefore remains: to what world is ICT directing us in the future, and to what world we want to be directed to by ICT in the future.

3 ICT in Luxembourg

3.1 Luxembourg's economy in general

Today, the economy of Luxembourg can be considered as highly industrialized, diversified and export-intensive and has led itself to one of the highest per capita gross domestic product in the world.

Historically, the economic development of the country goes back to the second half of the 19th century, during which the extraction and refinement processes of iron ore were greatly improved. Due to new techniques in metallurgy imported form Great Britain, the rather poor quality of the Luxembourg iron ore could be transformed more efficiently into steel products, leading thus to the development of the Luxembourg steel industry, which remained for over a century the core industry of the country. Still today, the steel industry remains an important sector of the economy, with 29% of all industrial exports, 1,8% of the GDP and 3,9% of the work force. However, proportionally to other industrial sectors, the steel industry is declining in importance.

Today's diversification goes back to the post World War II period, as the Luxembourg government extended its economic policy and strove successfully to attract new industries in a series of sectors, such as the chemical one.

Furthermore, since the 1970s, Luxembourg has become an internationally renowned banking centre, specialising today in private banking and fund administration. The banking centre plays today a very important role in the Luxembourg economy, with an almost 40% contribution to the GDP, and with an even more important generation of secondary business (financial services, law and accounting firms, construction, security, ...).

The development of the banking centre has been seconded by the development of other industrial activities, such as telecommunications (RTL, SES), or logistics, tourism, agriculture, film industry, ..., and most importantly also the crafts sector with a large share in GDP and employment.

However, as all of these sectors are nowadays heavily depending upon ICT software and hardware, quite automatically, an important ICT sector has emerged in parallel in Luxembourg.

Therefore, the question is whether one should still consider the ICT sector as a subsidiary of all the other sectors, or should one already consider the Luxembourg ICT sector as a mature sector in its own right, thus contributing to enlarge and diversify the economic portfolio of Luxembourg even further?

3.2 Luxembourg's ICT economy

The recent study entitled *Luxembourg and ICT: a snapshot* published by *Luxembourg for Business* enumerates a series of characteristics with regard to the national ICT sector.[43]

First of all, it reports that the country has not only a high proportion of highly skilled workers, but also one of the highest shares of ICT-using occupations among OECD countries. The Luxembourg labour market is characterised by one of the largest shares of knowledge-intensive activities in Europe, with 56% of all the jobs in 2011 (an activity being knowledge-intensive if the tertiary-educated persons employed represent more than 33% of the total employment in that activity) - and can thus be considered as a **knowledge-intensive economy**.

Furthermore, the KOF Index of Globalisation on the economic, social and political dimensions of globalisation, calculated by the Swiss Federal Institute of Technology[44], indicates with regard to economic globalisation a second position for Luxembourg, just behind Singapore.

[43] http://ict.investinluxembourg.lu/ict/sites/ict.investinluxembourg.lu/files/Luxembourg_and_ICT_-_a_snapshot.pdf
http://ict.investinluxembourg.lu/ict/sites/ict.investinluxembourg.lu/files/Boardroom%20report%202014_web_final.pdf
www.investinluxembourg.lu/ict/very-high-speed-broadbandstrategy
http://www.gouvernement.lu/3938170/et-2013-ict-snapshot.pdf

[44] ITU (2014). *Measuring the Information Society. Report 2014*. Geneva: ITU.

With regard to ICT infrastructure and connectivity, this report states that Luxembourg has invested considerable efforts to build and operate efficiently state-of-the-art multiple high capacity fibre networks, to ensure performant **national and international connectivity**, connecting Luxembourg to the major hubs in Europe and positioning Luxembourg as a major player in the middle of the so-called *Golden Ring*, which shapes the major Internet hubs of Europe: London, Amsterdam, Frankfurt and Paris. Also in terms of communication access paths, Luxembourg occupies one of the strongest positions within OECD countries, as 230 access paths could be calculated per 100 inhabitants in 2009.

Already in 2009, 100% of Luxembourg's population was covered with **3G or third generation networks**, whereas in 2012 64% of the population was covered by the 4G network. Similar considerations apply to broadband connectivity and will be even further developed, as in its national strategy for very high-speed networks, issued in April 2010, the Government intends to increase the speeds of the existing networks, and provide, in the medium term, access to optical fibre in the entire territory. It is the Government's intention to transform Luxembourg into the first fibred country of the European Union.

Luxembourg has also grown into a premium location for **data centre parks** in Europe, as more than 19 data centres are operational, presenting generally the highest securities standards.

With regard to the **ICT equipment in enterprises**, the afore-mentioned study relates for 2012 on the basis of figures provided by STATEC that among enterprises with 10 or more employees, practically all (98%) have Internet access, virtually all (95%) through a broadband access and many (54%) also through a mobile connexion. Three quarters of the enterprises feature their own website, 48% an Intranet, 32% an extranet, 16% videoconferencing facilities and among the enterprises using computers 100% worked with a wired local area network (LAN) and 43% had also a wireless local area network (WLAN). It can be assumed that these numbers have since then improved even more.

The 2014 STATEC Bulletin on Information and Communication Technologies in households and among individuals[45] in 2014 highlights the recent **expansion of social networks and cloud activities**, especially among young people. In 2014, 60% of residents aged 16 to 74 participated in social networks of which Facebook is the winner as 57% of residents were present there, with only 8 à 9% for LinkedIn, Google+ and Twitter combined. Generally, customers only consult one social network (64%), with only 36% of users consulting several networks. Not surprisingly, young people are very active: 91% are present in at least one social network against 26% of the 65-74 years' category. Social networks are used primarily to maintain existing relationships (82%), to renew past relationships (74%) and share photos and videos (57%). As for the absentees in social networks, they often justify their desire to keep their private life for themselves (74%).

The Cloud also marks a great success as the country moves with 37% of users to the third position of EU28. The cloud is mainly a case for youth with 50% of users and is linked to the level of education: Postsecondary graduates are 44% against 26% for lower secondary graduates and non-graduates.

In comparison to previous studies, this STATEC bulletin denotes that in 2014 96% of the resident households had **access to the Internet**, an increase of 6 points compared with 2010 and 26 percentage points compared to 2006. Luxembourg is now positioned at the top of all European countries. The computer remains the number one tool for Internet access (87%) followed by the smartphone (70%).

Similarly, with regard to **online commerce**, in 2014 74% of residents made purchases of goods and services on the Internet. This proportion has doubled in 10 years (39% in 2005). Among the most common purchases, there are those related to holidays (vacation dwellings (45%) and transport rental tickets, 39%). Purchases of books and magazines are also common (44%).

At a European level, Luxembourg is in 4th position with regard to purchases over the Internet.

The ICT Development Index (IDI) is an index published by the United Nations International Telecommunication Union based on internationally agreed information and communication technologies (ICT) indicators.

[45] http://www.statistiques.public.lu/catalogue-publications/bulletin-Statec/2015/PDF-Bulletin1-2015.pdf

Finally, the estimate of the **average annual expenditure** incurred by households in ICT (which includes primarily equipment and services related to telephony, audio-visual and IT) amounted over the period 2011-2013 amounted to 1.837 EUR, or 3.2% of the annual budget.

As the study *Luxembourg and ICT: a snapshot* further relates in terms of **computer skills**, the European survey on ICT usage in households and by individuals[46] showed that Luxembourg, together with the Nordic countries, features the highest shares of highly skilled computer users in Europe.

Concerning features like Internet skills, participating in social or professional networks, Internet banking, online shopping, ordering goods or services over the Internet, a similar picture of Luxembourg as being part of the leading European nations arises. It shows that e-skills are acquired by individuals to 35% through formal education, 26% through training courses upon demand of their employer, 27% through self study, 66% through learning by doing, 69% through informal assistance from colleagues or friends. Again Luxembourg lies in first or second place of all EU member States.

Considering the importance of the **information and communication sector in the national economy**, it encompasses a large variety of activities as well as a diversified array of local and multinational companies, large and small, that contribute with 6,6% to the total gross value added (GVA) generated in Luxembourg in 2012. Again, this share lies considerably over the EU-27 average (4,6% of the total GVA) and is the highest among the 27 EU Member States.

In **comparison to other European countries**, however, the Digital Economy and Society Index 2015[47] indicates that Luxembourg has an overall score of 0,53 and ranks 9th out of the 28 EU Member States in terms of a digital economy and society. Luxembourg is 6th among EU countries on connectivity. Luxemburg has completed broadband coverage and a fast broadband connection (at least 30 Mbps) is available to 94% of households. Take up is strong, also for the faster connections.

With a Human Capital score of 0,65, Luxembourg holds a 6th place among EU countries, including the share of Internet users in the population (93%) and the share of those having basic digital skills (82%) which are the highest in the whole EU.

However, the transmission of technology into new ideas and products hinges on the availability of a vast pool of aptly skilled workers. Despite widespread basic digital skills, there is a **shortage of qualified ICT experts** in Luxembourg: In 2014, 58.5% of enterprises which recruited or tried to recruit staff for jobs requiring ICT specialist skills reported problems in filling these positions, up from 52.8% in 2012. This is the second-highest figure in the EU. This problem is also related to Luxembourg's low number in science, technology and mathematics graduates, where it is the worst performer in graduates in these areas with a mere 2,8 graduates per 1000 individuals compared to an average of 17 graduates per 1000 individuals for the EU.

In terms of the propensity of individuals to use Internet services, Luxembourg scores 0,54 and ranks 5th among EU countries. The use of internet continues to grow in most categories.

Following this study, Internet users in Luxemburg are skilled and do not hesitate to engage in a broad range of online activities. They read news online (85%), listen to music, watch films and play games online (59%), use the Internet to communicate via video calls (42%) or through social networks (64%), and obtain video content using their broadband connections (28% of households with a TV use Video on Demand). For most of these activities, engagement among users in Luxembourg is in line with or higher than the EU average.

On the integration of digital technology by businesses, Luxembourg scores only 0,33, its second worst score among the five DESI 2015 dimensions, and ranks only 16th among EU countries. Luxembourg has still efforts to be made, as a true digital economy is one where businesses take full advantage of the possibilities and benefits offered by digital technologies, to improve their efficiency and productivity, and to reach out to customers to sell goods and services. In this respect, the adoption of e-business practices by companies in Luxemburg shows a contrasted picture, as on the one hand Luxembourg's businesses exploit well Electronic Information Sharing and RFID technology, whereas on the other hand, the proportion of those using electronic Invoices, the percentage of

[46] http://ec.europa.eu/eurostat/cache/metadata/DE/isoc_bde15c_esms.htm
[47] https://ec.europa.eu/digital-agenda/en/scoreboard/luxembourg

SMEs selling online and the share of e-Commerce in SME's turnover are still quite low, as SMEs from Luxembourg appear to take advantage of the Internet to access non-domestic markets and sell cross-border. This is partly due to the size of the country and the openness of its economy.

With regard to e-Government, Luxembourg has shown some improvement as well in its use as well as in the supply of e-Government services. Luxembourg's scores place it among medium-performance 4 countries.

3.3 Characteristics of the Luxembourg ICT market

The **thematic study E-JOBS**[48] realized in 2014 by the Institut Universitaire International Luxembourg (IUIL) provides a fairly accurate overview of the structure of the Luxembourg ICT sector. It indicates that 91% of the 1.750 companies of the ICT sector in Luxembourg have less than 19 employees and 62% have only one employee.

On the other hand, more or less 30 big ICT players - national and international - are present in Luxembourg and which should be considered as the first movers with regard to setting up a new VET offer within the ICT sector in Luxembourg.

The importance of the ICT sector in Luxembourg is thus reflected by its weight in the economy in general. With nearly 5% of the total turnover of all Luxembourg companies, the Luxembourg ICT sector represents one of the highest in Europe. The study also indicates that 6% of all Luxembourg companies and 6,3% of the workforce outside the financial and insurance sector work in the ICT sector (without considering the workforce active in ICT departments in other sectors).

Therefore, one may conclude that the ICT sector does not only play a major role in the Luxembourg economy as such, but it can also be found on the international ICT map as many internationally renowned actors have chosen Luxembourg as their platform to access international markets (f.ex. RTL Group, SES, iTunes, eBay, PayPal, Vodafone, Amazon, RealNetworks, Rakuten, Skype, etc.), making Luxembourg a major player in the ICT sector in Europe and beyond.

3.4 Luxembourg's ICT stakeholders

At this stage, we would like to highlight one particular characteristic of the Luxembourg ICT eco-system: the extremely numerous and various ICT stakeholders that are active in Luxembourg.

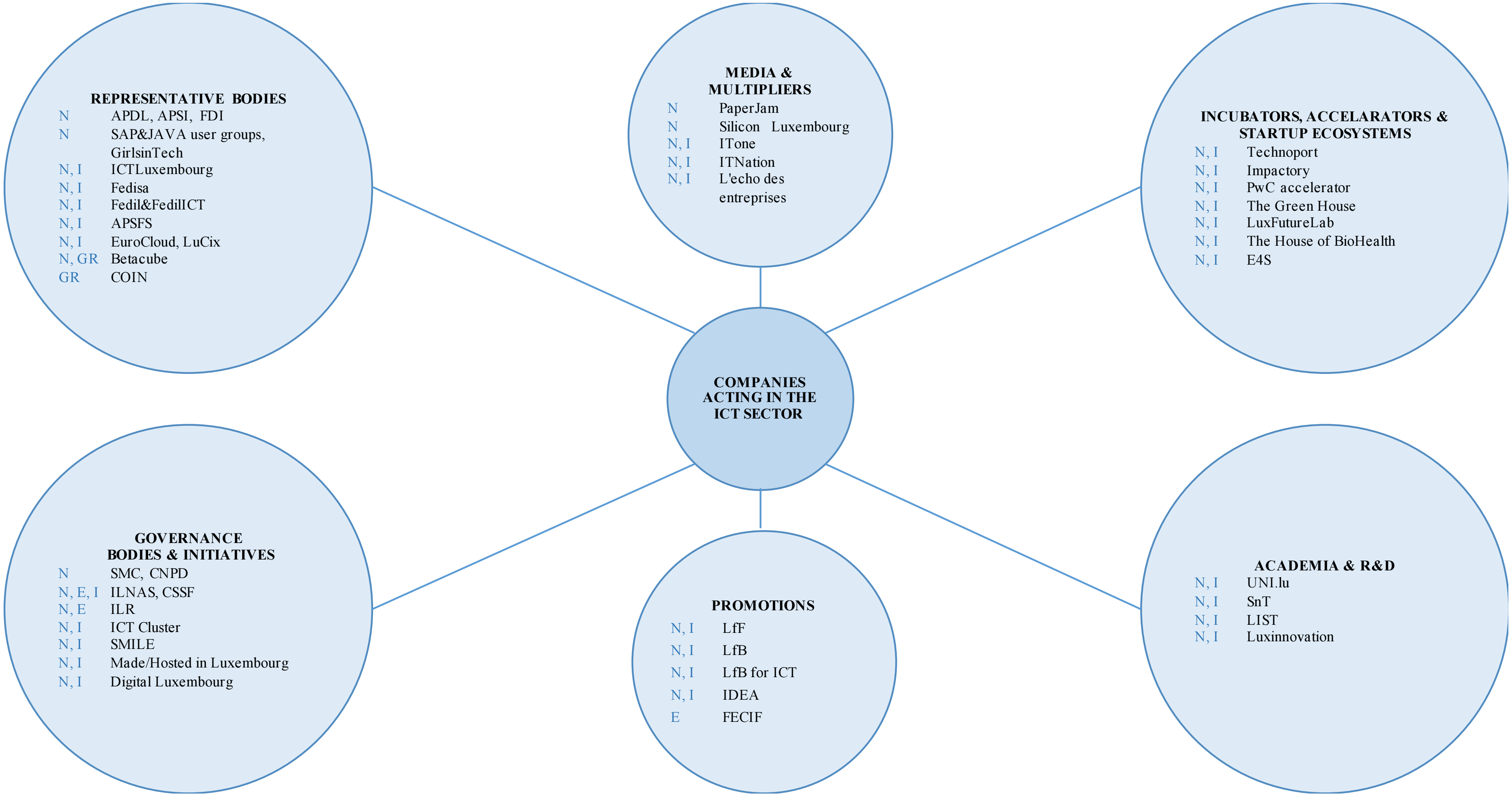
Different groups of ICT stakeholders can be identified with regard to their National (N), European (E), International (I) or Greater Region (GR) role:

- governance and administrative bodies or initiatives,
- media and multipliers,
- representative bodies (federations, sectoral organizations and user platforms),
- academia and research and development,
- business incubators, accelerators and start-up ecosystems,
- promotion agencies.

We describe this eco-system with the following figure and description

[48] http://www.iuil.lu/uploads/documents/files/e-jobs-rapport-final-light.pdf

Figure 2: Stakeholders composing the Luxembourg ICT ecosystem



3.4.1 Governance and administrative bodies

Media and Communication Service **(Service des Médias et des Communications - SMC)** was established in 1991. Its missions are media regulation, protection of data and the digital economy.

The Luxembourg Institute of Standardisation, Accreditation, Safety and Quality of Products and Services **(Institut Luxembourgeois de la Normalisation, de l'Accréditation, de la Sécurité et qualité des produits et services - ILNAS)** is a public service under the authority of the Minister in charge of the Economy. ILNAS is a competency network at the service of competitiveness and consumer protection. ILNAS represents Luxembourg's interests in the European and the international standardization organizations.

ILNAS's terms of reference in the field of standardization are:

- to organize, coordinate and develop the wording, dissemination and implementation of normative documents at national level;
- to ensure the participation of the various economic sectors in the development of European and International standards;
- to implement European standards at national level;
- to set up a standards watch;
- to promote the use of standards.

The Luxembourg Institute for Regulation **(Institut Luxembourgeois de Régulation - ILR)** regulates the telecommunications, energy sector and postal services. It is an independent regulator which is financed by the operators of the sector. The ILR competence is to stimulate and guarantee competitiveness, to determine the fees and conditions at which communication networks are operated, to prepare statistics, annual reports and regulations. ILR can also lead sanctions against operators, which infracted laws or regulations. The ILR sets rules in accordance with European directives and national laws.

The National Commission for Data Protection (**Commission Nationale pour la Protection des Données – CNPD**) is an independent authority created by the Act of 2 August 2002 on the protection of individuals with regard to the processing of personal data. It verifies the legality of the processing of personal data and ensures the respect of personal freedoms and fundamental rights with regard to data protection and privacy.

The Surveillance Commission of the Financial Sector (**Commission de Surveillance du Secteur Financier - CSSF**) is a public institution which supervises the professionals and products of the Luxembourg financial sector. It supervises, regulates, authorizes, informs, and carries out on-site inspections and issues sanctions. Moreover, it is in charge of promoting transparency, simplicity and fairness in the markets of financial products and services and is responsible for the enforcement of laws on financial consumer protection and on the fight against money laundering and terrorist financing. It responds to the following objectives:

- to promote a prudent business policy in compliance with the regulatory requirements,
- to protect the financial stability of the supervised companies and of the financial sector as a whole,
- to supervise the quality of the organization and internal control systems,
- to strengthen the quality of risk management.

The initiative **security made in Lëtzebuerg" (SMILE)** launched in February 2015 is the online source for cyber security in Luxembourg. Its goal is to provide news, relevant information as well as a toolbox with useful cyber security solutions for private users, organizations and the ICT community. It centralizes, all news and other valuable material from its three fields of activity (CASES, AWARE and CIRCL). It builds on the integration of the pre-existing services, infrastructures, platforms, experience and competence of partners, and thus represents a central place for information security awareness-raising, information, support and problem solving material. SMILE also initiates new markets with high added value to deliver high-quality services accessible to municipalities, SMEs and companies of every size, by developing new solutions and competent services for the Luxembourg economy.

Cyberworld Awareness and Security Enhancement Services (CASES) and **Cyber Emergency Response Community Luxembourg (CERT)** are institutions whose objectives it is to create a community gathering of all security professionals under one label and platform and to represent the sector on all national and international levels.

The **Computer Incident Response Centre Luxembourg (CIRCL)** is an initiative designed to provide a systematic response facility to computer security threats and incidents. CIRCL provides a reliable and trusted point of contact for any users, companies and organizations based in Luxembourg, for the handling of attacks and incidents. CIRCL's aim is to gather, review, report and respond to cyber threats in a systematic and prompt manner.

The Luxembourg **ICT Cluster** is part of the Luxembourg Cluster Initiative, launched by the Luxembourg Government to encourage networking between the private and the public sectors. The Luxembourg ICT Cluster brings together various actors in the field of ICT in Luxembourg with the goal of fostering new and sustainable business opportunities through collaborative research, development and innovation projects. The cluster provides specific support activities and services to its members and offers a platform for networking, collaboration and exchange of experience. It aims to optimize enabling technology for various sectors and the further development of the existing ICT sector in Luxembourg by encouraging networking and collaboration between the private and public sectors. The Luxembourg ICT Cluster is a network that supports and brings together the various actors in the field of ICT in Luxembourg with the goal of fostering new and sustainable business opportunities through collaborative research, development and innovation projects.

The objective of the initiative **Digital Lëtzebuerg** is to strengthen and consolidate the forward positioning of the country in the field of ICT and make it the international ICT centre. It promotes the existing initiatives in different sectors and combines them into a comprehensive strategy to increase their visibility. This is done to highlight and promote the completed and ongoing projects in the various ministries to identify opportunities for collaboration and potential coordination measures and to draw perspective areas for development.

The label **Made in Luxembourg** is a registered trademark since 1984 at the initiative of the Ministry of Foreign Affairs and the Chamber of Commerce. The label is used to identify the Luxembourg origin of products and services.

The label **Hosted in Luxembourg** is a trademark for holding companies to identify web applications and webservices hosted in Luxembourg.

3.4.2 Academia and R&D

The mission of the **Computer Science and Communications Research Unit (CSC)** of the University of Luxembourg is to conduct fundamental and applied research in the area of computer, communication and information sciences. The goal is to push forward the scientific frontiers between these fields. CSC focuses on such areas as communicative systems, information security, intelligent and adaptive systems, software and systems in particular to strengthen the interdisciplinary centres LCSB and SnT.

The research unit **Laboratory of Algorithmic, Cryptology and Security (LACS)** is part of the CSC. It focuses on cryptography, building secure public-key cryptosystems, computational number theory systems and network security and information security management. As parts of its activities, LACS organizes a regular seminar, and an annual workshop.

The **Luxembourg Institute of Science and Technology (LIST)** is active in the fields of materials, IT, environment, space technologies or the public health sector. LIST was created from the merger between the Public Research Centres Gabriel Lippmann and Henri Tudor in 2015. It benefits from the competences of these two major actors of the Luxembourg research system. LIST participates in national and European competitive research programmes. In order to support companies in their innovation projects, LIST enables them to enhance their competitiveness in regional, national, and international markets. It also contributes to the setting up of new companies in Luxembourg through the development of innovative technology and expertise.

The **Interdisciplinary Centre for Security, Reliability and Trust (SnT)** at the University of Luxembourg contributes to establishing Luxembourg as the European centre of excellence and innovation for secure, reliable and trustworthy ICT systems and services. The interdisciplinary approach brings together expertise from engineering, natural, law, and human/social sciences to address common challenges. SnT fosters interaction and collaboration with industrial, international and government partners.

The **Research Unit in Engineering Science (RUES)** is an interdisciplinary group active in the classical domains of civil, electrical and mechanical engineering. The main focus of research is the development of technological solutions, the sustainable and economical use of all kind of resources, the establishment of a centre of expertise for the technological requirements of Luxembourg's industrial and public actors.

Luxinnovation, the national Agency for Innovation and Research, is the first-stop shop for information and guidance on innovation and R&D in Luxembourg including national and European programmes. Luxinnovation assists companies in identifying abilities and requirements, finding the right instruments for financial and technological support and facilitating access to support programs for innovation and research at national and European levels. Its missions include:

- to promote research, innovation, technology transfer and the creation of innovative companies in Luxembourg,
- to inform and support company creators, enterprises, and research organizations,
- to support enterprises, research organizations and promoters of innovative projects at each phase of their projects, from the identification of their needs to assistance in finding financing and the launch of a product or service,
- to assist and advise the government in the area of research, development and innovation,
- to raise public awareness on research, development, innovation, creativity and design

Luxinnovation offers services to actors involved in the fields of R&D and innovation (enterprises, researchers, research organizations, company creators, students, etc.).

3.4.3 Promotion bodies

Luxembourg for Finance (LFF) is the Agency for the Development of the Financial Centre. It is a public-private partnership between the Luxembourg Government and the Luxembourg Financial Industry Federation (PROFIL). Founded in 2008, its objective is to promote the expertise of the financial centre and the diversification of its services abroad through different communication channels. The agency continuously monitors global trends and evolutions in finance to identify development opportunities for the Luxembourg financial centre and to serve different target markets and target groups. In cooperation with the various professional associations, LFF develops documentation on products and services available in Luxembourg and their relevant legal and regulatory framework.

Luxembourg for Business (LfB) was founded in April 2008. LfB operates as a trade promotion agency and functions as a network agency establishing a platform for its members to review, coordinate and improve their trade promotion efforts.

The objective of the **ICT division of LfB** is to provide companies with a one-stop-shop for detailed information on business opportunities in Luxembourg and hands-on administrative guidance and contacts in the ICT and media sectors. It gives company leaders easy access to key decision-makers in Luxembourg. It also aims at developing Luxembourg as an attractive environment perfectly fit to the needs of the digital economy. Finally, the ICT division of LfB commissions' studies on the Luxembourg market, edits information material and promotes Luxembourg as an ICT and media hub abroad.

IDEA is an economic policy think tank launched by the Chamber of Commerce of Luxembourg. IDEA endeavours to work as an autonomous, versatile and open entity and strives to lead reflections in terms of sustainable development in Luxembourg by pursuing the general economic interests of the country, and to contribute to the improvement of the socio-economic debate. Its ambition is to contribute to this debate through high-quality economic analyses and innovative ideas presented and discussed in public within the framework of open debates with various audiences.

The **European Federation of Financial Advisers and Financial Intermediaries (FECIF)** was chartered in June 1999 for the defence and promotion of the role of financial advisers and intermediaries in Europe. It is the European body representing European financial advisers and intermediaries. FECIF is keen to promote PSF.

3.4.4 Representative bodies

The **Support PSF Association (APSFS)** is a non-profit organization founded in 2007 in order to represent the interests of companies operating under the status of support PSF. The mission of the association is to inform, help and encourage synergies between member companies and the proactive treatment of subjects directly linked to the development of the Support PSF industry. It promotes PSF status on the international level.

EuroCloud Luxembourg was founded in December 2009 with the support of Fedil - Business Federation and the ABBL. It acts as a coordination platform to position Luxembourg as a leader in the field of Cloud computing and SaaS applications. It aims to contribute to the development of the cloud computing business in Luxembourg by creating an exchange platform for cloud service providers, to promote and encourage the uptake of cloud services and applications, and to develop legal framework for cloud computing on a national, European and international levels. EuroCloud Luxembourg organizes EuroCloud Luxembourg Awards.

The **Association for Data Protection in Luxembourg (APDL)** is a non-profit association aimed to promote the exchange of experiences, knowledge and ideas within all individuals regularly practicing law, economics, engineering and research. It aims to contribute to the dissemination of knowledge, particularly through the organization of conferences, by the communication and documentation of the actions or training partnerships and to create links in Luxembourg and abroad and particularly in the European Union with any entity of the same material.

The Association of the Professionals of the Information Society (**Association des Professionnels de la Société de l'Information - APSI)** is a business federation focusing on the ICT industry in general. Its mission is to inform, represent and defend the interests of member companies and participate in the promotion of the ICT sector information in Luxembourg. Since 2009 association organizes the so-called APSI days on behalf of the ICT sector.

The Committee for Numerical Interactivity (**Comité d'Organisation des Interactivités Numériques - COIN)** is an association and online community established in 2012. It aims to federate the actors of the video game creation in a network, to promote the careers and trainings, help in starting businesses, to promote cultural aspects related to video game creation through events, such as the organization of Game Jams in the Greater Region.

The Federation of Integrators in Telecommunications, IT, Multimedia and Security **(Fédération des Intégrateurs - FDI)** represents a group of professionals with interests covering all activities in ICT, multimedia and security systems.

The **Business Federation Luxembourg (Fedil)** was founded in 1918 and is representing companies in the sectors of industry, construction and business services. FEDIL's main objectives are to defend the professional interests of its members and analyse all economic, social and industrial issues relating thereto, to develop the spirit and solidarity among Luxembourg employers. Maintaining regular contact with the national and European levels with politicians, public authorities, the business community and trade unions, the FEDIL strives to influence political and administrative decisions in the interests of free enterprise. In order to promote the Luxembourg economy, the FEDIL also participates in numerous trade missions abroad. Its subsidiary **Fedil ICT** represents the platform for ICT companies that are also member of Fedil Business Federation. Since 1983, Fedil has been handing out the Innovation Award of Fedil as a way to encourage creativity and innovation. This award is handed out every 2 years.

The Federation of Alternative Operators Luxembourg (**Fédération des Opérateurs Alternatifs du Luxembourg - OPAL**) was founded in 2007, the association aims at the promotion of telecommunication services and the representation and defence of the interests of alternative operators to the bodies in charge of the ICT market, including the ILR, relevant ministries and European authorities.

The **Luxembourg SAP User Group** created in 2006, forms part of the FEDIL, it regroups all companies (e.g. international groups, SMEs, actors from the public sector or the industry, the health care, transportation and logistics) using SAP. Its mission is to share project experience between different SAP users, to detect and address local specific requirements towards SAP.

Betacube organizes regular Hyperlink meetups. This event allows web professionals, developers, designers, entrepreneurs and startups share their knowledge and expertise about new technologies, methodologies, ICT, new media, marketing and other web related disciplines. The aim of Betacube is to build an active web community in Luxembourg and in the Greater Region.

Girls in Tech Luxembourg is part of Girls in Tech Worldwide (created in 2007 in USA), and has been founded in January 2014. The organization promotes, supports and educates entrepreneurial and innovative women in the technological space.

LUxembourg Commercial Internet eXchange (LU-CIX) was founded in 2009 as a cross-industry initiative of national and international internet players. It hosted in four data centres in Luxembourg. The organization allows internet service providers to exchange internet traffic between their networks. To promote the exchange of contacts, experience and ideas in the ICT sector of Luxembourg and beyond, LU-CIX organizes the Luxembourg Internet Days.

The **Luxembourg Java User Group (LuxJUG)** is an independent, non-profit and moderated newsgroup. It provides a place and infrastructure to share experiences and knowledge about the Java platform and related technologies.

The **Federation of ILM (Information Lifecycle Management)** and the **Federation of Storage and Archiving in Luxembourg (FedISA)** act as a part of FedISA International. The purpose of FedISA is to create a relevant forum for professional users, providers and consultants in the field of archiving and information security. It aims at:

- bringing together stakeholders and informing them by working with existing national associations to educate the public and the private sectors about the concepts of ILM and digital archiving,
- promoting the use of digitized information by contacting the public law and private law organizations, national, regional and local authorities,
- informing and assisting project managers on technological developments, new processes and new regulations in performing work of many technological monitoring that legal and normative,
- promoting the introduction of norms and standards in the professional repository involved in conservation processes, exchange, and digitized information.

The **YAJUG is a Java User Group** that aims to promote the technologies, applications and methods related to Java, to foster the associated open-minded culture, to be the link between research, users and suppliers of Java, to support the exchange of experience and expertise gathering all stakeholders around Java.

ICTluxembourg is a non-profit coordination platform for the ICT trade associations. The organization brings together ICT professionals for discussions on the future of the sector, represents the interests of all national and international companies and supports key initiatives. It aims to enhance synergies, exchange information and best practices between all the players of the sector and to create a welcoming environment that will attract and retain ICT companies. It supports and fosters ICT related projects and initiatives throughout the country for a strong national positioning and a more effective international reach. It is made up of six major federations and associations in the field of IT and its ICT users: FDI, APSI, EuroCloud APSFS, FEDIL-ICT and ABBL. On the international level, ICTluxembourg works in close cooperation with Luxembourg for Business – Proud to promote ICT. Besides, ICTluxembourg participates in the business and trade missions organized by the Luxembourg government.

3.4.5 Incubators, accelerators and coworking places

Technoport is a coworking place and technology oriented business incubator. It was created in June 2012 as the result of the merge between the former technology-oriented business incubator Technoport and business support infrastructure Ecostart. The goal of Technoport is to promote and support the creation and development of innovative and technology-oriented companies. It provides entrepreneurs with office space, equipment, human and technical resources. Technoport organizes Startupweekends and Apps Foundry Contests events.

The **Impactory** is a coworking space and a business incubator where creative people come to share their knowledge, discuss projects and ideas and learn from each other. The Impactory was created in March 2012 and promotes social entrepreneurship and innovation in Luxembourg. The business initiative 1,2,3 GO and Impactory became Nyuko in 2015.

The **PwC Accelerator** helps companies to become global, providing access to business networks and decision makers, reviews sales and delivery approach to create value, ensures instant visibility in selected markets.

The **Green House** incubator promotes startups in ICT, mobile, social media, gaming and digital health sectors.

The **Lux Future Lab** is a business incubator, created in 2012 by the Luxembourg bank BGL BNP Paribas as a part of its corporate social and economic responsibility program. The Lux Future Lab is providing office space, training programmes, coaching, access to the lux future lab networks, both national and international, and supports marketing services, events management, new entrepreneurial activity in Luxembourg. Majority of companies which work in The Lux Future Lab have business related to ICT.

The **House of BioHealth** incubator was inaugurated in 2015 and is supported by the Ministry of the Economy as well as the BioHealth and ICT clusters. It promotes startups and existing businesses in the areas of biotechnology, ICT and environmental technologies.

Europe4StartUps (E4S) is a non-profit organization which helps e-business and multimedia companies coming from all over the world and wishing to develop, startup or boost their ventures in Europe by providing 12 preselected companies with 12 months of premium cloud storage, network and other business services for free.

3.4.6 Media support and multipliers

IT One, the ICT Community of Luxembourg, was created in 2007. IT One strives for the recognition of Luxembourg's ICT community, the development of the entire sector and the promotion of its professionals as well as for the diffusion of best practices, innovative solutions and valuable services. IT One's Luxembourg-based leading web portal deals with ICT trends and topical issues at national and international scales. In order to promote sector, IT One organizes awards and events, such as the IT One Gala where the best national practices are rewarded with the Luxembourg ICT Awards, the ICT Spring Europe, a two-day event that brings together more than 4000 ICT key decision makers from all over the world and IT Days Luxembourg, and the Information Security Days, a two-day event focused on security, gathering in one venue security specialists, CIOs and key decision makers from different Europeans countries.

ITnation is a magazine specialized in B2B communication, news and event organization for ICT professionals.

Paperjam is the leading magazine for the business world in Luxembourg and strongest media brand in the country founded in 2000. **The Paperjam Club** is an essential platform in Luxembourg which was launched in 2008. The club consists of over 600 member companies and over 4,000 executive members. It offers its members a variety of events, allowing exchange of knowledge and ideas through networking. The Club is approved by the Ministry of Economy.

Founded in 2013, **Silicon Luxembourg** is a media channel designed to profile startups and promote entrepreneurial activity in Luxembourg. Media platform aims to bring together all entrepreneurial and startup information from Luxembourg and become contact for entrepreneurs and investors from around the world."

L'**Echo des entreprises**, a publication of FEDIL, is devoted to economic and social issues affecting companies in the sectors of manufacturing, construction and business services. As such, it represents a targeted advertising medium of choice, its readership is composed, mostly, executives, business managers and other decision makers, including political on national and international levels.

Insert: SWOT-analysis of the Luxembourg ICT sector

Strengths	Weaknesses
a. International infrastructures i. Connectivity – golden ring ii. RTT latency values iii. Internet exchange point b. Data centres i. 99.995% availability ii. 13% of the world's Tier IV capacity iii. Redundancy, security, trust c. Nationwide fibre network d. Fiscal policy i. Intellectual property law ii. E-commerce law (until 2015) e. Competitive price for electricity f. PSF Status g. PSDC Status h. Law on "cloud computing" i. Financial sector as main driver j. Simple access to authorities and political decisions makers k. High GDP l. Multilingual workforce	a. Small country – no critical mass i. Market structure – a few large players dominate ii. No single EU market iii. Applied R&D not well developed b. ICT skills underdeveloped i. Limited venture capital available ii. Risk averse iii. High salary costs
Opportunities	**Threats**
a. Development of specialist functional skills to service large ICT suppliers or their customers. b. Development of advanced networking solutions and intelligent networks, social network computing and GPS applications. c. Providing advanced capability in data storage, data processing, data mining and knowledge extraction for any organisation in the world but in particular locally. d. Attraction multinational investment e. Position Luxembourg as secure, trusted HUB f. Redundant electricity grid g. Cyber security h. Pro-active Government (Luxembourg for Business, Luxembourg for ICT) i. Small country – innovation lab	a. Failure to invest in infrastructure on a constant basis b. Competing in a local market where international brands are most trusted c. Competing on a world wide scale d. Innovating and producing in fragmented markets e. Intensive Competition from neighbouring countries f. New VAT and tax regimes g. EU and G20 pressures h. Political pressure on international companies i. Dependant on electricity grids of neighbours j. ICT workforce and skills missing k. Limited creativity j. Increasing public debt, limited investment capacity

3.5 Current Luxembourg ICT strategy

3.5.1 Government initiatives

The Luxembourg ICT stakeholders have recognized the invaluable role that the information and communication technologies (ICT) play in the national economic development.

Luxembourg has, in recent years, experienced a major advancement with the accelerated development of the country's innovative technology companies, whether in the media sector, e-commerce, digital content, cloud computing, Big Data, electronic payments, security issues, etc.

A considerable investment has been realised to transform Luxembourg into a highly connected country, while providing the necessary support structures, such as communications infrastructure (connectivity, data centres, security-related services, etc.), research and innovation institutions (university, research centres, support to innovative companies, etc.), or at adapting the legislative framework for a dematerialized digital society. It was thus possible to create an attractive setting for companies that wish to develop their activities in the country, as well as to provide new employment perspectives for highly specialised workers, thus increasing the nation's competitiveness on the whole.

As a consequence, the ICT sector has in the meantime become an economic player in its own right and is not merely limited to its function as a service provider to other economic sectors, especially the financial sector. In both ways, as an economic sector by itself and as a vector of competitiveness for all other socio-economic sectors, the ICT sector will continue to play an ever more important part in the modernisation, performance, competitiveness and efficiency of the country.

In order to strengthen and consolidate the country's position in the field of ICT and to transform its ICT sector into a high tech centre of excellence, the Luxembourg government in conjunction with its stakeholders has adopted a comprehensive and coherent digital strategy, encompassing subjects as diverse as the computerization of government services, e-skills, the adaptation of financial support instruments, the development of new niche markets for new markets (big data, health technologies, innovation in services to the financial sector (FinTech), virtual currency, creative industries, etc.), and the Government accepts this strategy of horizontal and consistently across all its policies that may be relevant.

Also in Luxembourg, ICT have undoubtedly changed our ways of living and our ways of thinking more than any other technique or technology before. ICT have become completely embedded in our daily lives, our work and our leisure time. It is certainly one of the driving forces behind Luxembourg's dynamic and sustainable economic growth, employment creation and social development and will eventually enhance our national well-being. It contributes substantially to the efficiency and the competitiveness of industry in general, while covering simultaneously an enormous economic potential as an industry in its own right. If handled well, ICT will be the key factor for Luxembourg companies to achieve large gains of productivity as well new innovative products and services through which a distinct differentiation will be made possible.

3.5.2 ICT Vision: Luxembourg 3.0

As the Luxembourg Minster of Economic Affairs, Mr. Etienne Schneider[49], has recently stated, Luxembourg has undergone over its recent two hundred years history three major economic leaps:

The first one is related to the industrial revolution concerning the **steel industry** in the first half of the 19th century, which could be designated by Luxembourg 1.0.

The second one relates to the implementation of the **financial sector** in the second half of the 20th century, as Luxembourg 2.0.

And the third industrial revolution made in Luxembourg is now devoted to the **ICT sector** and can be called Luxembourg 3.0.[50]. It stands for a vision to further diversify Luxembourg's economy and to

[49] http://paperjam.lu/news/etienne-schneider-veut-un-luxembourg-30?language=de

boost Luxembourg into the digital age as a high-tech nation, opening new horizons for its companies and its citizens. The vision could be described as the willingness to transform Luxembourg into a **globally competitive world premier centre of excellence in ICT**.

In terms of the strategic implementation of this vision, it defines a pathway for the creation of a highly performant ICT nod or hub for the very high speed Internet, the implementation of ultra secured big data centres, or the development of new activities such as electronic payment and virtual money systems, IT platforms, online video games, e-commerce, e-services, e-logistics and biotechnologies. A subsequent infrastructure investment policy has been installed over the last ten years in order to generate further economic growth through massive investment in technology - hardware, software and brain ware.

Thus, Luxembourg ought to become a significant and outstanding provider of a highly performant world class ICT infrastructure and business environment to enable national and international companies, established or starting-up, to develop new and innovative business opportunities that are successful and sustainable under rapidly changing market conditions and customer needs.

3.5.3 ICT Strategy

3.5.3.1 General orientation

Due to past investments, ICT is on its way to become a new strategic industry for Luxembourg. If Luxembourg intends to further become a significant player on the European or even international ICT map, it will be essential not only to allocate legal, financial and organizational resources to attract key ICT players in order to generate a sustainable performance through offering value to clients and stakeholders in ways that are superior to competitors. For that reason, Luxembourg needs to identify and create sources of differentiation and distinctiveness that provide value to potential investors and entrepreneurs.

In order to achieve this overall objective, Luxembourg has to continue to create a fully competitive environment, with products, infrastructure and services of highest quality in order to highlight its distinctive competitive advantages and to generate new products and services, thus creating new sources of revenue.

One particular pathway for implementation of such a forward looking and dynamic strategy is linked to the indispensable necessity to attract a further scarce resource: talent. Talent undeniably constitutes a compelling reason for new companies to invest and existing ones to grow. Therefore, talent development ought to be at the centre of the entire innovation ICT policy spectrum.

If Luxembourg wishes to develop into a globally competitive ICT centre, it will not only need to continue to invest massively into an appropriate ICT infrastructure, by establishing collaborative links between different actors in the form of clusters, by supporting both well-established and internationally renowned companies and small start-ups, by reinforcing hybrid platforms such as FinTech, by developing ancillary businesses, to enhance research and development, it must also and by all means develop proactively the digital community of people.

In order to further trigger the development of the ICT sector, it will be necessary, next to policies such as land zoning, advisory policies, broadband provision, specific government development projects such as Digital Lëtzebuerg, intellectual property rights, regulatory environment, security issues, enhancing public-private partnerships and business incubators, to complete the strategy by an ICT skills and employment development policy, while creating new markets and opportunities for education and training institutions and projects. Attracting and retaining experts and other skilled people is one of the key factors of the ICT development scheme in Luxembourg.

[50] http://www.lesechos.fr/30/01/2014/LesEchos/21616-142-ECH_les-ambitions-du---luxembourg-3-0--.htm#5a2b3Zexl5P3xH5I.99

3.5.3.2 Concrete implementation projects[51]

3.5.3.2.1 Digital Lëtzebuerg[52]

In order to implement this strategic vision, the Luxembourg Government has established a new initiative called **Digital Lëtzebuerg**. It refers to the definition, development and implementation of a comprehensive digital strategy for Luxembourg and is meant to indicate a new face of the country and to share a coherent and common strategy to make Luxembourg a synonym for a modern, open, and highly connected country, ready for the digital economy and society.

The development opportunities for Luxembourg are to be seen at the intersection between sectors and centres of traditional skills in the country and the paradigm changes resulting in the digital society and the technological innovation. Thus, for example, the financial sector is part of the evolution of Big Data, cloud computing, virtual payments or other alternative currencies to open new areas for development in what is commonly called FinTech.

This platform is meant to support and enhance new opportunities in those fields such as Big Data or data protection and security, trust centres for sensitive data, e-commerce, content providers, research, health services, biotechnology, etc., and this mainly in several chosen key economic sectors: environmental technologies sector, health and biotechnology sector, logistics sector, financial sector, and also the information and communications sector,

From the organizational point of view, the Digital Lëtzebuerg platform strives to create synergies and exchanges between different initiatives and different public and private actors through variable configurations.

Within the Digital Lëtzebuerg initiative, the following thematic cells have been identified:

- Infrastructure
  - National and international connectivity
  - Fixed and Mobile Internet
  - Infrastructure Data Centres
- Support for innovation
  - Public support for start-ups
  - Favourable framework fir Seedfunding and Venture Capital
  - Facilitation for the establishment of new businesses and simplification of interactions with administration
- FinTech
  - Technological solutions for the financial sector
  - Electronic and Mobile Payments
  - Virtual Currencies
  - Innovative services in the filed of financial data analytics
- E-skills
  - Research and Development
  - Attractivity of the Grand Duchy for foreign skilled workers

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[51] http://www.finance.gov.au/files/2011/04/Draft-ICT-Strategic-Vision.pdf
http://images.fastcompany.com/madetostick/sticky-srategic-vision.pdf
http://www.ida.gov.sg/Tech-Scene-News/Smart-Nation-Vision
http://www.arabiangazette.com/singapore-unveils-building-blocks-of-smart-nation-vision-20140616/
http://www.slideshare.net/hjs0199/smart-city-and-smart-government-strategy-model-and-cases-of-korea?related=1
https://www.youtube.com/watch?v=QPu4v_Ae0Vc
https://www.youtube.com/watch?v=UZrTl16hZdk
http://www.egov.gov.sg/egov-masterplans/egov-2015/vision-strategic-thrusts
[52] Gouvernement du Gand-Duché de Luxembourg, Ministère d'Etat, Service des médias et des communicationy
Digital Lëtzebuerg Conférence de presse du 20 octobre 2014
http://www.gouvernement.lu/4441131/dossier-de-presse-digital-letzebuerg-20141017.pdf

- Education
- Training and retraining

- E-government
  - Electronic administrative procedures
  - Modernisation of Administration
  - Promotion of the use of Eid
  - Facilitation of Open Data

- Promotion
  - Coordination of missions abroad
  - Promotion Strategy

3.5.3.2.2 Digital (4) Education

The strategy in the field of ICT of the Luxembourg Ministry of Education, entitled *Digital (4) Education*, reflects the efforts to train from an early age on future specialists in the ICT sector and to promote entrepreneurship within it. It also aims to reduce the digital divide, granting all young people, independent of their social background, access to quality educational resources in the field of ICT.

It includes two main priorities and objectives:

- Digital Education: preparing young people for a complex and ever-changing working environment, and in their role as citizens in the public and private sector.
- Digital for Education: promoting new learning strategies and innovative educational projects, using digital in schools

At its core, Digital (4) Education can be broken down into several dimensions:

- BEE SECURE: a programme aiming to promote safer use of ICT, through coherent information and advice to citizens.
- EduSphere: a portal for educators, to support teaching and learning.
- MathemaTIC: a digital mathematics learning tool for Cycle 4 of primary education.
- Digital Classroom Lëtzebuerg (DCL): a technical and technological skills development programme in two strands:
- The introduction of "Office 365 for Education", which will enable 12,000 primary and secondary school teachers, 45,000 secondary school students, and 5,000 administrative officials to have free access to a modern production and collaboration digital environment.
- Innovative Schools – a project using digital tablets in classrooms and promoting new learning strategies.
- BEE CREATIVE: a programme, which aims at improving the digital skills (programming, security, design, communication) of young Luxembourg residents and contributes to the development of a digital culture in the Grand-Duchy. Within this framework, creative hotspots called "Maker-Space" will be established, where young people can put their digital tools to good use.
- The future *Lycée de Clervaux*, which will open for the 2018/19 academic year, and will prioritise the development of digital skills.

3.5.3.2.3 Initiative ICT Luxembourg - Government

On the 30th July 2015, a delegation of representatives of the Luxembourg ICT sector has encountered the Luxembourg Government and presented an extensive list of ideas and projects that could eventually ensure Luxembourg's primary long-term position on the world ICT map.

These include amongst others:

- Create a label « Luxembourg for ICT » to promote Luxembourg as an ICT centre
- Introduce new fiscal measures for startups

- Create a « Seed-Fund ICT »
- Strengthen mechanisms for technology transfer from research to commercial activities
- Strengthen R & D in the field of FinTech to seize the opportunities created by the transformation of the financial market
- Create ICT skills centres for high level continuing education
- Ensure complete wiring of private residences
- Enable high performance computing
- Apply new principles in public management such as « digital by default » and « once only »
- Establish transparency in processes and data managed by Administrations and Municipalities, providing access to an open data portal
- Create a digital single market
- Reinforce cyber security institutions and frameworks to strengthen the character of Luxembourg as a data secure hub"
- Create a label « Secure Luxembourg »
- …

It is meant by this initiative that the members of ICT Luxembourg and related professional associations, such as APSI, will conceive and undertake the necessary measures and projects in order to achieve a large number of objectives set out in this programmatic framework.

3.6 Conclusion

Over the past few years, Luxembourg has been striving – and quite successfully, one must say – to become a major European hub for ICT technologies and services, especially in the field of e-security and financial technology (FinTech). The basis of this success has to be attributed to Luxembourg's heavy investments in ICT infrastructure, an active Government support and its dynamic ICT sector.

Furthermore, the willingness of the Luxembourg population to use ICT in their professional and private lives is also remarkably developed. Businesses and households are directing themselves quickly towards the Internet age and use a very wide range of related commodities and services.

Thus it can be concluded that the ICT sector has slowly but surely been migrating from a support organ to the financial sector to an economic sector in its own right. The existing highly performant infrastructure, the variety and seize of ICT providers and vendors, large and small, as well as the number of highly skilled ICT specialists are a proof of this tendency.

However, in order to further promote and develop a performant national ICT economy beyond its present level, it will be necessary to invest and develop a series of issues:

1. In order to maintain the proposed performance level, a stable and constantly up-dated, innovative and secure ICT infrastructure is needed, as the ICT sector will not work without it. That is why the previous high level of investment in ICT infrastructure to boost the so-called Internet highways needs to be continued and even expanded, by both public and private partners.

2. Despite the existence of highly performant Internet highways in Luxembourg, one must see that these Internet highways are not yet overcrowded, as the number of people, companies and services using them is not elevated enough. It is therefore essential to increase the number of initiatives that aim at delivering products or services and at creating economic added value.

3. Here, the support measures already in place for the industrial players in the ICT sector need to be encouraged by further public initiatives to increase the scope of their activities and to develop new solutions, products and applications in order to maintain their positions in the markets.

4. A further step consists in supporting actively a highly performant, innovative and creative ICT related eco-system (education, research, financing, support systems, regulations, …), that

encompasses a large series of measures, programmes and projects that are needed to finance and implement all relevant measures in a coordinated, systematic and professional way.

5. As the Government policy with regard to ICT is only slowly showing its results, it will be necessary to invest even more into a precise, coordinated and coherent long-term vision and strategy with regards to the development of the ICT sector, on both a national and a regional level. For that reason and in order to achieve new goals and to develop the country fully towards the digital society, Luxembourg with its Government, its ICT industry and its non ICT industry, in conjunction with all the citizens, needs to establish and implement a coherently elaborated and a well thought overall ICT strategy – a challenge which all public and private ICT actors should not only have in their minds, but which should guide their daily business behaviour.
6. In Luxembourg as in Europe in general, the quantity and quality of ICT specialists to further boost traffic on the Luxembourg Internet highways is by far insufficient. The demand for professional ICT specialists still continues to largely exceed its supply.
7. Luxembourg's school system cannot be considered as being a dynamic driver in matters of ICT, as not only the number of students in ICT related branches is by far too low, but also the Luxembourg school system is not able to integrate a digital agenda and to expand its curricula to the realm of ICT. Even if the first attempts to introduce ICT in the school curricula go back as far as 1986, little has changed ever since – as ICT is not yet used generally as a pedagogical instrument, but only as a means for information distribution. In these terms it is by far not enough to create highly specialised research centres to promote ICT learning and teaching on a wider basis, as in order to close the gap of missing ICT professionals, the potential laying in primary, secondary and tertiary education or even quaternary training needs to be fully addressed. The objective should be a most highly developed digital literacy for all companies and persons in Luxembourg.
8. The current eco-socio-system of ICT in Luxembourg appears to be too disrupted as the players and actors of ICT in Luxembourg are not able to define common policies and activities that would enhance the development of the country as an ICT hub on the whole. For a small country, which is competing in this field not only on a European, but definitely also on an international scale, it is essential that all actors collaborate and are able and willing to define common strategies, instead of letting personal interests and individual dispositions prevail. In short, there are too many institutions and too many different interests in the field – but no common logic.
9. Furthermore, as Luxembourg has replaced over the past years its dependency on the steel sector with a new dependency on the financial sector, it risks to follow the same strategy again and to become highly dependent on the ICT sector. In any case, all economic development in one sector needs to be counterbalanced by further economic diversification into new promising directions.
10. Luxembourg needs to raise its productivity standards and comply as much as possible with international norms and regulations.
11. As Luxembourg is and will remain a high-end country and mass production will ever be too expensive and not realistic, the country needs further development towards industries, products, services and professions that are highly performant, innovative and that are producing extended added-value in order to be able to remain competitive, to strengthen resilience and to reduce vulnerabilities.

3.7 Recommendations to further leverage Luxembourg's strengths in the field of ICT

To strengthen its position as an internationally renowned ICT centre of excellence, Luxembourg must therefore continue to leverage and upgrade its existing strengths.

For this reason, we would like to recommend beyond the above-mentioned general issues the implementation of the following strategic and practical elements:

- General
  - Create an environment to facilitate the development, adoption and use of ICT in all businesses, in all sectors, for all people, to achieve both growth (more) and development (better).
  - Foster the acquisition, development and dissemination of new technologies into industry and the broader community.
  - Rapidly develop hard and soft infrastructure to maintain competiveness and employability, achieve organic growth and productivity gains, to foster innovation, commercialisation and differentiation of products and services.
- Government
  - Define and implement a national ICT vision, strategy and policy on a continuous basis upon which the Government and their different ministries plan and implement their ICT related policies in conjunction with the ICT stakeholders.
  - Reinforce the active role of government in providing hard infrastructure.
  - Reinforce the active role of government in providing soft infrastructure.
- Infrastructure
  - Build up, maintain and update permanently a performant, state-of-the-art hard and soft ICT infrastructure (data highways, data centres, universities, innovation centres, …), both large scale and small scale, that is competitive when benchmarked against international standards, and which is organized with a large part of public investments and initiatives to enhance developments, in conjunction with business initiatives (combination of market-pull and market-push).
  - Set up a high-speed broadband capability, fibre to node and high-speed wireless connections with a large coverage, to constantly become faster and better.
- Capital
  - Attract new investors with the help of the banking system.
  - Develop joint public and private investments.
- Attractors
  - Attract Industry champions by creating and supporting institutions such as clusters, universities, research institutions, …
  - Establish key providers, to attract and supply talent and skilled labour
- Working environment
  - Foster a creative working and living environment to attract ICT specialists
- Business environment
  - Create a business environment to attract performant ICT companies and ICT specialists.
  - Foresee opportunities for financial investments, administrative facilitation and start-up support.
- Entrepreneurship
  - Establish an entrepreneurial culture that provides the environment and support infrastructure to undertake business development.
  - Develop entrepreneurial infrastructure and spirit.
  - Develop leaders and entrepreneurs.
  - Foster a highly entrepreneurial culture by actively seeking out and encouraging the growth of new and existing companies, markets, products and services.
  - Support entrepreneurial initiative at all levels.

- Foster an ICT enterprise creation and development programme through an appropriate start-up policy.
- Encourage the creation of new start-ups.

- Education and Training
  - Support an education and vocational training system to develop from an early age and at all levels e-skills.
  - Develop further high level education and training facilities and institutions.
  - Provide training, assessment and consultancy services (hardware, Internet and multimedia technologies, networking, operating systems, software applications and programming).
  - Develop curricula that meet the needs of industry.
  - Ensure that graduates are industry ready by having been exposed to the latest software products being used in industry.
  - Support greater knowledge transfer and interaction between the world of academia and SMEs.
  - Increased intake of students into ICT study programmes
  - Performant and up-to-date equipment at schools and universities, integration of ICT in all subjects and improved teacher training.
  - Create programmes to close the gap between demand and supply to overcome the huge shortage of skills in this sector.
  - Invest in STEM education (Science, Technology, Engineering and Mathematics) to compensate professionals that will retire each year compared to today, increase the supply of new graduates in STEM sector will not meet the demand.

- Research
  - Develop further high level research facilities and institutions.
  - Support leading edge research at a university and research institutions level.
  - Support practical research and transfer at a level of institutions of applied research and knowledge transfer.
  - Upgrade and develop innovation and research.
  - Further develop a strong research and development culture that links the Luxembourg ICT Cluster, local economy and education sector.

- Skill development
  - Permanent adaptation on a high level of the skills and aptitudes of ICT professional to real market needs.
  - Permanently up-date curricula of the universities and the training institutions to provide skills directly to industry.
  - Support cooperation between institutions of higher education and vocational training and industry to adapt their training programmes and to deliver the skills actually needed by industry.
  - Increase emphasis on e-leadership skills.
  - Install recurrent initiatives concerning e-Leadership and Digital Entrepreneurship.
  - Support largely stakeholder initiatives to enhance ICT literacy at all levels.

- Career management
  - Increase the attractivity of professional careers in the ICT sector.
  - Ensure career management and career paths by companies for their ICT staff.
  - Promote careers in ICT among young people and by modernising the education system in order to enable it to provide the required ICT practitioner skills.

- Technological Transfer

  - Establish mechanisms for fostering useful and relevant research and knowledge transfer translating ideas into new businesses.
  - Ensure a rapid and efficient transfer and proliferation of ICT to non ICT businesses.
  - Establish stronger linkages with the local sector, to ensure that ideas developed at a university level are adapted and commercialised by local enterprises.
  - Foster applied research, ICT development and commercialisation initiatives.

- Technology parks
  - In partnership with all relevant actors, create and develop technology parks as an ICT focal point.

- Innovation
  - Create an environment for innovation and the and development of new products, f.ex. FinTech.
  - Create further centres for innovation to ensure a rapid and practical implementation of emerging technologies.
  - Create linkages between ICT and applications of specific relevant industries.
  - Form multidisciplinary teams to work with Luxembourg's major industry sectors to identify new ICT related technologies that could provide them with ongoing competitive advantages.
  - Identify at an early stage emerging trends, to attract investment, to develop and put to market new products and services that are internationally competitive.
  - Foresee actions to keep companies abreast of the latest trends and developments by organising specific and regular events, forums, seminars or workshops with high profile speakers presenting the latest ICT thinking.
  - Create a system to identify and interconnect individuals, companies, research organisations and other enterprises that are developing new ideas and innovations.
  - Accelerate valuable commercialisation projects by developing a joint agenda for a networked and supportive environment which will assist individuals and organisation in more rapidly taking ideas from concept stage to market release.
  - Facilitate new industry based research and innovation and knowledge partnerships and programmes through innovative and interlinked projects.
  - Establish a programme for technology prospective to anticipate at an early stage emerging technologies.
  - Establish a permanent idea's manufactory to collect, develop and disseminate (marketing and communication) ideas at an early stage.

- Cluster Management
  - Attribute further roles to the ICT Cluster to improve the attractiveness and competitiveness of Luxembourg's ICT industry, as well as skilled professionals and collaborative partnerships.
  - Create a strong coordinating body to monitor and foster the implementation of the ICT to plan an annual programme of events and activities.
  - Give priority, support and incentives to the core areas where Luxembourg is likely to present a competitive advantage.
  - Introduce a professional cluster management to manage the interaction between ICT leaders, innovative partners and the end users through the establishment of national private-pubic-partnerships and as well as international partnerships
  - Develop and manage effectively local, regional and international clusters of companies and institutions
  - Support local institutions to facilitate linkages between firms and sources of support and advice
  - Develop collaborative networks and consultative forums between cluster participants.
  - Bring companies together for joint projects.

- Support ICT companies to expand to other countries in the search for active collaborative partnerships.
- Enhance a cooperative, creative and diverse exchange between ICT companies and non ICT companies.
- Reinforce the social cohesion of the ICT community by involving stakeholders and to provide them with the necessary infrastructure.

- Networking and collaboration
  - Support the transversal collaboration of collaborative networks to maximise the benefits derived from ICT related development and adoption.
  - Manage more professionally and more productively the large number of associations in ICT.
  - Foster collaboration and social networking.
  - Foster the development of specific collaborative projects.
  - Build local, regional and international linkages.
  - Foster collaboration with public, private and academic institutions to spinout ICT enterprises into incubator sites.
  - Bring related actors together on a regular work base to work on common projects.
  - Develop of collaborative networks and consultative forums between cluster participants
  - Bringing companies together for active collaborative partnerships and joint projects.
  - Enhance cooperative, creative and diverse exchanges between ICT companies and non ICT.

- Ancillary measures
  - Support ancillary industries that provide important services, components and inputs to the ICT sector.
  - Ensure the establishment of new start-up companies to create a competitive environment that will drive innovation.
  - Ensure existence of support measures for a large and active ICT community, including large forefront companies as well as associations of ICT specialists, which are willing to coordinate their activities with government policies and universities/research institutions.

- Transversal Partnerships
  - Create strong partnerships between public institutions, ICT companies and non ICT companies, as well as professional associations, research and support institutions.
  - Seize opportunities of conversion or upgrade from other occupations towards ICT occupations, in a general context of growing unemployment and persisting shortage of ICT professionals, as a partnership between the ADEM and the ICT sector.

- Brand and Marketing
  - Develop a strong brand and identity for the Luxembourg ICT sector on a worldwide scale.
  - Strengthen Luxembourg's reputation by actively promoting and branding it as a dynamic and vibrant place to live and work.
  - Create an identity for the country that serves as a brand to attract investment and talent.
  - Promote projects of major impact, positive action and track record to enhance the image of the Luxembourg ICT sector.
  - Nominate specific spokespersons for issues and projects associated with ICT.
  - Develop a campaign and events to attract ICT professionals to Luxembourg.
  - Develop lobbying and marketing strategies to put Luxembourg on the map and to promote opportunities.

4 Study on e-Skills Requirements in Luxembourg

4.1 Objectives

In order to analyse in more depth the situation in Luxembourg especially with regard to e-skills and the associated gaps, we have realized an empirical study in order to identify in conjunction with the relevant Luxembourg ICT stakeholders the kind of ICT professional profiles that are needed or lacking today and which will be needed during the days after tomorrow.

Furthermore, the objective of this study was to gain a better understanding of the national ICT ecosystem and its relevant players, of the trends and tendencies of the ICT sector in Luxembourg and of its relationship to the issue of the ICT skills gap, the overall objective being to contribute to designing a new framework for education and training in the ICT sector.

It has therefore been the focus of this research part to develop a broader understanding of a number of critical aspects that are relevant for the reinforcement of the continuing vocational training market in the field of ICT, such as:

- to identify current trends and developments in the ICT sector relevant for Luxembourg,
- to identify priority areas for future development,
- to identify current and future professional profiles in the ICT sector,
- to understand the needs and requirements of the ICT community with regard to the trends and development of ICT in general and the consequences for e-skills development in particular,
- to define in consequence an appropriate strategic plan and to specify adequate instruments for implementation.

For that purpose, we proceeded in three steps:

1) Realisation of a series of interviews with ICT experts and entrepreneurs based in Luxembourg, which provided a deeper insight in what ICT profiles are lacking in Luxembourg.
2) Analysis of the ICT profiles that were most notified by employers to ADEM (Agence pour le Développement de l'Emploi).
3) Desk top research on main trends within the field of e-skills and e-leadership skills.[53] based n the mainly the study prepared by, which puts a specific focus on SMEs.

In order to achieve these objectives, we mainly focused our investigation upon the following questionings:

- How do you see the actual situation of ICT in general and in Luxembourg in particular?
- What future trends and tendencies can you identify?
- What kind of skills (ICT and beyond) are needed today for Luxembourg's current economical state of development?
- What kind of skills (ICT and beyond) will be needed tomorrow and in the future?
- How many ICT skilled people are needed, when and by whom?
- How and where can skilled ICT practioners be found today and tomorrow?
- What facilitating role could an ICT Competence Centre play?

4.2 The exploratory interviews

For that purpose, a series of open face-to-face interviews was undertaken over the Summer period 2015 with a wide range of representatives of the ICT sector in Luxembourg, such as Post, SES Astra, BCEE, CMD Solutions, Telecom Luxembourg, Telindus, Eltrona, and related stakeholders, such as DCL Group, BSH, Docler Holding, consultants, such as KPMG, PWC, Kurt Salmon, headhunters, such as Lancelot, and representatives of the Luxembourg ICT Cluster.

[53] IDC study for the European Commission DG Enterprise and Industry

The chosen experts represent a significant group of ICT experts in Luxembourg and provided evidence-based opinions on the present state of ICT in the country and its future trends and developments. The diversity of opinion is to be considered an important step towards the development of a broader vision for the future.

First of all, interviews reveal that **programming competences** like PhP, CSS/Graphic Design and Java are still the most needed, whereas competences in the field of mobile applications have only been scarcely mentioned.

The "Geek phenomena" in relationship to the existing global app-sphere and uberisation trend does not shine through our exploratory interviews, a result that could be explained by the fact that the Luxembourg ICT sector has a lack of geeks and of flanking drivers.

In the competence area of PhP, Java, CSS, a push to excellency can be noted, meaning that more and more experienced top talents are needed.

Customer support (following ITIL) is also an issue.

Skills related to **innovation management** are considered relevant, as a switch from coding to assembling existing widgets in a new, smart and efficient way can be observed. As for example the development of apps is not an end of a project, but merely represents its starting point, skills going beyond the realm of ICT are more and more needed, such as social, communication and marketing skills to boost the interaction with customers.

Furthermore, as start-ups strive for maturity, their leaders will need to trespass the state of an ICT creator to become a **manager of people, businesses and organizations**, so that the associated managerial, business and organizational skills will become more and more relevant.

In the field of **webtechnologies**, SEO, SEA and analytics have been identified by the participants of the interviews as being critical skills in the future.

Also, the user himself starts to play a role in the Luxembourg ICT sector, cf. **user experience**, user integration and ergonomics, design thinking, with implications on the development of multifaceted or hybrid skills emerging from different fields and domains.

Coding skills related to the mastery of programming languages such as Java, Cobol and C are still needed, as well as the skills of system administrators (Microsoft, Linux, VMware…) and **network engineers**, although a trend can be observed to recruit more junior profiles in order to reduce the effect of the currently ongoing salary spiral in Luxembourg.

As the **Internet of Things** trend is originating the creation of more heterogeneous networks (4G, Wifi, Sigfox, Bluetooth, M-Bus, RFX…), a need for more specific skill sets in network engineering, system administration and data analytics has been expressed. Furthermore, as the Internet of Things trend will more and more hit the Industry 4.0 wave, it is understood by all participants of the interviews that a large number of new and challenging opportunities emerge on the horizon. For example, the impact of the Internet of Things has been mentioned as a key element in the future development of the health sector, as this technology is bound to contribute to reduce costs and to increase the quality of services provided.

Evidently, a stronger need for **cybersecurity skills** has been mentioned continuously, in conjunction with the upcoming regulation in the field of NIS, Data Privacy and e-IDAS. As Luxembourg intends to become a centre of excellence in the fields of FinTech, hybrid cybersecurity and cryptography skills, block chain encryption will play an important role in the development of this centre of excellence.

Business analyst skills and data scientists will also be of an outmost importance, even if the latter is found today primarily within the scope of the larger consultant companies. Nevertheless, as there will be a stronger demand for data scientists and big data analysts and operators in the near future, it is evident that associate skills will also be needed.

Hybrid skillsets like technology and business development, technology and project management, technology and design thinking are also likely to be in demand, as these hybrid skills allow a better exploitation of the business goals of ICT firms. Furthermore, there will be a higher demand for industry specific skills in conjunction with highly developed ICT skills.

And of course, **soft skills** (team player, communication, open mind-set) leadership skills as well as language skills (English, French) have also to been mentioned as a major requirement, especially as in the recent past, ICT companies and their employees have mainly focused on the development of their technical abilities and tended to neglect these social and managerial skills. Today, however, with complex market settings, it will be necessary for all ICT actors to invest in a holistic approach towards skills development.

In any case, it can be concluded from all interviews that the front-, mid- and back end structure of ICT, which had been en vogue for over 15 years in Luxembourg, does not fully reflect anymore the upcoming ICT trends.

There is a general agreement that the ICT world is today in the midst of a new wave of innovation characterised by the confluence of social, mobile, and cloud technologies, the rise of Big Data and new kinds of analytics needed to create value in an environment handling by extremely large quantities of data.

Luxembourg and its economic sectors therefore need to change and to integrate at all levels of the production processes new, fast, innovative, agile and performant ICT solutions. It will therefore also need a further developed vocational training system that can provide solutions in almost real-time, while investing not only in technological solutions, but mainly also in a new ICT mind set.

4.3 The contribution of ADEM

Together with the representatives of ADEM, we investigated the kind of ICT professional profiles that were most required by Luxembourg companies.

A twofold picture resulted from this analysis, as a significant difference in the competence needs can be noted between required professions from the FDI sector and the required professions from the generic ICT sector.

1) The FDI sector expresses needs in professional profiles and thus in terms of skills related to security and desk agents, technical-commercial support people, technicians for setting up security systems, but only a weak demand for telecom engineers or information system architects.
2) The generic ICT sector, on the contrary, expresses its needs in terms of developers (coding and web) and analysts (functional and developers). Furthermore, there seems to be a need for SaaS consultants or Business Intelligence and Information security consultants.

However, following this analysis, there seems to be no need for specialists in the fields of Big Data, Internet of Things or Customer Experience.

The problem here is to know whether there is no real need, or the real need is not expressed or not seen as urgent or as not relevant for smaller Luxembourg ICT providers, or whether the ROME classification system used by ADEM is not providing the appropriate taxonomy (as the ROME classification of professional profiles is neither specific nor up-to-date enough to cope with new emerging professions).

Furthermore, these first two pillars of our analysis are more focused on the current situation and integrate less the future trends on ICT profiles and competencies. Here of course, the picture needs to be completed.

In any case, even if a need for a specific ICT job profile and the related skills is not expressed, it does not mean that the need is not apparent, relevant or emerging. In any case, the ICT sector should remain vigilant and be encouraged to introduce these skills, even if it were only to anticipate trends and evolutions in order to be ready for the upcoming events.

4.4 Additional Desk Research

As we have highlighted in previous parts of this study, the ICT sector in the world and in Luxembourg is in the midst of a new wave of innovation characterised by the confluence of social, mobile and cloud technologies, the rise of Big Data and of new kinds of analytics needed to create value in this environment.[54]

This tendency will of course also have its effects upon the kinds of skills that will be needed in the future.

From our lecture of different relevant documents and studies, and in line with our previous analysis on trends and tendencies in the ICT sector, we identify the following future skills needs and requirements:

- It seems as if needs for skills in the field of **ICT architecture**, at all levels and in various roles, still prevail. The term ICT architect englobes a wide range of activities and specialisations, from network to cloud architects, and is in constant demand as this profession contributes to the development of technology-driven projects of all kinds. Furthermore, these technical skills should be completed by more managerial and business linked skills in order to drive complex ICT projects forward efficiently.

- **Cloud technologies and SaaS** (Software as a service or software on demand) will induce a need for new skills in order to develop and market cloud related services, i.e. setting up. Integrating and securing cloud deployments, that will proliferate significantly in the near future.

  Furthermore, mobile engineers will still be in demand, as mobile has become the new platform, instead of the desktop computer, to ensure cross-platform and cross-device mobile developments.

- In conjunction, a revival of **hardware related ICT skills** can be identified, as the new and performant data centres, the industry 4.0 and the Internet of Things wave are in demand of these skills.

  Also, competent **network engineers** are in demand, as the rising number of technologies that need to be connected and merged, kept clean, stable and secure, in networks (hard and soft ware) is without boundaries.

- On the one hand side, programming expertise has become a commodity that is available quickly and cheaply over the Internet. On the other hand, however, the new trends in ICT, such as mobile applications, Industry 4.0 or the Internet of Things, will enhance a supplementary need for **programming and application development skills** in new areas and with new techniques, as only programmers and application developers will make it possible that the innovative high tech installations will eventually work.

  As a corollary to these factors, skills linked to **web development technologies** (f.ex. JavaScript, PHP or Python) are also on the rise for the reason that companies will rely heavily on the Web as a channel for connecting with customers, providers and staff, or any other stake holder. This evolution is less about establishing a Web presence anymore, but about developing a Web related business surfaces to drive incremental sales.

  These business surfaces ought to be customer oriented. That is why user creative and innovative **experience designers and developers** will be increasingly in demand in order to create software interfaces that are as self explaining, simple and intuitive as possible, in order to enhance the shopping or gaming experience.

- Of course, **Big Data, Big Data analytics and database management** is an upcoming issue, as companies will need more and more specialists that can help them to analyse, manage, package, interpret, visualize and use large amounts of data analytics for business purposes and to help

[54] As the future CDC ICT has to take into consideration both the short term (now) and the mid term perspective (2018), we have refined the recommendations of the future needs of skill sets by selecting the most relevant parts of the IDC study: Main Trends for Information and Communication technologies (ICT) and their Implications for e-Leadership Skills, prepared in 2014 for the European Commission DG Enterprise and Industry. This study synthesizes studies like IDC Predictions, IBM Global Technology Outlook, MGI report on disruptive technologies and Accenture Technology Vision and AT Kearny IT 2020.

them to take informed business decisions on such grounds. However, for the present time, this kind of expertise is so far only needed by many companies on an experimental or pilot project basis.

- **Security and compliance issues** are also a major priority with regard to skills' needs. Highly developed skills related to cybersecurity are in high demand as the topic continues to play a critical role in all sorts of companies. Compliance skills will also increase in importance through the increasing number of legal rules and regulations, and the proliferation of business standards, as well as the need for companies to document their compliance to these ever more complex themes.

  This trend goes alongside with the need to better explore **risk management strategies and skills**, as the increasing business and ICT complexity. Linked to ever shortening innovation cycles, we will produce a larger amount of unintended or unexpected impacts and consequences that need to be predicted and controlled to a maximum degree.

- For professional ICT practitioners, one can identify an enlarged **business- and project-orientation**, as not only designing new services, applications and apps on existing standards and platforms is the only relevant area of expertise, but also the management and the marketing from A to Z of these applications and products over the Internet distribution channel. Therefore, ICT practitioners will need more and more skills that go beyond the ICT domain and that will include general business and project management skills. This trend is about a combination of these three kinds of skills, as ICT professionals should not only confine themselves to the technical component of their tasks, but also keep in mind in parallel aspects such as finances, management of time, priorities and of people, as well as the requests and expectancies of the customer with regard to high quality service provision (cf. helpdesk and technical support).

- In general, skills related to ICT professions tend to become either **highly specialised or specific skills** due to the complexity of the different sub-sets of the ICT domain, or **holistic, interdisciplinary or hybrid skills**, as many professional ICT practitioners will have to enlarge their realm of skills to business, managerial, leadership, social, organizational, marketing or commercial skills.

- There will be a growing need for so-called **e-leadership skills**[55] with ICT professionals in order to lead qualified ICT and other staff towards identifying, designing, implementing, exploiting, deploying and making best use of new and innovative ICT based business opportunities and models. E-leadership is therefore considered as a general approach with the aim to deliver innovation and value to large or small companies via the ICT channel in its broadest sense. It is about creating links between the ICT and executive departments to ensure that ICT projects are in line with the business needs and the strategic orientations of a company.

- Finally, as Luxembourg can be assimilated to a high end ICT country, there is a general need for **high level ICT practitioner skills** (general or specific), whereas the demand for skills in the field of ICT infrastructure or management, and for operational and practical ICT skills is decreasing.

[55] http://www.eskills-lead.eu/home/
http://eskills-vision.eu/fileadmin/eSkillsVision/documents/VISION%20Final%20Report.pdf
http://www.cio.com/article/2860455/it-skills/16-of-the-hottest-it-skills-for-2015.html

4.4.1 Summary[56]

4.4.1.1 Summary of main demand trends of ICT practitioners' skills

	ICT Industry		ICT User Industries	
	Increased Demand	**Reduced Demand**	**Increased Demand**	**Reduced Demand**
General	Skills to design and implement sophisticated identity and access management solutions Skills on standardisation/ IT regulation/ interoperability developments Ownership of skills certification	Operational skills to manage and maintain corporate IT systems Maintenance and support of legacy systems (PCs, desktops...)	Selection, configuration, combination, orchestration of cloud services, either public, private or hybrid Integration of fixed-mobile systems (BYOD management) Systems management skills for highly integrated, automated and scalable infrastructures (IoT) Data protection/ Privacy protection/ new IT security challenges Implementation and management of end-to- end protection of emerging smart networks and cyber infrastructures	Operational skills to manage and maintain corporate IT systems Maintenance and support of legacy systems (PCs, desktops...)
R&D	Sophisticated R&D and development skills (especially for interoperability and standardization challenges)	None evident	Sophisticated R&D and development skills, focused on industry needs	None evident
	Increased Demand	Reduced Demand	Increased Demand	Reduced Demand
Infrastructure	Design, development and management of data centres and cloud services Integration of fixed-mobile systems (BYOD management) Data protection/ Privacy protection/ new IT security challenges Systems management skills for highly integrated, automated and scalable infrastructures (IoT) Design and management	Operational skills to manage and maintain corporate IT systems Maintenance and support of legacy systems (PCs, desktops...)	Selection, configuration, combination, orchestration of cloud services, either public, private or hybrid Integration of fixed-mobile systems (BYOD management) Systems management skills for highly integrated, automated and scalable infrastructures (IoT) Data protection/ Privacy protection/ new IT security challenges	Operational skills to manage and maintain corporate IT systems Maintenance and support of legacy systems (PCs, desktops...)

[56] Source :

	of end-to-end protection of emerging smart networks and cyber infrastructures		Implementation and management of end-to-end protection of emerging smart networks and cyber infrastructures	
Application	Development and implementation of apps/ services based on mobility/cloud/Big Data/ Social Media/ IoT Business data analytics, Data scientists, Big Data skills Apps, web, IT service development for customer- centred design and deployment (CXIT)	Maintenance of legacy applications	Development and implementation of apps/ services based on mobility/cloud/Big Data/ Social Media/ IoT + industry knowledge Business data analytics, Data scientists, Big Data skills Apps, web, IT service development for customer- centred design and deployment (CXIT)	Maintenance of legacy applications

4.4.1.2 Summary of main demand trends of e-Leadership skills

	Emerging Demand	Implications for High tech, high growth SMEs
General Management	Strategic management of business and contractual relationships with IT suppliers - partners - subcontractors – clients over extended value chain/ digital ecosystems In-depth understanding of IT offshoring/ outsourcing issues and cost-benefits balance to make informed choices Strategic Management of interaction between CIOs and business line managers	Strategic management of the role of the company in the digital ecosystem with specific attention to SMEs vulnerabilities (insufficient IPR protection, for example) Ability to outsource/delegate necessary IT services and make appropriate buy/train decisions of necessary skills
Hybrid Business/ IT	Strategic management of company information and data flows, including design and development of “data supply chains” to leverage company’s data and partners’ data and make them usable Combination of business analytics skills with industry-specific skills and understanding of IoT issues Strategic management of data protection/privacy issues	Similar demand, since customer expectations will be similar “Native” digital companies (e.g. web entrepreneurs) may have innate e- leadership skills in this area Challenge to source/ maintain scarce specialist skills, particularly data analytics and data scientists skills
Industry Specific	In-depth understanding of industry-specific business development opportunities driven by IT innovation Combination of business analytics skills with industry-specific skills and understanding of IT innovation implications for business processes Ability to use IT for customer-centred apps and services (CXIT) within specific industry	Similar demand, since customer expectations will be similar Risk of missing e-leadership skills necessary for competitive advantage; relative relevance linked to business model

4.5 Conclusions

While looking at the interviews with Luxembourg experts in comparison to the general tendencies that emerge from an international literature analysis, it can be concluded that both worlds are hardly distinguishable, i.e. that the trends identified by the Luxembourg experts converge largely with the international trends and tendencies that were identified.

This should not come as a surprise because if the Luxembourg experts had been far out of range with the global trends, Luxembourg would not have become a major ICT hub in Europe.

In any case, it is clear that the skills for the innovative present and the future ICT technologies are heavily being sought after and that more traditional ICT skills and their respective holders are on the decline.

In general, so-called stem skills (science, technology, engineering and math) are on the rise on the demand side in order to cope with the accelerated and ubiquitous technological developments, as big data and Internet based computing systems pervade all aspects of our lives. In addition, a new trend has started to set in and it consists of adding to the emphasis on of technological and job related skills also skills related to communication, management, business, strategy, etc.

This need for ICT and related skills is not limited to a particular type of company, such as start-ups or large ICT vendors, but ICT skills are in demand everywhere, in large or small businesses, in public or private organizations, in ICT related or non ICT related industries.

At the same time, the Luxembourg experts share the international bemoaning of the shortage of available ICT skills and the consequent increase of salaries in the sector, so that individuals with the required skills are in demand and will undoubtedly have an easy time finding an appropriate professional position amongst a myriad of options, whereas for companies this skills gap may have a negative impact on their future economic development.

Of course, all major and minor ICT regions or complexes are suffering from the same malady so that new innovative endeavours must be undertaken, while providing for instance new education and training opportunities for more people in the ICT related businesses.

5 Problem definition: Skills gap

The combination of societal and economic change, the permanent introduction of new technologies and tools in everyday life of almost all citizens and under almost any conditions, as well as the startlingly growing competitive pressure on both businesses and the labour forces means for organizations of all kinds as well as for individuals that they must take responsibility for constantly up-dating their skills or acquiring new skills, not only to progress in their careers, but even to maintain their current professional situations. In other words: nowadays, we even have to run in order to stay on the same spot.

The reasons for this necessity are numerous: anticipated increase in competitiveness and productivity, reduction of costs, up-dating with new technologies, increase of credibility, maintenance of employability, preparation for new positions, fulfilment of job requirements, increased career prospects, etc.

For Luxembourg one can conclude that despite - even because of the fact - that the country has been able to invest considerable sums and efforts in the development of its ICT sector, the problem of the so-called e-skills shortage or gap still remains or is even becoming more urgent then ever.

As it is not the objective of this study to provide options for possible solutions for all the aspects that have been enumerated above, but only for the aspects related to issues of skills, we would like to narrow down from here on our scope to this particular aspect of the ICT sector.

5.1 Quantitative shortage of ICT professionals

Despite the fact that the ICT industry has become a very crucial and particularly important factor in our societies, that the digital economy is growing at seven times the rate of the rest of the economy (European Commission, 2014) [57] and that the ICT sectors are certainly very attractive in terms of employability and variety of professions and activities, it remains true that Europe on the whole and Luxembourg in particular are confronted with a shortage both in ICT work force and in ICT or e-skills.

The problem in this context is that a significant shortage of highly qualified ICT practitioners still prevails. As the maintenance and development of high levels of competitiveness, scientific or technological advances, innovation and job creation within the European industry are increasingly being driven by ICT, it is more than evident that this trend must be backed up by a workforce with the necessary knowledge and skills to master these new technologies.

According to Hüsing et al (2013), the ICT workforce in Europe in 2011 amounted to 6,671 million, which represents 3,1% of the overall workforce. 5,25 million of these come from the occupational groups representing ICT practitioners and 1,42 million can be described as ICT professionals at a management level and include CIOs, ICT operations managers, project managers but also those ICT workers responsible for planning and strategy such as enterprise architects, systems analysts and ICT consultants. If ICT mechanics and manual worker skills were to be included, 3,7% of the European Labour Force, or more than eight million workers in the EU are ICT professionals.

Hüsing et al (2013) also indicate that the ICT workforce and the number of ICT practitioners in Europe has been growing over the past decades by an average annual rate of 4.26% (2000 to 2010) and will continue to grow in the future in a robust way, generally absorbing all ICT graduates.

However, although the demand for ICT professionals at all levels has been growing over the past years and will continue to amplify in the future, individuals with creativity, innovation and higher-level conceptual ICT skills are increasingly in demand (Arbesman, 2015).

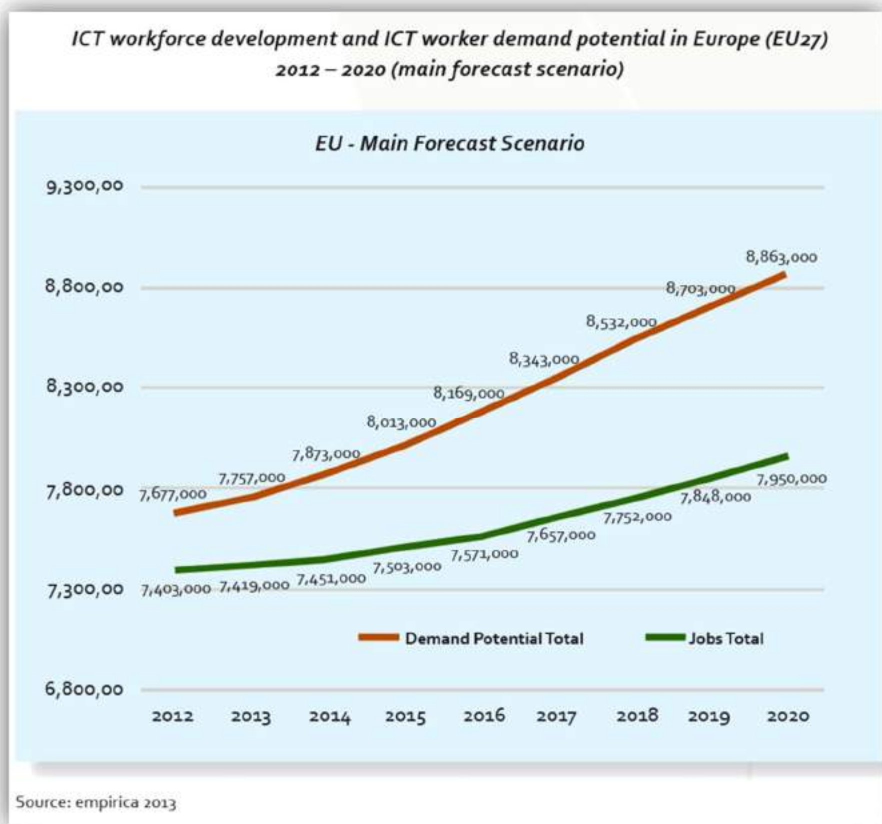
Today, the demand for ICT workers has largely outnumbered the supply and one must conclude that there is a significant gap between the offer and the demand in the field of ICT practioners at all levels. Studies show that already in 2012 the excess demand for e-skills could be estimated at around 255.000. It is also estimated that 70% of ICT related job vacancies can be found in SMEs.

[57] European Commission. (2014). *Digital agenda for Europe.*

According to estimates, the shortage of ICT pracitioners amounts to 373.000 in 2015 and to 889.000 in 2020 for the whole of Europe under the hypothesis of a cautious growth of the EU economy, and to amounts to 866.000 in 2015 and to 1.685.000 in 2020 under the hypothesis of a return to confidence.

The following graph visualises this scenario for the years 2012 to 2020:

Figure 3: ICT workforce development



With all relations kept, these general tendencies on the European and international labour markets do also apply to the Luxembourg ICT sector.

We estimate that the reasons for this development are the following, most certainly amongst others:

1) There are simply not enough ICT professionals available on the job market that have the right qualification at the right moment. It seems that the current interest in studying ICT related subjects and pursuing ICT careers seems to be diminishing or at least not augmenting among younger generations. The number of computer science graduates was growing in the past, but has been in continuous decline in Europe since 2005 – although a slight reverse trend is emerging.

   But yet, schools and universities are still not providing a sufficient number of graduates required by the ICT industry – although this discrepancy may not be solely attributed to the schools or universities themselves, if the number of interested students remains below expectations. As for example, it seems that for the moment in Luxembourg there are far more students engaged in studies in the field of psychology as there are students studying computer science or any other so-called STEM subjects (**s**cience, **t**echnology, **e**ngineering, **m**athematics). There seems to be a structural problem as such.

2) The decrease in the number of entrants to the ICT workforce is even more amplified by the fact that Europe is also facing an increasing number of exits of ICT practitioners from the ICT workforce to orient their careers towards other business areas or functions within a company.

3) It will become more and more difficult for companies to locate and retain specialized and highly qualified ICT practitioners, so that techniques to identify and forecasted future needs – however complicated it might be – will become a more and more important task for companies.

4) The need for ICT practitioners is particularly intense within SMEs, whereas large companies seem to have less problems for recruiting ICT professionals. But this circumstance is again a major setback, as particularly SMEs are considered as job motors in Europe and their development risks to be slowed down due to a lack of qualified ICT workforce.

5.2 Qualitative shortage of e-skills

Besides the quantitative lack of ICT professionals to ensure an adequate economic growth, it also has to be considered that in the context of the famous half-life of knowledge and the fact that particularly ICT knowledge becomes obsolete very quickly, the active ICT professionals have tremendous difficulties to maintain their high level of expertise and are very often not able to undertake the necessary steps to remain up to date – may it be for reasons of time, motivation or availability of adequate support and offer.

Due to this *Halbwertszeit des Wissens* or skills obsolescence in ICT, employees need to ensure their own career progress and their ability to plan adequately their career paths. Furthermore, vertical and horizontal professional mobility becomes ever more important. The speed with which people move will continue to increase, especially as they are being asked to react flexibly to changes related to technological and organisational developments, to labour market demands or to corporate policies.

From a corporate point of view, due to the short, disruptive and emerging technological life-cycles in the ICT sector, investments in education and training are necessary to overcome the continuous depreciation of human capital. Therefore, a reinvestment on a continuing basis in the form of supplementary training is essential to overcome for skills obsolescence.

It is therefore necessary to develop and implement measures and initiatives that operationalize lifelong learning for both the individual and the organization, while making available adequate systems, structures and processes.

Furthermore, we identify a shift within the realm of required ICT skills:

- A first shift is directed at high-end ICT skills that will extend more and more to highly specialised occupations.

- A second shift is directed at e-leadership skills, where ICT professionals will orient themselves increasingly towards strategic planning, implementation and management of ICT, in combination with business or other non technical skills.

- A third shift relates to the demand for hybrid skills related to both business, technical, organizational, commercial and ICT skills to develop growth opportunities with new products in new markets.

  The trend with regards to skills acquisition leads to the new hybrid skills that merge ICT expertise with relevant professional knowledge and skills. The typical high level worker does not master either ICT or a profession, but has excellent knowledge and abilities in both domains at the same time. In order to exert flexibility and mental and geographical mobility, and to stay competitive, individuals have to actively maintain and acquire both job relevant skills, as well as ICT skills, in combination with developed social, managerial and sector or company specific skills.

- A fourth shift, following the already quoted the E-JOBS study[58] realised by IUIL indicates a trend towards cross-cutting between technical and soft skills, referring to language skills, project management skills, team management skills and marketing skills. A combination between technical and behavioural skills seems to be particularly sought after by Luxembourg companies (and not found, despite high salary packages).
- A sixth shift refers to new ways of transferring skills, as besides traditional ways of acquiring e-skills, such as formal education, work experience, vocational training, self- or informal learning , new ways of learning and skills acquisition have become relevant as well as an increase in the demand to document learning outcomes in the form of recognised certificates or qualifications, but not only for the purpose for an individual's career development and to increase the individual's labour market value, but also because more and more ICT vendors require specific trainings.

Furthermore, despite these trends or even future desiderata, it becomes at the same time increasingly difficult for companies and individuals to recognize, identify or foresee their ICT training needs. The questions are how to identify the missing skills, on what basis, with the help of what instruments, and how to supply the skills requirements by which learning and training measures, towards which certifications and qualifications?

Learning and training must become more visible, hence better documented, comparable to industry standards, adequately assessed in terms of processes and outcomes, and recognized through certifications and qualifications by appropriate and accredited bodies in the framework of a training system, constituting thus a core element of a genuine lifelong learning process

It will therefore be essential to tackle these issues more efficiently, as it will become more and more difficult to maintain high levels of competitiveness or innovation in our economies as a whole, and the worst case scenario of a general decline of e-skills will be become probable.

We conclude that in order to overcome the significant and relevant shortage of ICT practitioners and of e-skills available throughout Europe in the next years, it is absolutely essential that all relevant stake holders must contribute to their uttermost to develop measures and projects in order to counterbalance this unsatisfactory evolution, which risks to jeopardize the further economic and social development of the European countries.

We also conclude from the previous analysis that ICT support, delivery and operation in infrastructure and software, however, will diminish in relative importance.

Also, it remains difficult to compensate the ICT gap entirely by trying to train and integrate unemployed persons into the ICT market, as very often these categories of people lack necessary basic qualifications and skills (hence the digital divide), so that it needs a proportionally large amount of time and effort to raise their skills to expected levels.

Furthermore, around 198 million European people do not have any e-skills at all and are far away from being digitally literate.

Another problem refers to the differences between the different Member States, as only a few States have been able to develop long-term e-skills strategies and that for those having commenced activities, a huge variation between countries must be identified.

Here again, Luxembourg is confronted by the same issues as almost any other highly industrialised country in Europe and beyond.

5.3 Homemade structural issues

5.3.1 General education system

Besides these international (negative) trends with regard to the ICT labour market, a series of issues are specifically homemade in Luxembourg.[59]

[58] http://www.iuil.lu/uploads/documents/files/e-jobs-rapport-final-light.pdf
[59] http://eskills-monitor2013.eu/fileadmin/monitor2013/documents/country_reports/country_report_luxembourg.pdf

We should like to express these issues in terms of contradictions:

- On the one hand side, Luxembourg is undergoing a very positive development with respect to the demand for ICT practitioner, as the country intends to become one of the leading European hubs for ICT services in the near future, but on the other hand, the necessary activities in the fields of education and training are not in line with the expressed and recognized demand.
- On the one hand side, the percentages of students in Luxembourg with relatively high levels of infrastructure, connectivity and connectedness is relatively high in comparison to other European countries, but the use of these commodities in schools by teachers is well below EU averages. Not enough schools or teachers seem to consider e-skills as a necessary part of the curricula, ICT and the use of computers is too much confined to the computer room and not integrated in the curricula of other subjects, and also school authorities do not follow a more active policy with that regard in both primary and secondary schools.
- On the one hand side, Luxembourg's policy with regard to high level university education, i.e. University of Luxembourg, is characterized by the policy to develop internationally competitive research centres in ICT, including the recruitment and substantial financing of renowned international specialists, that are able to produce excellence and work on the edge of scientific research. On the other hand, the higher education of ICT practitioners that are able and willing to work for Luxembourg companies has been neglected for many years. The profits of high level research for Luxembourg companies are at the most indirect and are mainly beneficial to those (and their careers) that produce the intended scientific outcomes.

Therefore, it can be concluded that (cf. European Schoolnet[60]) that the ICT uptake in Luxembourg schools is not as developed as it could be or as it should be.

5.3.2 Continuing vocational training

As in many parts of the Luxembourg economy, there is a further contradiction with regard to the field of continuing vocational training.

Again, on the one hand side, the number and variety of the ICT training offer is almost overwhelming and the catalogues of the main general and ICT providers are getting thicker every year.[61] Yet, this offer does not seem sufficient, as many companies have to send their collaborators to expensive foreign trainings.

However, a more profound analysis of the situation with regard to the continuing vocational training situation in ICT indicates that in Luxembourg a sufficiently appropriate, systematic and generalized training system in this sector des not exist.

Furthermore, the training offer is too aleatory, randomized, not based on professional needs analyses, and for the collaborators, a more systematic approach to the concept of permeability is desperately lacking.

Also, ICT professionals are quite mobile and thus expect in the context of their training efforts to receive accredited, recognised and validated qualifications in order to continue their training and career paths in other countries and situations, but there is no institution available to fill in this gap.

As the concept of lifelong learning is extremely important in the ICT sector, Luxembourg should also make available an ICT training offer - in line with the creation of an adequate institution - which will provide an ICT qualification (and not only vendor linked certificates) to those persons that wish or need to update their skills.

We consider that an overall policy with regard to systemize the offer and the demand within the field of continuing vocational training in ICT does not exist.

[60] https://ec.europa.eu/digital-agenda/sites/digital-agenda/files/Luxembourg%20country%20profile.pdf
[61] See www.infpc.lu for a list accredited providers.

5.4 Conclusion

We conclude that a major **skills gap** in both quantitative and qualitative terms still prevails in the field of ICT in Luxembourg (and elsewhere). It means that there is a major discrepancy between the existing ICT workplace knowledge and the knowledge required to achieve both strategic and operational business objectives. In other words: the major problem with regards to e-skills is the insufficient matching or gap between offer and demand on the ICT labour market. Either there are not enough specialists available or those available are not sufficiently or adequately qualified or trained.

Furthermore, it is not easy to follow the desiderata of the companies with regard to their needs and requirements: Do they really know what e-skills they need in terms of quality and quantity, what instruments – if any – did they apply, what measures do they undertake to overcome their particular gaps.

The fundamental question is then how to ensure an appropriate qualitative and quantitative matching between the training demand and the training provision? How to ensure that both the individual and the organization know what they know, know what they need to know and know how to acquire the appropriate knowledge and skills?

As people will not no longer acquire the skills needed for their vocational insertion and professional development solely through their initial education, but through a variety of structural settings (further education, vocational training, self-learning, informal learning, professional experience, …), it will become necessary for reasons of planification, comparability, transparency, recognition and quality assurance to introduce adequate systems that enable people and companies to acquire the skills they need, and when they need them.

That its why all endeavours to support lifelong learning should be supported. However, this cannot only mean an endless proliferation of training providers and training provision on all possible and impossible subjects without any underlying professionally organized system that is mainly meant to organize, structure and combine the training market, i.e. the offer and demand in training provision and needs.

This necessity is even more relevant as the ICT skills market is slowly deterring the walls separating highly specialized ICT skills from content knowledge in the different crafts and businesses.

Luxembourg ICT companies and non-ICT companies, especially also SMEs, permanently need highly qualified and available specialists in the different domains of ICT, but these persons, resp. these skills, are not available in sufficient numbers and quality, neither in Luxembourg, nor in the Greater Region.[62]

But, building up a **strong digital economy** in Luxembourg as a further pillar of its economic expansion and diversification is a vital endeavour to ensure growth and development, innovation, employability and competitiveness, as all companies and workers need more and more a profound understanding and practice of ICT.

Therefore, it is essential to create a thoroughly systematic approach towards developing ICT related skills (e-skills) on a high level and on a continuous basis for all categories of companies and for all categories of the workforce in order to confront the challenges induced by the technological changes and disruptions we have mentioned in earlier chapters of this report.

It is thus our intention to propose in the following chapter a possible and hopefully viable solution to enhance the situation in the field ICT training in Luxembourg at all levels.

[62] We wold like to avoid to speculate abour the real numbers of specialists needed, as their are no relyable figues available.

6 Problem solution: Virtual e-Skills Training Centre

6.1 Questioning the skills gap

But the question remains: **How to overcome the ICT or e-skills gap in Luxembourg?**

Of course, in order to respond to this question, a series of alternatives can be enumerated, as for example:

- Delocalising ICT activities to foreign ICT centres, with all known advantages and disadvantages.
- Recruiting ICT specialists from more distant countries (f.ex. Eastern European countries), with all known advantages and disadvantages.
- Paying higher wages or offering more extras to retain ICT specialists, speeding up that way the salary spirals even further.
- Recruiting younger (and less expensive) ICT practitioners and train them in-company.
- Applying a more professional strategy in the domain of human resources.
- Enlarging partnerships with ICT providers, vendors or academic institutions.
- Subcontracting entirely the ICT part of the company.
- Reducing expectations to recruit for a low salary the purple squirrel (*eierlegende Wollmichsau*, *mouton à cinq pattes*), which does not exist or which a normal company could not finance anyway.
- Investing in a continuing vocational training system.

All these and many more suggestions all have their advantages and disadvantages, which are commonly known in the meantime. And of course, as usual, in reality the solution will not be found by applying one single option, but by referring to a mix.

But, as indicated in the objectives of the present study, we confine ourselves to analysing and making proposals for amelioration solely in the domain of continuing vocational training.

In our reflections, we will start from the principle that the skills gap in the ICT sector can only be overcome by creating and implementing a coherent, systemic and fully integrated initial and continuing vocational training system that is able to react flexibly and fast to changes, needs and demands from the ICT sector, that is able to take into account a substantial number of ICT jobs and skills profiles, and to create and coordinate a permeable and viable ICT offer.

We therefore would like to suggest and to develop in the following paragraphs a **comprehensive and dynamic skills and competence framework** that should meet the expectations of all actors of the ICT market in Luxembourg and beyond (providers, vendors, associations, policy makers, customers, users, students, …).

We base our reflections on a series of principles that will be integrated throughout our proposal:

- Creation of a **complete system of continuing vocational training in ICT**, i.e. foreseeing the use or the foundation of all elements necessary (projects, programmes, institutions, collaborations, …) and establishing efficient and institutionalised links between these elements.
- Integration of existing systems and structures, as f.ex. **standardized ICT job profiles**, the **European e-Competence Framework** and the **European Qualification Framework**, based on the EU e-Skills agenda, existing institutions and structures such as the **Centres de Compétences de l'Artisanat**.
- Promotion of a stronger, more efficient and less competitive **long term cooperation** between all Luxembourg ICT stakeholders (Government, federations, institutions, companies, consultants, experts, schools, …).
- Consideration of a **large range and variety of skills**: technical, technological, transversal, ecological, leadership, soft, etc.

- Increase of **awareness of the attractiveness** of the ICT sector and its related jobs, while creating a system of lifelong learning and enhanced permeability and validation of acquired skills.
- Creation of **appropriate institutions and financing systems** in order to ensure the sustainable and durable development of the intended ICT continuing vocational training system.

We strongly expect that these measures in the field of ICT initial and continuing vocational training will contribute to close the e-skills gap in an innovative, efficient and productive manner, as well as in a long-term perspective.

In that perspective, we will develop in the following pages a series of concepts and strategies, such as:

- e-skills reference framework,
- e-skills matching platform,
- institutionalized e-skill virtual training institution
- …

6.2 e-Skills reference framework

6.2.1 Description

6.2.1.1 Definition

A skills reference framework (*référentiel de compétences*) corresponds to a set of hierarchically structured skills, which are derived from a specific or a series of job profiles. It is considered as the key factor of a professional human resources management system and allows to articulate the human potential within an organization. It corresponds to the basic qualitative tool to adjust the skills to the requirements of the recruitment policy, internal mobility, training and corresponds to a projection of a medium-term employment development plan with regard to the skills required by an organization in order to cope with change and development in particular contexts. (Perrenoud, 2001)[63]

The purpose of an e-skills reference framework is to identify the knowledge and skills that an individual needs to master in the field of ICT in order to fulfil the tasks associated to a profession, a job, a certain occupation or activity, or a specific function.

Furthermore, its purpose is to contribute to diagnose a possible gap between the knowledge and the skills needed in the job and the current and available knowledge and skills level of the individual. From the diagnosis of this gap, it can be identified what kinds of trainings and learnings are needed in order to close the identified gap.

An e-skills reference framework should also contribute to the increase of the permeability and mobility of ICT careers, as a person can follow a specific learning and training path, either to ensure a job enrichment (more specialized position), a job advancement (higher hierarchical position) or a job rotation (new function). In that sense, it contributes largely to an individual's career development needs, career paths or aspirations, and enables employers to understand clearly what someone should be able to do and what standard of performance can be expected. A skills framework allows employers to recognise training to a well defined, structured and comprehensive standard, and trust and situate that information with regard to a hierarchy of skills.

The model will then also inform on the objectives and contents of qualifications, curricula, education and training modules and courses to be developed subsequently.

[63] Perrenoud, P. (2001). Construire un référentiel de compétences pour guider une formation professionnelle. Genève: Université de Genève.
http://www.unige.ch/fapse/SSE/teachers/perrenoud/php_main/php_2001/2001_33.html

Finally, if structured vertically (different levels) and horizontally (different domains of skills), such a e-skills framework could even contribute to the provision of a collective or an individual career and pay progression scheme based on a single agreed system.

It is our intention to refer as much as possible to concepts and tools that have acquired the status of full-standards or semi-standard, i.e. that are gradually gaining in recognition internationally throughout a profession, and where it is ensured that the concepts and tools are being developed constantly.

6.2.1.2 Characteristics

Currently, it can be observed that e-skills reference frameworks do exist on a larger scale and can be subdivided into three different categories:

- Public or semi-public initiatives, European e-Skills Quality and Standards Framework, SFIA.
- Initiatives form ICT vendors, f.ex. Cisco or Microsoft certifications.
- Formal qualifications provided by public education and vocational training providers.

Of course, in the past, several e-skills certification schemes and systems have been developed, but only a few developments gained a more sustainable status. In general, it can be concluded that the proliferation of a large amount of competitive systems would be counterproductive as comparability and oversight will be lost.

On the contrary, a pragmatic approach to e-skills should be based on individual and corporate learning expectations and outcomes, which ought to be described in relation to an agreed skills and qualifications reference framework, which itself should be based upon extensive, elaborated and precise ICT job profiles.

Second, the skills reference system should be allocated to structured and standardized certification schemes and should equally include aspects of standardized accreditation procedures and processes, validation and certification of non-formal learning as well as professional experiences.

Third, the management of an e-skills reference system should be attributed to a central body, which ought to establish and maintain common quality standards for ICT training and certification and be based on an agreed reference framework for both ICT skills and qualifications.

The establishment of such an e-skills reference system should then contribute to the following objectives:

- To enhance the collaboration between education authorities, training providers and certifying bodies in order to create an appropriate system.
- To develop appropriate and innovative models and approaches.
- To define joint actions in order to establish a national policy and practice for certification, qualification, quality assurance and standardization of e-skills.

6.2.1.3 Structure

A skills reference framework is generally made of three elements:

1) **Precise <u>job profiles</u> for different professions and activities in a specific professional sector.**
2) **<u>Structuring of the job profiles</u> with regard to different levels of complexity or to sequences of different professional occupations.**
3) **Extrapolation of these job profiles in terms of a hierarchy of e-skills, structured as an <u>e-skills framework</u>.**

6.2.1.4 Objectives

In the framework of this project, it is intended to base the Virtual e-Skills Training Centre upon a specific skills framework, which by itself is based upon existing and standardized tools, as well as to develop within the following pages all the necessary tools and instruments needed for such an endeavour.

6.2.2 Job profiles

6.2.2.1 Definition

We consider job profiles as more or less elaborate and precise descriptions of a particular work function, profession or position in terms of required education and qualifications, personality features, professional experience, skills, tasks, responsibilities, hierarchical integration and reporting, objectives and expected outcomes, …, in order to perform a certain position efficiently and successfully.

A job profile is usually developed on the basis of a job analysis, which consists of a series of instruments and tools (observations, interviews, critical incidents, work diaries, qualitative and quantitative questionnaires, checklists, standards, …) to identify the content of a job in terms of activities, attributes and requirements involved to perform a certain professional activity.

The objective of developing job profiles is to determine a best fit for a specific job between the job requirements on the one side and the characteristics and expectations of the job seeker on the other one. Job profiles are meant to help individuals develop their well-being at work and their careers, and to help organizations to develop their employees in order to maximize outcomes.

The permanent comparison between a job profile and the performance of an employee is a key element for designing career paths and advancement, training plans or job rotation and promotion.

In most cases companies develop their own specific job profiles in order to dispose of the instruments that best fit their needs.

However, if one is concerned by creating job profiles for a whole sector, a certain need for standardisation is needed, as these job profiles are to fit more than one company and are to respond to the criteria of comparability. In any case, the number of job profile taxonomies is almost endless, but yet none is sufficiently complete to cover all areas of interest.

As for example, the *Répertoire Opérationnel des Métiers et des Emplois (ROME)*, developed in 1989 by the French *Administration Nationale pour l'Emploi (ANPE)*, consists since the 2009 version of a structured taxonomy of 531 job profiles and 10.000 job designations, used also by the Luxembourg ADEM.[64]

This taxonomy, however, is not suited fully for the ICT sector, as it does not provide a sufficient number of ICT job profiles and those provided are not elaborate enough.

That is why we propose in the following part to analyse a series of alternative and more appropriate ICT job profiles systems.

6.2.2.2 European ICT Professional Profiles

With regard to the huge number of ICT profile frameworks and profile descriptions used today in the European ICT business, we prefer to rely on representative ICT profiles covering, at their level of granularity, the full ICT business process. These profiles are being used for reference, and should constitute the basis to develop further profile generations.

As a starting point, we would like to refer to the European ICT Professional Profiles, published in 2012 by the European Committee for Standardization (CEN)[65], established as a result of a workshop led by representatives of interested parties going as far back as 2009. In this document we refer to version 3 from May 2012.

The prime objective of this CEN Workshop Agreement was to increase the transparency of the European ICT skills landscape and to continue its convergence by providing a set of European ICT professional profiles.

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[64] http://www.pole-emploi.fr/candidat/les-fiches-metiers-@/index.jspz?id=681

[65] European Committee for Standardization. (2012). *CWA 16458. European ICT Professional Profiles.* List/ICT/CWAs/CWA%2016458.pdf" ftp://ftp.cen.eu/CEN/Sectors/

By embedding e-skills within ICT profiles that can be readily understood by experts or laymen, the European ICT Profile Family provides a universally applicable solution for communication between stakeholders, with interests in ICT skills, knowledge and attitude development.

It enables employers who invest in and commission programs of education and training to enhance the skills of individuals and subsequently of the organization, as well as while articulating the skills of ICT professionals to identify skills- and knowledge gaps, which are needed to be improved individually and then enlarge organizational performances as a result.

As a result, the European Committee for Standardization defined a European ICT Profile Family Tree, subdivided into 6 families and into 23 ICT professions, which belong into one of these families each.

Table 1: European ICT profiles family tree

European ICT Profiles Family Tree

Six families

Business Management	Technical Management	Design	Development	Service & Operation	Support
23 European Profiles					
– Business Information Manager – Chief Information Officer – ICT Operations Manager	– Quality Assurance Manager – ICT Security Manager – Project Manager, Service Manager	– Business and Systems Analyst – Enterprise and Systems Architect	– Developer – Digital Media Specialist – Test Specialist	– Database and Systems Administrator – Network and Technical Specialist – Service Desk Agent	– ICT Consultant – Account Manager – ICT Trainer – ICT Security Specialist

The European ICT Profiles family tree provides a first approach to the concept of ICT profiles, and we suggest to take this construct as a starting point for further analysis.

The advantage of this system is that it provides a European, structured and standardized approach towards ICT job profiles, but its disadvantage lies in the fact that the contents of the CEN model are quickly outdated and need a permanent up-grading, which is unfortunately not available.

6.2.2.3 Le Portail des métiers de l'Internet

A second ICT job profile system is suggested by the French Ministry of Economics, and is entitled *Les familles des métiers de l'Internet*[66]. It is meant to orient people in initial education and vocational training, to support companies and to define training programmes. The information available is completed by further links towards training vendors or other resources.

It represents a taxonomy of 7 categories and 75 ICT professions, described following a precise and elaborated structure.

Table 2: Categories of Internet professions by the Portail des Métiers de l'Internet

Programmation et développement	Production et gestion de contenu
Interfaces et creation numérique	Infrastructures et réseaux
Formation et assistance	Conception et gestion de projet
Communication et marketing	

The advantage of this system is to be seen in the fact that it is quite recent and should englobe quite a large number of up-to-date ICT job profiles. The job profiles themselves are also quite elaborate and encompass the notion of different kinds of skills. It is to expected that this system will be kept alive systematically.

[66] http://www.metiers.internet.gouv.fr/

Unfortunately, the model has not been linked to the taxonomy of the *Répertoire Opérationnel des Métiers et des Emplois (ROME)*.

6.2.2.4 G3 Web Skills Profiles

Concerning the Web sector, and based on the European ICT Profiles Family Tree, an elaborate structure is provided by the **G3 Web Skills Profiles**[67].

The G3 Web Skills Profiles is a document that was created by a working group of professionals from the ICT sector and its purpose is to define the general third generation European ICT professional profiles that are primarily relevant to the Web sector. It is based on the European ICT Professional Profiles and the E-Competence Framework 2.0.

It refers to the following professional profiles:

Table 3: G3 Web skills profiles

community manager	web server administrator
web project manager	information architect
web account manager	digital strategic planner
user experience designer	web accessibility expert
business analyst	web security expert
db administrator	mobile application developer
search engine expert	e-commerce specialist
advertising manager	online store manager
frontend web developer	reputation manager
server side web developer	knowledge manager
web content specialist	

This model constitues a well-made prolongation to the CEN and is specialized in web profiles.

6.2.2.5 Information and Communications Technology Council

The ICT competency profiles framework is the national standard for ICT occupations in Canada and provides a comprehensive description of six ICT career clusters. It outlines work streams, relevant education and experience, sample job titles, and tasks and performance indicators for key activities within each stream. It gives a complete list of technical competencies and identifies the business and interpersonal competencies needed by ICT workers to perform their job successfully, including the behavioural indicators for each of these competencies and the preferred level of proficiency.

The Competency profiles of the **Information and Communications Technology Council** (ICTC)[68] comprises occupation descriptions, key activities and tasks, technical competencies as well as business and interpersonal competencies.

[67] http://www.skillprofiles.eu/en/

[68] http://www.ictc-ctic.ca/what-we-do/programs/standards-and-certification-2/competency-profiles/ict-job-profiles/
http://www.ictc-ctic.ca/wp-content/uploads/2012/06/ICTC_CPOFrameworkHighlight_EN.pdf

Table 4: ICTC competency profiles

Software	Hardware	Infrastructure
• Analysis Design	• Design Engineering	• Data Administration
• Analysis Programming	• Hardware Scientist	• Database Administration
• Application Software Implementation	• Manufacturing Engineering	• Capacity and Performance
• Business Analysis and Service	• Product Line Management	• Help Desk
• Software Design and Delivery	• Technical Marketing	• Network Planning and Support
• Technical ICT Architecture		• Problem Management
• Web Design		• Systems Programming
• Web Development		• User Technical Support

Testing/Quality Control	Documentation and Training	Management
• Audit	• Education or Training	• ICT Management
• Management	• Technical Writing	• Intellectual Property Management
• Quality Assurance		• Production Management
• Quality Professional		• Project Management
		• Supply Chain Management
		• ICT Consultancy

6.2.2.6 Recommendation

As with regards to the advantagas and disdavantages of all models, we consider that none is sufficiently developed and up-to-date in order to respond to the actual or real-time needs of the ICT companies.

That is why we recommend for the purpose of the intended creation of the Virtual e-Skills Training Centre in Luxembourg to further develop these models and to create one overall approach, which is intended to integrate, to complete, expand and to keep up-to-date the existing models.

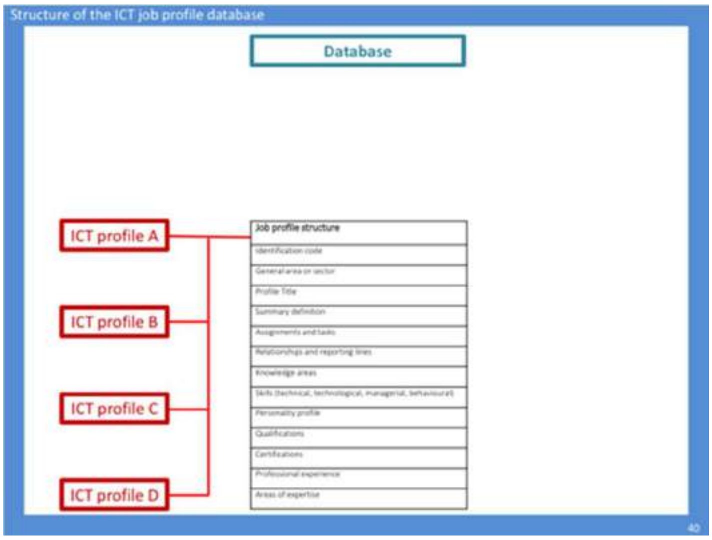
In order to achieve this objective, we recommend to create a database managing and exploring these different ICT job profiles into one coherent structure, combining and connecting the existing models and completing them for those ICT profiles that emerge and that do not fit into one of the previous ones.

As a basic taxonomy we propose to use the European ICT Profiles family tree and to complete it by other taxonomies from thereon.

We suggest to foresee the following job profile structure:

Job profile structure
Identification code
General area or sector
Profile Title
Summary definition
Assignments and tasks
Relationships and reporting lines
Knowledge areas
Skills (technical, technological, managerial, behavioural)
Personality profile
Qualifications
Certifications
Professional experience
Areas of expertise

Figure 4: Structure of ICT job profile database



6.2.3 Hierarchy of job profiles

6.2.3.1 European Qualification Framework (EQF)

As a second point, we would like to introduce the notion of structuring hierarchically the different job profiles. While doing this, we do not mean to structure the different job profiles amongst themselves, but to structure principally - as far as possible - each job profile into different levels of expertise, i.e. from the mere beginner, to the experienced practitioner and the highly qualified expwrt in a certain subject matter.

In order to hierarchically structure the job profiles, we suggest to refer again to a standard system, in this case the **European Qualification Framework** (EQF)[69], which originally represents a structured tool to compare qualification systems in Europe.

It is subdivided into eight common European reference levels that are described in terms of learning outcomes: knowledge, skills and competences.

Table 5: Description of EQF levels

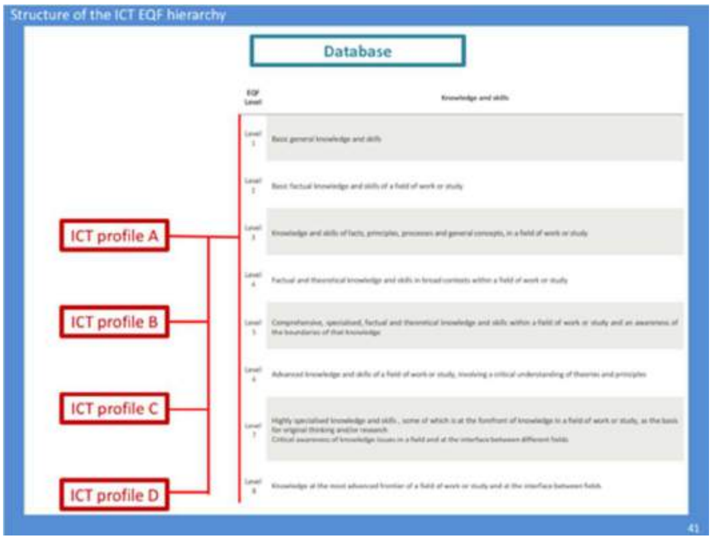
EQF Level	Knowledge and skills
Level 1	Basic general knowledge and skills
Level 2	Basic factual knowledge and skills of a field of work or study
Level 3	Knowledge and skills of facts, principles, processes and general concepts, in a field of work or study
Level 4	Factual and theoretical knowledge and skills in broad contexts within a field of work or study
Level 5	Comprehensive, specialised, factual and theoretical knowledge and skills within a field of work or study and an awareness of the boundaries of that knowledge
Level 6	Advanced knowledge and skills of a field of work or study, involving a critical understanding of theories and principles
Level 7	Highly specialised knowledge and skills , some of which is at the forefront of knowledge in a field of work or study, as the basis for original thinking and/or research
Level 8	Knowledge at the most advanced frontier of a field of work or study and at the interface between fields

But this framework can also be used to structure a particular qualification or training provision system, in so far as the learners, graduates, providers and employers can thus asses, identify or achieve their levels of qualifications within a specific education or training system.

It is the objective of the Virtual e-Skills Training Centre to provide and certify all kinds of further vocational edication and training on the grounds of the European Qualification Framework (EQF) in the field of ICT in order to meet the real needs of the businesses in terms of their e-skills.

[69] https://ec.europa.eu/ploteus/en/content/descriptors-page

Figure 5: EQF Structure of ICT job profiles database



6.2.3.2 European Qualification Framework (ECTS)

Furthermore, and in line with our intention to refer to Europan standards as much as possible, we also would like to introduce at this stage the **European Credit Transfer and Accumulation System** (**ECTS**)[70] which represents a European standard for comparing the study attainment and performance of students of higher education. One academic semester corresponds to 30 ECTS credits equivalent to 750-900 hours of study.

This means that we intend to attribute in the framework of the Virtual e-Skills Training Centre ECTS points to all the different trainings and seminars that are being realised under its auspices, so that participants can eventually sum up their training workloads and obtain an adequate academic qualification, delivered preferable by the academic partner of the Centre, namely ISEC.

Altough the ECTS is complemented by the **European Credit Transfer System for Vocational Education and Training** (ECVET)[71], we will not rely on this system as it has not yet reached the status of a European standard and as it has not yet reached the level of maturity or consensus between training insitutions.

[70] http://ec.europa.eu/education/ects/ects_en.htm
[71] http://ec.europa.eu/education/policy/vocational-policy/ecvet_en.htm

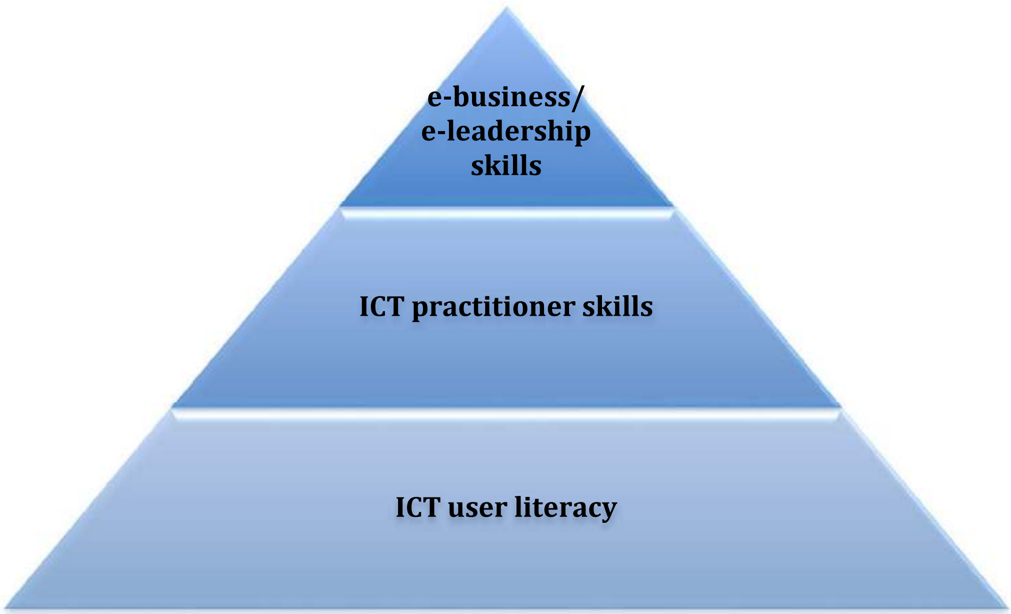
6.2.4 E-Skills framework

6.2.4.1 Definition of e-skills

Prior to a more profound elaboration of a virtual e-skills system, we first would like to define the concept of e-skills, although it must be acknowledged that to date a comprehensive and widely accepted definition of e-skills does not exist. It encompasses a wide range of ICT related elements, such as knowledge, skills, abilities, attitudes, performances, and must be seen in a wider perspective of social and managerial skills.

The European Commission provides in the framework of the European e-Skills Forum and the Career Space initiative in its report *e-Skills for Europe: Towards 2010 and beyond* a comprehensive model for a definition and hierarchy of e-skills that is divided into three levels: (McLaughlin & Sherry, 2014).[72]

Figure 6: E-skills pyramid



- Bottom of the pyramid: ICT user skills/digital literacy
  Skills that are fundamentally necessary for the effective use and application of common ICT systems, devices and software tools in support of their own work and their personal interests. At the general level, they cover the term *digital literacy*, which refers to the confident and reflected use of ICT for work, leisure, learning and communication.
- Centre of the pyramid: ICT practitioner skills
  Skills, which are necessary for researching, designing, developing, planning strategically, managing, producing, consulting, marketing, selling, integrating, installing, administering, maintaining, supporting and servicing ICT systems.
- Top of the pyramid: e-business/e-leadership skills
  E-Business skills are also called e-leadership skills and refer to the abilities needed to exploit strategic opportunities by using ICT technology (especially the Internet), to assure stronger performance of organisations and to research capabilities for new ways of improving or implementing business, administrative and organisational processes. e-Business skills are linked

[72] McLaughlin, S. et al (2014). e-SKILLS: the international dimension and the impact of globalization. European Commission. http://www.eskills-international.com/files/FINAL_INTERNATIONAL_e_Skills_report_Aug_14.pdf

to strategy and innovation, and contain in addition a significant part of generic, i.e. non-sector and non-ICT specific skills.

In general, e-skills refer to competences that individuals and corporate institutions need in order to remain competitive within the global information society. They encompass a broad set of different knowledge, skills and attitudes, and they include, besides technical, technological, transversal and cross disciplinary components, also social, organizational and managerial skills, as well as personal skills such as cognitive, analytical, problem-solving and linguistic abilities.

6.2.4.2 European e-Competence Framework (e-CF)

In general, a skills framework corresponds to a model that broadly defines the blueprint for the ideally required skills within a profession or an activity. Generally, a skills framework will consist of a number of knowledge elements and skills descriptors, which can be generically applied to a broad number of professions, functions or activities within an organisation or a professional sector. Each of these skills is then defined in a way that makes them relevant to the organisation or sector, using language that is clear enough to ensure that everyone has a common understanding of what the ideally required job behaviour looks like within the generic context. This common understanding then becomes the benchmark against which the performance of an individual, team, project, or even entire organisation, can be assessed.

Based on the (standardized) European ICT Professional Profiles, the **European e-Competence Framework** (e-CF)[73] version 3.0 (2013) provides a common European framework for ICT professionals in all industry sectors as a reference to 40 competences as required and applied at an ICT workplace, using a common language for competences, skills and proficiency levels that can be understood across Europe. It represents the first sector-specific implementation of the European Qualifications Framework (EQF) and was created for application by ICT service, user and supply companies, for managers and human resource (HR) departments, for education institutions and training bodies including higher education, for market watchers and policy makers, and other organisations in public and private sectors.

The European e-Competence Framework is based on 5 categories of skills or competences (comparable to the EQF system). Its purpose is to provide general and comprehensive e-competences specified at five proficiency levels that can then be adapted and customised into different contexts from ICT business and stakeholder application perspectives.

Table 6: Correspondence between EQF and e-CF skill levels

EQF 3	***EQF 4***	***EQF 5***	***EQF 6***	***EQF 7***	***EQF 8***
e-1	***e-2***	***e-2***	***e-3***	***e-4***	***e-5***

The four dimensions of the European e-Competence Framework reflect different levels of business and human resource planning requirements in addition to job/work proficiency guidelines. They are specified as follows:

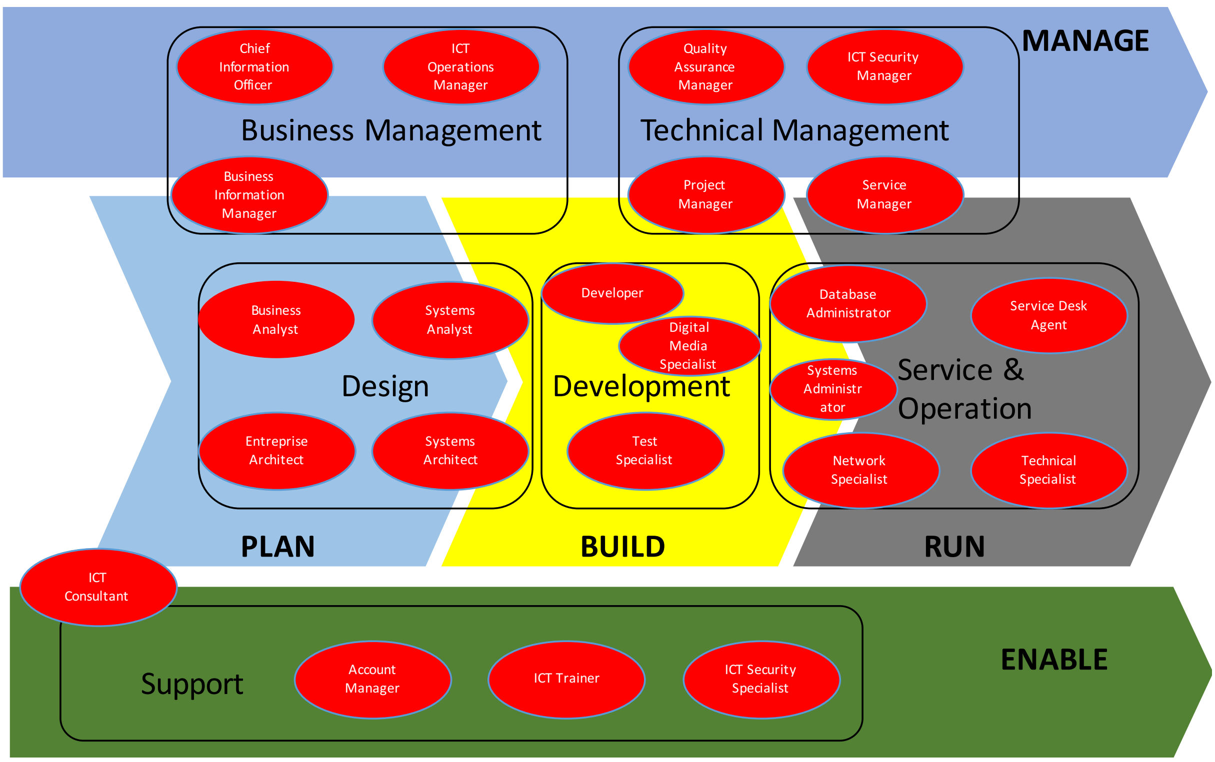
[73] http://www.ecompetences.eu/

Table 7: Four dimensions of the European e-Competence Framework

Dimension 1	5 e-Competence areas, derived from the ICT business processes PLAN – BUILD – RUN – ENABLE – MANAGE
Dimension 2	A set of reference e-Competences for each area, with a generic description for each competence. 40 competences identified in total provide the European generic reference definitions of the framework.
Dimension 3	Proficiency levels of each e-Competence provide European reference level specifications on e-Competence levels e-1 to e-5, which are related to EQF levels 3-8.
Dimension 4	Samples of knowledge and skills relate to e-Competences in dimension 2. They are provided to add value and context and are not intended to be exhaustive.

The following scheme indicates the structured integration of both the European ICT profiles family tree and the European e-Competence Framework: Along the 5 e-Competence areas, derived from the ICT business processes, *Plan, Build, Run, Enable, Manage*, and in conjunction with the 6 ICT families, *Business Management, Technical Management, Design, Development, Service & Operation, Support*, and the 23 European profiles, *Business Information Manager ... ICT consultant*, 36 different kinds of e-skills were extracted and graded along an adapted version of the European Qualification Framework.

Figure 7: Structure of European ICT job profiles



6.2.4.3 *SFIA skills reference framework*

A further and similar example is the **Skills Framework for the Information Age** (**SFIA**)[74], which is also a model for describing and managing competencies for ICT professionals. It is intended to help match the skills of the workforce to the needs of the business. It maps out the range of skills as a two-dimensional table, by tagging each skill with a category and responsibility level.

[74] http://www.sfia-online.org/en

These categories are divided into six main areas: Strategy and Architecture; Change and Transformation; Development and Implementation; Delivery and Operation; Skills and Quality; and Relationships and Engagement.

Each of these is then further divided into sub-categories, mapping out 97 separately identifiable skills. Each of these skills has a general description and a description at one or more of the seven levels.

There are seven levels of responsibility, in ascending order: Follow; Assist; Apply; Enable; Ensure and advise; Initiate and influence; and Set strategy, inspire and mobilise. Each of these responsibility levels has a generic description showing the level of autonomy, influence, complexity, and business skills required.

From a functional perspective, responsibility levels 3-7 can be thought of as equivalent to seniority levels: Associate professional, Professional, Senior professional, Lead professional, and Principal professional.

Each level of responsibility within each skill has a brief description of the typical characteristics of someone with that skill at that level. Skills apply at one or more of the seven levels.

The current published version of the SFIA model is version 6, published in June 2015. SFIA6 was developed during 2014 and early 2015 through an open consultation process involving users of SFIA around the world and was launched at an event on 01 July 2015.

The benefits of SFIA are to be seen in the fact that the tool is on the edge of becoming an internationally recognized standard and that its purpose is precisely to address specific skill gaps and performance development of existing staff that can be overcome by subsequent targeted learnings and trainings.

6.2.4.4 Information Security Skills Framework (IISP)

The skills framework of the Information Security and Information Assurance Professionals (IISP)[75] describes the range of competencies expected of information security and information assurance professionals in the effective performance of their roles. It was developed by collaboration between both private and public sector organisations and world renowned academics and security leaders. It defines the skills and capability expected of security professionals in practical application and not just an assessment of their knowledge. Not all roles require detailed experience in all competency areas, and for more information about how the framework can be applied, please contact the Institute.

6.2.4.5 Référentiel de compétences TIC du Collectif genevois

This IISP Skills Framework 6.3 was elaborated by the association of adult education professionals from Geneva (*Collectif genevois pour la formation de base des adultes*)[76] and constitutes a conceptual framework, which enable to identify skills and to construct training plans upon them. The advantage of this framework is its coherent structure and outline.

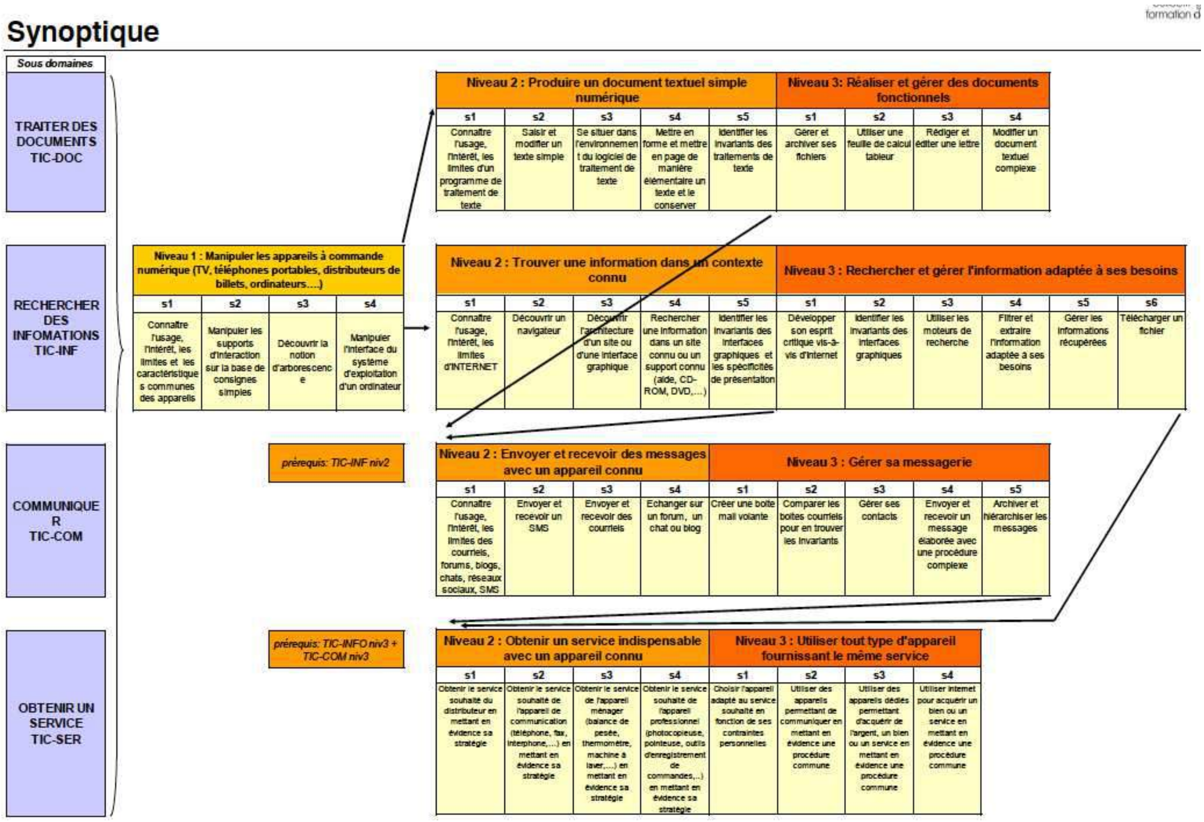
It includes four different domains of e-skills:

- To process documents
- To research information
- To communicate
- To receive a service

[75] https://www.iisp.org/.../CMDownload.aspx?...

[76] http://www.modulesdebase.ch/wordpress/wp-content/uploads/2015/10/Referentiel-de-competences-C9FBA-Utiliser-les-TIC-sept2015.pdf

Table 8: Geneva skills framework



6.2.4.6 *Further examples of skills frameworks*

- Conceptual framework of digital competence (DIGCOMP)
- The tech partnership[77]
- Canada's Association of IT Professionals[78]
- Information and Communications Technology Council / Occupational Skills Framework (OSPM)[79]
- Kibnet - Kompetenzzentrum IT-Bildungsnetzwerk[80]

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[77] https://www.thetechpartnership.com/
[78] http://www.cips.ca/node/56
[79] http://www.ictc-ctic.ca/
http://www.ictc-ctic.ca/wp-content/uploads/2012/06/ICTC_CPOFrameworkHighlight_EN.pdf
[80] www.kibnet.de

6.2.4.7 Recommendation

On the basis of these existing ICT skills frameworks, we recommend to create a database storing, managing and exploring a vast array of different ICT skills into one coherent structure as a synoptic table, combining and connecting the existing models and completing them for those ICT skill profiles that emerge and that do not fit into one of the previous ones.

Each of these e-skills is assigned to an EQF level and can then potentially be associated with a specific ICT job profile, respectively with one of its categories.

As a basic taxonomy we propose to use the e-CF tree in conjunction with SFIA and to complete it by other taxonomies and skills examples from thereon.

However, we also recommend to sharpen the level of details, as the description of skills remains too general and too little operational for a precise evaluation of the acquisition of a specific skill. We suggest at least 7 structural levels in order to maximise the level of precision.

Figure 8: Structure of e-skills database

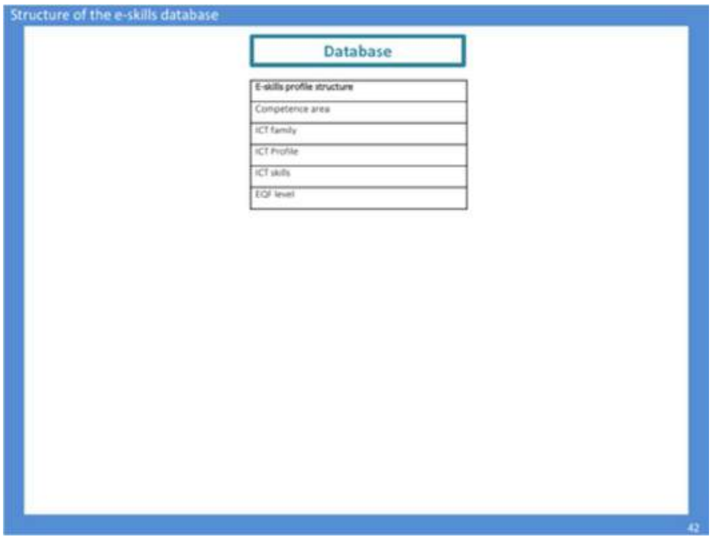
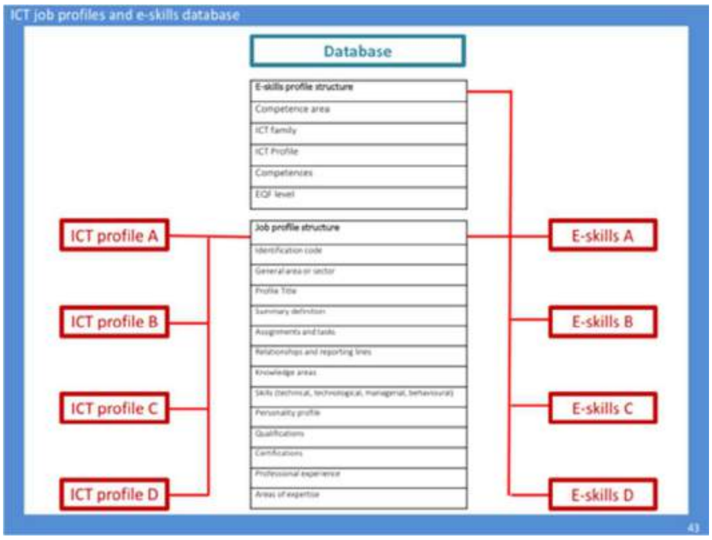


Figure 9: Combined ICT job profiles and e-skills database



6.2.5 ICT training offer database

As a counterpart of the combined ICT job profiles and e-skills database, it will be necessary to create a comprehensive and competitive database of the existing training offer, both nationally and partly internationally.

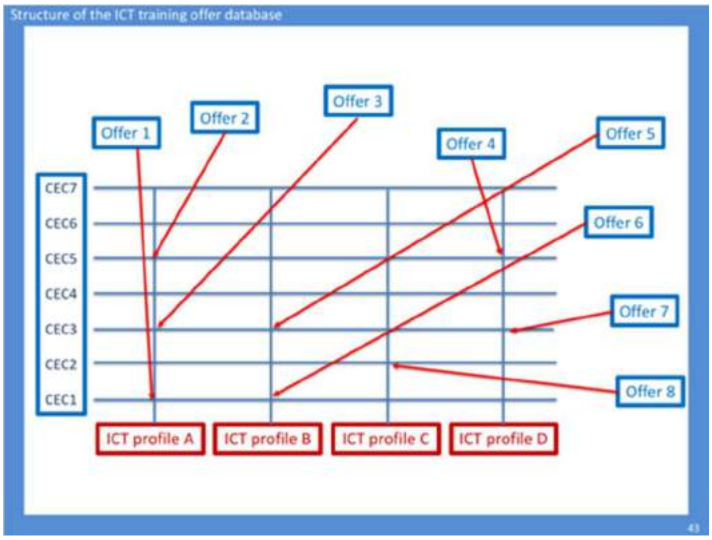
However, it is a fact that an ICT training offer exists on the market for almost any need that could possibly or potentially be expressed, especially with specialised e-skills training institutions or ICT software and hardware providers or vendors.

It would therefore be very costly and time intensive, or utterly unrealistic, to try to establish a new and specific training offer, and it would be even more complicated to keep up to date adequately the latest versions of the available and required soft- and hardware systems. The specific e-skills training needs and the available offer are just too manifold to find a satisfactory viable solution.

Therefore, we recommend to create a database whose objective it is to establish on a continuous basis contractual relationships with ICT vendors and e-skills training providers in order to integrate their offer and solutions in real time and permanently into this specific database, integrating under precise conditions the nationally and internationally available training offer.

Furthermore, we recommend to integrate the existing training offer on the market into the structure of the European Qualification Framework, assigning to each particular training an offer specific EQF reference number.

Figure 10: Structure of ICT training database



6.2.6 e-Skills matching platform

6.2.6.1 Description

The objective of the e-skills matching platform mainly consists in the management or the comparison of the offer and the demand in matters of ICT training in order to match supply and demand of e-skills.

On the demand side, we have the combined the database of the ICT job profiles and the e-skills, and on the offer side we have the ICT training providers' database.

The question is now, how to match the information between the offer and the demand side, adapted to a specific need of an individual or of a company as a whole.

Therefore, we recommend to create an e-skills matching platform, which should be working like a dating site, but instead of matching people to one another, it matches people and their e-skills to specific job profiles and related training offers in the ICT sector.

The application of this concept to an individual or a corporate institution corresponds to applying a Skills/Training Needs Assessment (STNA), which is a method that determines on the basis of an analysis of existing e-skills if a specific or general training need in terms of a discrepancy between IST and SOLL exists and that hence a specific training intervention needs to be processed out of the large array of proposals from the ICT training offer database.

If so determined by the identified discrepancy between the available and the required skills, the STNA determines the sort of training required to fill the individual gap. The gap between the present status and the desired status indicate discrepancies, gaps or lack that in turn can be translated into a training need, and furthermore into a training plan at a subsequent moment.

For this objective, a performant computerised platform should be established to create a comprehensive link between the training demand from an individual or a corporate customer based on an e-skills assessment and the ICT training offer.

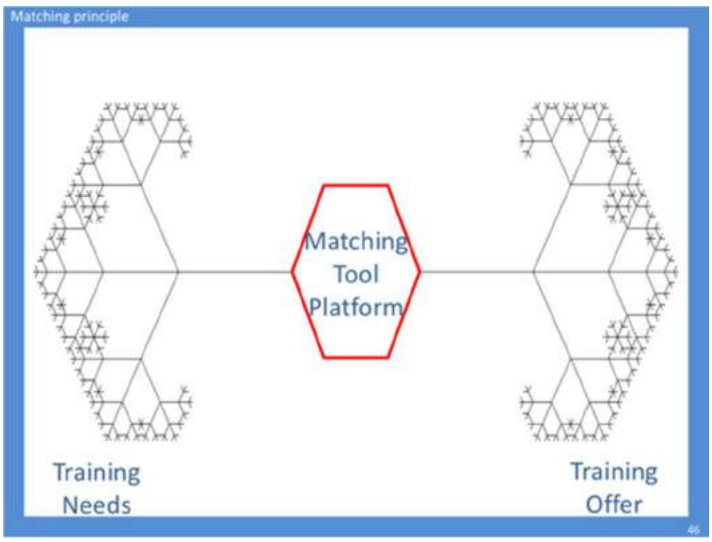
For this particular purpose, it will be necessary to put into place a specific software driven platform that is able to realise in a most consistent and economical way this task.

Furthermore, it is recommended to complete this matching tool by further instruments, such as:

1) individual or corporate counselling, advisory and monitoring services;
2) further testing tools, such as personality or intelligence tests or tests of professional interests.

The general objective of an e-skills matching platform is to merge supply and demand in terms of e-skills.

Figure 11: e-Skills matching principle



6.2.6.2 Examples of e-skills matching platforms

- Worx[81]
- CEPIS e-Competence Benchmark[82]
- validateskills[83]
- BSMimpact[84]
- Lexonis[85]
- Seera[86]
- mySFIA[87]
- janzz[88]
- IBM KENEXA[89]
- ...

[81] https://www.trainingindustry.com/suppliers/i/ictworx.aspx
[82] http://cepisecompetencebenchmark.org/
[83] http://www.validateskills.com/
[84] http://bsmimpact.com/services/sfia/
http://bsmimpact.com/wp-content/uploads/SFIA-

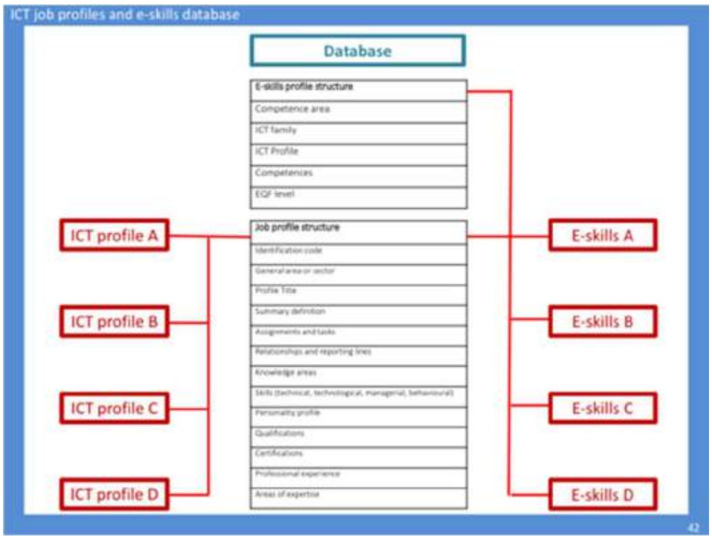
[86] https://www.lexonis.com/sfia
[87] https://www.acs.org.au/sfia-certification/mysfia
[88] http://janzz.technology/
[89] http://www-01.ibm.com/software/smarterworkforce/

6.2.6.3 Recommendation

Finally, the two databases need to be combined in order to create a comprehensive association between the job profiles and the vast array of available e-skills in order to associate for each ICT job profile a number of relevant and structured e-skills.

Thus, it is possible to define a series of relevant e-skills profiles that can be used as the basis to determine a skill needs or a training needs assessment.

Figure 12: Combination of ICT job profiles and e-skills



6.3 Structural framework

6.3.1 Virtual E-Skills Training Centre

6.3.1.1 Objectives

With regard to the issue of being confronted by a significant lack of highly skilled ICT practitioners, in combination with an inadequately developed system to assess and match training demands and training provision, we conclude that is is necessary to implement a professionally structured e-skills provision system.

We think that it is essential to create an appropriate institutional structure of its own, with an independent management and financial setting, in order to guarantee the durability and the sustainability of such a system.

Without any doubt, the existence of an e-skills provision system, including assessment, matching, provision and certification are key elements for promoting attractiveness, employment and career development in the ICT industry and should contribute largely to labour mobility due to an increase of quality, transparency and recognition of certifications and qualifications. Thus, the promotion of e-skills ought to contribute to the economic competitiveness of a country, and to Luxembourg in particular, to better jobs and to reinforce social cohesion. It certainly can contribute to the attractiveness of this labour market segment.

It is therefore the objective of this chapter to describe the creation of a virtual system for the assessment, matching, provision and certification of e-skills in Luxembourg. (*Centre de compétences ICT*).

The objective of the Luxembourg **Virtual E-Skills Training Centre** is to answer the question as to *How to bring the system to the people* and of *How to bring the people to the system?*

As with regards to the gap between offer and demand in the field of e-skills, in combination with the lack of an adequate, up-to-date and practical and training offer, it becomes necessary to:

- Create an integrated and industry driven Virtual E-Skills Training Centre in Luxembourg.
- Enhance the development, learning, transfer and application of practical knowledge, skills and strategies in ICT.
- Create a performant education and training system in ICT.
- Conceive, deliver and certify up-to-date computer literacy knowledge and skills to all kinds of industry employers, to established specialists or to novices to the ICT world.
- Use for this purpose the most modern pedagogical tools and methods, at a fraction of the cost and time of traditional schools.
- Provide a vocational training offer at all levels of the European Qualification Framework (EQF) by sector or line of business to meet the real needs of small businesses and addressing their collaborators and their collaborators.
- Provide the same training logic to all sectors and branches.
- Increase the permeability between training levels.
- Consolidate and systemize the existing vocational training offer.
- Provide support in training engineering.
- Establish a system of validation of acquired experience and sectoral certifications and qualifications.
- Establish and manage the collection of training funds in the form of a pooling system.
- Ensure an assistance for companies.
- Submit a range of training and professional insertion measures for those excluded from the labour market.
- Provide initial vocational training offer and continue in the interest of businesses and employees in the field of ICT in Luxembourg and abroad.
- Consolidate, professionalize and systematize existing or new trainings.

- Act as an organ of structuring and coordinating all actions, projects and initiatives in initial and continuing vocational training in the field of ICT, including those of the players in the social and solidarity economy, as well as private and public organizations.
- Establish a system of validation of acquired specific experience and certification to trades and ICT skills.
- Develop and participate in projects of all kinds and of all sizes in the field of ICT, either in Luxembourg or abroad.

The general objective of the of the Virtual E-Skills Training Centre is to create a virtual, hence computer assisted and Internet based ICT training needs evaluation, matching and provision system.

Furthermore, it is meant:

1. To assess professionally and systematically, on the basis of scientifically and technically proven instruments, methods and tools, individual and corporate ICT training needs, technical, technological, behavioural and managerial, in conjunction with a thorough analysis of available skills (to identify the difference between the skills available and skills needed by both the individual or the company).
2. To encompass and structure the complete training offer, from both ICT vendors and ICT training providers, national and international, in order to integrate it into the Internet based system and following the EQF classification.
3. To create a professional Internet based matching system between the individual or corporate need's assessment and the existing training provision to bring the ICT training offer and the ICT training demand intelligently together.

In order to attain these objectives, the Virtual E-Skills Training Centre will create progressively the necessary instruments and tools, and rely as much as possible on the existing offer of training instruments and tools, as well as on the offer of training provision provided by the national and international ICT vendors and providers, or ICT training institutions, which are already active on the ICT training market.

Therefore, the Virtual E-Skills Training Centre itself will only organise training provision itself under exceptional circumstances or when the training market cannot provide adequate solutions. Under normal conditions, the Virtual E-Skills Training Centre will obtain the required training provision from the ICT training market or in conjunction with selected quality providers.

Furthermore, the Virtual E-Skills Training Centre intends to rely as much as possible on existing standards and systems with regard to ICT jobs and skills profiles.

6.3.1.2 General characteristics

- Industry dynamics
  - Undertaking driven by industry requirements, needs and interests
  - Practical, applicable and viable provision of training, transfer of high level and state-of-the-art knowledge and skills from industry to industry

- Enlarged permeability
  - Overcoming restrictive entry requirements
  - Opening to admission based on validation of experience (VAE)
  - Consideration of actual knowledge and skills of candidates via validation of prior professional experience

- Structure of offer and demand
  - Structuring of the training offer and demand following the
    - European Skills Framework
    - European Qualification Framework (EQF)
    - European Credit Transfer System (ECTS)

- Integrated e-skills training offer
  - Integration of external seminars (of various origins) to EQF levels per subject field
  - Integration of external seminars (of various origins) to ECTS points per subject field and per CEC level
  - Integration of different subject fields to full range ECTS points per EQF level
- Individualised qualification pathways
  - Enabling individual study pathways based on prior knowledge and skills and intended corporate or individual targets or objectives
  - Linking academic education, professional training and professional experience
- Recognition of prior knowledge and experience
  - Accreditation of prior and experiential learning enabling the formal recognition of skills acquired throughout life by granting a corresponding certificate or diploma
- Multimodal provision of education and training modules
  - Diverse origin from different providers of education and training modules assembled and completed into a coherent curriculum and corresponding diploma
- Focus on skills, strategies, transfer and application
  - Focussing on transferable knowledge and skills on the basis of scientific research and evidence based results
- Integrated double-/triple-subject curricula
  - Providing double-/triple-diplomas in different fields of studies
  - Creating integrative/interdisciplinary/transversal oriented disciplines as basic units for research and teaching as an alternative to course-/discipline related structures
  - Merging of faculties and academic staff to functional units
- Innovative pedagogical concepts
  - Respecting an industry/enterprise logic by underlining the viability, feasibility, practicality and utility of things
  - Orienting towards a problem solving approach rather than a theoretical analysis
  - Introducing challenging pedagogical approaches
  - Offering flexible study and certification conditions
- Cumulative certification
  - Certifying acquired skills rather than ensuring compliance to pre-established curricula and academic regulations

6.3.1.3 Technological and innovation watch

The Virtual e-Skills Training Centre should also integrate a performant and internationally oriented **Technology and Innovation Watch** (veille technologique) in order to help innovators to showcase, demonstrate and experiment their ideas, service and products in front of a professional ICt audience in Luxembourg.

In this area, the Virtual e-Skills Training Centre should initiate high level national and international collaborations and partnerships as well as build up und amange appropriate projects.

6.3.1.4 Platform for training in ICT of unemployed persons

A third pillar of the Virtual e-Skills Training Centre should concern the training and develppment of persons that are unemployed or at the risk of unemployment.

A specific large scale initiative *Fit for ICT* should therefore be enhances in close collaboration with ADEM.

6.3.1.5 Coordination platform for ICT training initiatives

As the number of new training initiatives, projects and institutions still progresses (école 42, webforce 3, …), the Luxembourg ICT training market risks to become a wild zoo.

Therefore, it would also be essential that the Virtual e-Skills Training Centre should also become the coordination hub for all new inititives that are to launched in Luxembourg.

Furthermore, it could ensure that the training offer related to these initiatives are in line wth the E-CF and EQF system that the Virtual e-Skills Training Centre wishes to implement.

6.3.1.6 Evaluation and certification

Industry related certifications integrate the concept of assessment of acquired skills and question the monopoly of the right to title of public education institutions. These certifications can be looked upon as a voluntary evaluation process, whereby an individual's knowledge and skills in a particular subject area is verified against a set of predetermined industry related skills standards by the means of an adequate assessment.

We intend to implement a certification system that corresponds to a set of procedures and resources for carrying out the certification process and leading to a certification or qualification by an accredited certification body. It includes application, content management, examination, evaluation, decision on certification.

It respects a certain amount of criteria and quality standards, deducted from the pre-established skills profiles. It includes to conduct ex ante and ex post assessments, tests, examination, which are based on predefined criteria.

The certification body will define the methods, tools, instruments and mechanisms to be used to evaluate the skills of candidates.

The certification will be based upon a professionally organised *ex ante* and *ex post* skills assessment system, in line with the e-skills thesaurus and the ICT job desriptions.

Furthermore, the Virtual e-Skills Training Centre intends to establish a torough system for the validation of previously acquired skills by experience (*VAE - validation des acquis de l'expérience*).

6.3.1.7 Partners

In order to realise the strategic, conceptual, financial, administrative, structural or technical aspects of the intended Virtual E-skills Training Centre, we recommend to create a specific legal structure, in the form of a *Groupement d'Intérêt Ecoconomique* (GIE) to assure the mentioned tasks.

It is suggested to include as partners and shareholders of the GIE the following partners:

- **House of Training**[90] (HOT), affiliated to the Chambre de Commerce (CdComm), the Association des Banques et Banquiers Luxembourg (ABBL) and the Chambre des Métiers (CdM);
- **Institut Supérieur de l'Economie**[91] (ISEC), affiliated to the Chambre de Commerce (CdC) and the Chambre des Métiers (CdM);
- **Fédération des Intégrateurs**[92] (FdI), representing the ICT sector as well as ICT Luxembourg;
- **Centre de Compétences Génie Technique du Bâtiment**[93] (CdC GTB), representing the crafts sector.

Its agreed between the partners that each one is in charge of a specific part of the framework of the Virtual E-skills Training Centre, depending on the EQF level. For instance, the **CdC GTB** and **FdI** will take charge of the EQF 1-4 trainings and certifications, the **HOT** of the EQF 5-8 trainings and certifications, and the **ISEC** of the EQF 5-8 trainings and qualifications qualifications.

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[90] https://www.houseoftraining.lu/
[91] ISEC is a university of applied ciences recently created in Luxembourg and that will integrate parts of the Virtual e-skills Training Centre in its ICT faculty.
[92] http://fdi.lu/qui-sommes-nous/
[93] www.cdc-gtb.lu

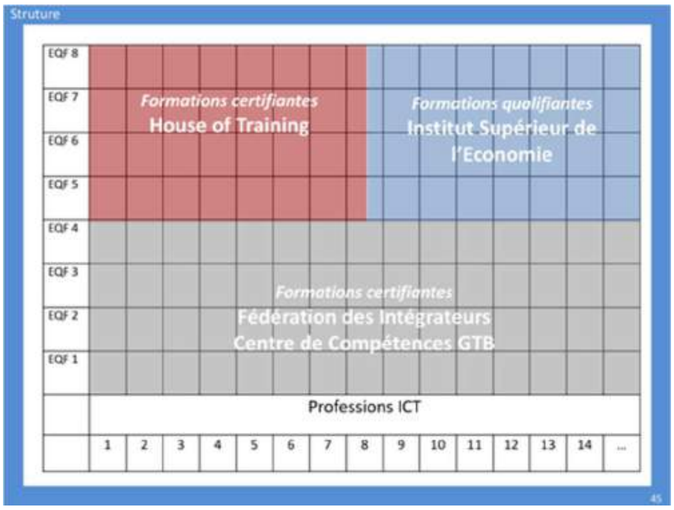
It is the role of the partners, amongst others, to organise the training provision. The Virtual E-skills Training Centre will mainly focus on its role as a e-skills matching platform with all attributed roles and functions.

It is also foreseen that ISEC will offer or validate complete academic programmes by granting Bologna/ECTS compatible qualifications or diplomas.

The partners HOT and CdC GTB will organise seminars that do not necessarily cover a whole range of courses that do not necessarily add up to a sufficient amount of ECTS points to obtain a diploma.

It is also understood that in the course of time, other partners will be invited to join the partnership, especially he **Chambre of Commerce** and the **Chamber of Crafts**, as well as professional associations as **ICT Luxembourg** for instance.

Figure 13: Role of partners



6.3.1.8 Recommendation

The Virtual e-Skills Training Centre will strive to affiliate a large number of ICT training providers and their training offer, as well as to validate and certify the acquired skills through either diplomas or certifications.

The idea for the training centre is to offer access to a large panoply of seminars and courses, going from nanodegrees, short or middle term specialised degrees to full academic degrees (bachelor/master), which accumulate in terms of ECTS.

The virtual e-skills training centre will be constructed as a matching platform that operates similar to the system of a dating website. The platform analyses the needs of the client and relates the offers from training providers to the demands from the clients.

It will be necessary to establish structured links (interfaces) between the ICT training offer delivered by ICT providers (hard and software) and an appropriate training offer management database.

To be able to implement this system, it is necessary to create a professional training needs analysis system in order to identify the individual and collective training needs. The system should also include coaching in order to support the individual or the collective.

We thus propose to conceive the structure and the proceedings of the Virtual E-Skills Training Centre under the following terms:

1) **Elaborate precise <u>ICT job profiles</u> for different ICT professions and activities in different professional sectors in the form of a database.**
2) **Extrapolate an <u>e-skills framework</u> from the job profiles in the form of a database.**
3) **Elaborate an <u>e-skills assessment and evaluation system</u>.**
4) **Elaborate a <u>training needs assessment and evaluation system</u>.**
5) **Create an <u>observatory of ICT provision</u>, national and international.**
6) **Implement an <u>Internet based matching platform</u>.**
7) **Initiate activities as an ICT <u>matching, consulting and coaching institution</u>.**
8) **Issue <u>certifications and qualifications</u>.**

6.4 Pedagogical framework

6.4.1 Introduction

Within this Virtual E-skills Training Centre, we will strive to create a modern and innovative education and training environment in the field of e-skills. It will be based on the latest available teaching and learning methods.

The pedagogical framework will have a two-fold structure, as it will be based upon:

1) the epistemology associated to social-constructivist learning theory,
2) the methods associated to the broad e-learning concept.

Our pedagogical approach will not necessarily include classroom solutions, but will rely as far as possible and as reasonable on distance and individualised training pathways.

The system will refer to the most modern and recent applications and methods such as **Massive open online courses** (MOOC) or the **Moodle** Platform. Constructivist learning as a theoretical background

6.4.1.1 Basic constructivist assumptions

We intend to base the Virtual e-Skills Training Centre from the pedagogical point of view on the social-constructivist epistemology and social-constructivist learning theory (Dewey, Piaget, Vigotsky, Gergen). The term constructivism refers to the concept that a learner constructs knowledge and meaning by and for himself while he or she is learning and while he or she is interacting with others.

As a basic assumption of constructivism states that there is no knowledge or meaning independent of the learner or the community of learners. Knowledge is constructed through the process of learning itself, it is not about understanding the "true" nature of things, but a personal and social construction of meaning is formed out of a very large array of physiological and social perceptions, which are being structured, transformed, interpreted, stored and retrieved through our individual cognitive abilities, which thus determine our subsequent behaviour.

This knowledge of our own making does neither reflect the "real" world as it is, nor is it entirely independent of it. It emerges through a dynamic process of communication and interaction between the person, the subject and the others.

The social-constructivist view of learning completes and overcomes the conceptions of the world induced since the era of Enlightenment and modernism, which were based on the idea that the world can be known rationally, that it can be perfectly structured and organized, as a vast and entirely predictable mechanical machine, fully independent of the learner himself. For that reason, science developed precise methodologies, categories and taxonomies. The task of the teacher was then merely to explain the functioning of this machine to the learner.

But, in this description, the learner does not appear anywhere. In constructivist theory, however, the learner is placed in the forefront of interest, so that each learner will be able to create his own model of nature and things. Nature is no longer objective, but it becomes subjective in conjunction with a permanent negotiation with the learning community in order to find a common ground of understanding (Ant, Nimmerfroh, Reinhard, 2013).

6.4.1.2 Pedagogical consequences

As a pedagogical consequence of the constructivist epistemology, the focus of the learning process has to be changed. Instead of highlighting the subjects or contends to be taught or instructed, the focus is here on the learner and his thinking about learning. Constructivist learning is not merely about learning facts and figures about the real world, nor about structuring it rationally, or manipulating its objects and presenting it academically, while keeping it independent of the learner.

On the contrary, the learning process will not only lead to a certain understanding of the world (*Kenntnis*), but also to a deeper personal meaning and interpretation (*Erkenntnis*) of things, as in this process new meaning is constructed by the learners, and not simply photocopied from the reality to the personality.

The constructivist position suggests to follow a pedagogy that provides learners with the opportunity to interact cognitively with sensory data and to construct their own worlds.

In short, learning is equivalent to the co-construction of meaning, and not to the accumulation of facts.

6.4.1.3 Principles of constructivist learning

1. Learning is an active process
During the learning process, the learner uses sensory input, interprets it and constructs meaning out of it. The learner therefore plays a very active part in the learning process and has to engage with the world in order to learn.

2. People learn to learn as they learn
Learning consists of both constructing meaning and constructing systems and structures of meaning. While learning facts, we not only learn the facts themselves, but also about the deeper meaning of those. With each meaning we construct out of these facts, we also construct meaning of the system and structure regulating and relating these facts.

3. The constructing meaning is a cognitive process
Beyond the necessity to engage actively and physically in the learning process, it is also necessary to engage in the cognitive aspects of learning, while reflecting the activity itself.

4. Learning involves language
It is commonly known that one best way to learn is to talk about the learning matter, to oneself or to others, or even to teach it. Language and learning are inextricably intertwined, and without language, may it social or personal, learning is not possible.

5. Learning is a social activity
Learning is intimately associated with the social interaction and communication processes with other human beings (teachers or trainers, peers, family members, work colleagues, casual acquaintances). Learning is not reduced to a one-on-one relationship between the learner and the learning matter to be learned. On the contrary, efficient learning relies largely on reflective conversations and interactions with others, as well as on the practical application of this knowledge in real situations.

6. Learning is situated
Learning about isolated facts remains isolated knowledge, which has no meaning and usefulness beyond the act of accumulating encyclopaedic knowledge. On the contrary, learning ought to be anchored and take place in real and realistic learning situations, with a close and explicit link between what we learn and what we do.

7. Learning needs structure
The mere accumulation of facts does not lead to reflexive learning. The learning process should be integrated in the pre-existing cognitive structures, schemes or patterns, thus enlarging and improving the latter, on the basis of previous experience. The more we have learned, the easier we can add new learning to the existing one, under the condition that the learning process is directly connected to the learner, his prior knowledge, his knowledge about the learning process and the existing cognitive schemes.

8. Learning is related to time

Learning is a matter that needs time, contemplation, reflection, thinking, exposure, preparation, trial, revisitation, repetition and practical application. It is not a matter of a few seconds to gain profound insight.

9. Learning is related to motivation
Motivation is essential for learning and is strongly related to our deeper understanding or meaningfulness and usefulness of the things we learn. Through this understanding, we increase our motivation for new learning, we learn more and more easily, which has again a positive effect upon our motivation, and so on and so forth.

6.4.2 Range of computer assisted learning approaches

As a second point, we intend to structure the Virtual e-skills Training Centre in the framework of computer-assisted or computer-generated learning. For this reason, we will develop in the following paragraphs a concept of a computer assisted learning process.

6.4.2.1 Programmed Instruction and CBT

The idea of learning with machines is not really new. A first attempt to use machines in education goes back to concepts of **Programmed Learning** or Programmed Instruction, relying basically on the behaviourist learning theory developed by B. F. Skinner in the late 1950ties.[94] Under this array, learning is regulated by a stimulus-response process, in which information is delivered in small entities and follows a learning pace which is self-directed by the learner and which normally provides on the basis of multiple choice questions and answers an immediate feedback.

At a certain moment, Programmed Learning was particularly widespread in self-teaching textbooks and was integrated into mechanical learning machines, which however did not lead to a success, as their features were often associated to mechanical failure and to difficulties to develop and implement appropriate learning materials.

With the upcoming of the first computers, the idea of machine integrated learning was developed from 1960 on for example by the **PLATO project** (Programmed Logic for Automated Teaching Operation) by the University of Illinois. Essentially, it combined the behaviourist learning concepts to the new and more powerful features of computers, such as graphics, animations, information exchange between users, message boards and chat rooms, etc.

However, despite many interesting concepts and promising projects, Programmed Learning did not survive in the long run. This is certainly not only due to the limited possibilities of mechanical apparatus or early computers, but also to considerations related to behaviourist learning principles that were gradually questioned with the rise of cognitive psychology and its associated learning theories. In learning settings of Programmed Instruction, the feedback was limited to true/false, no further explanations for improvement could be provided, and was in the end limited to fact or rule based courses, such as vocabulary learning. The cognitive moment was entirely absent.

Mainly for these same reasons, the concept of **Computer Based Training**, which appeared in the 1980ties, had to follow the same destiny. In short, Computer Based Training was the attempt to transfer the learning material developed under the Programmed instruction phase onto computers. Their advantage was certainly to be seen in their ability to provide wider options, a faster treatment of results, and certainly a more attractive graphical setting and layout. Also, due to the power of computers and specific software, more elaborate questioning and answering larger with ramifications of became possible. However, similarly to its preceding methods, there was hardly any scientific evidence that learning with and through the computer was more efficient in comparison to more classical ways. Thus, nowadays Computer Based Training has lost its interest, except maybe for niche domains, such as language learning.

[94] Skinner, B.F. (1958). Teaching machines. *Science*, 128 (3330), 969-977.

A major breakthrough was, however, achieved by **Seymour Papert**[95]**,** a MIT mathematician and computer scientist with a strong background in cognitive psychology. His special focus laid on the psychology of learning with computers and was based on the constructivist theories on child development by the famous Swiss developmental psychologist Jean Piaget. Papert reinvented the ways schools and pupils should work with computers by creating the Logo programming language to help children to improve their cognitive and problem solving skills, through the help of the Logo turtle, an idea which is still today featured through the Lego Mindstorms learning and playing material.

Another promising concept had been introduced through **Artificial Intelligence**, as the intention to make machines or software intelligent. However, the abilities of these artefacts to perceive, to process, store and retrieve information, to speak, to reason or to learn, remained largely unsatisfactory for teaching and learning purposes on a larger scale and were thus abandoned quite rapidly.

6.4.2.2 E-learning 1.0

Today, with the rise of new generations of computers and ICT-based communication tools since the 1990ties, the discussion focuses on **e-learning systems**. In general, the term e-learning refers to the use of a large array of technological tools (online, interactive, virtual, Internet based) in pedagogical settings. Today it encompasses all learning settings that are based on ICT technologies, including multimedia learning, computer- and internet-based training (CBT), and especially computer managed instruction and learning platforms, flexible, mobile and sandwich learning, and even digital education.

In summary, e-learning is a very imprecise concept as there seems to be a significant variation in the understanding and usage of term.

However, a distinction must be made between e-learning as the technological basis and its efficient and appropriate use in educational settings. Educational technology therefore refers to both the effective use of technological tools in learning contexts (media, machines, networking hard- and software), as well as to the underlying theoretical perspectives for their efficient application.

6.4.2.3 *E-learning 2.0*

In the framework of the emergence of the Web 2.0, e-learning 2.0 corresponds to a computer-supported collaborative learning (CSCL) or e-twinning model that emphases on learning in social contexts while using social software (blogs, wikis, podcasts and virtual worlds).

E-learning 2.0 is based on the constructivist assumption that knowledge, meaning and understanding is socially constructed through communication, interaction and the definition of a common ground.

E-learning 2.0 leads to online multi-user virtual environments (MUVEs) and to settings that connect learning institutions across geographical frontiers (Classroom 2.0). It is largely based on social networks, online learning communities and Mobile Assisted Language Learning (MALL) settings, using all kinds of mobile devices to support the learning process. Computer-supported collaborative learning (CSCL) enables learners in one learning institution to communicate with learners in another, enhancing collaborative educational processes, group experiences in learning and cultural diversification.

But let us also follow in this context the suggestion of Bernard Luskin[96], a pioneer on educational technology pioneer, advocated that the "e" of e-learning should be interpreted to mean *exciting, energetic, enthusiastic, emotional, extended, excellent, and educational* in addition to *electronic*.

In any case, old-fashioned teaching and learning institutions should trespass the confined world of talk and chalk.

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[95] Papert, S. (1993). *Mindstorms: Children, Computers, and Powerful Ideas*. 2nd ed. New York: Perseus.

[96] Luskin, B. (2010). *Think "Exciting": E-Learning and the Big "E"*. Educause Review Online.

On the contrary, e-learning 2.0 will take place in a revolutionary new setting, characterised by more and more mobile learning, powered by mobile devices, larger capabilities and omnipresent Internet access. At the same time, pedagogical applications are increasingly moving from the stand alone desk top computer towards server farms. It will be possible to deliver applications to every learner - based on its individual needs and capabilities - and create new innovative learning environments, necessitating the availability of personal learning devices. At the time, as the ICT devices become ubiquitous, learning also becomes ubiquitous. Through this technological evolution, learning opportunities can be provided and used almost anytime and almost anywhere, thus changing the fundamental role of the teacher, who is becoming a physical or virtual mentor or coach, instead of a knowledge transmission instance. Maybe one should then also reflect upon the integration of online game experiences of especially young people, as it focuses on increased playful social interaction and active participation.

Learning will become personalized and new learning environments will be created, leaving the classical school room for learning environments that foster collaborative, cross-disciplinary and student centred learning. Learning will be documented and evaluated in the context of personalized portfolios, supporting what students have learned, and not punishing them for what they don't know.

6.4.2.4 Instructional design

We also suggest to rely on the concepts of instructional design, which corresponds to a process of improving learning and teaching through the thorough analysis of learning needs, the creation and design of learning materials, as well as the systematic development and implementation of learning experiences, while relying on the use of technological and multimedia tools to enhance these leaning experiences.

We also suggest to refer largely upon the concepts and notions of instructional design, in a systemic perspective (Dick & Carey, 2005, p. 1-12)[97], which addresses learning as an complex system, focusing on the interrelationship between context, content, learning and teaching. We would like to recommend a learning and teaching model that is characterized by the following: Components such as the instructor, learners, materials, instructional activities, delivery system, and learning and performance environments interact with each other and work together to bring about the desired student learning outcomes.

The **Systems Approach Model**, developed by Dick and Carey, suggests that all components are executed iteratively and in parallel, rather than linearly. It includes the following elements:

- Identify instructional goal(s)
  A goal statement describes a skill, knowledge or attitude that a learner will be expected to acquire.
- Conduct instructional analysis
  Identify what a learner must recall and identify what learner must be able to do to perform particular task.
- Analyse learners and contexts
  Identify general characteristics of the target audience, including prior skills, prior experience, and basic demographics; identify characteristics directly related to the skill to be taught; and perform analysis of the performance and learning settings.
- Write performance objectives
  Objectives consists of a description of the behaviour, the condition and criteria. The component of an objective that describes the criteria will be used to judge the learner's performance.
- Develop assessment instruments

[97] Dick, W.; Carey, L. & Carey, J.O. (2005). *The Systematic Design of Instruction*. 6th ed. Boston: Allyn & Bacon.

Purpose of entry behaviour testing, purpose of pretesting, purpose of post-testing, purpose of proactive items/proactive problems.

- Develop instructional strategy
  Pre-instructional activities, content presentation, Learner participation, assessment
- Develop and select instructional materials
- Design and conduct formative evaluation of instruction
  Designers try to identify areas of the instructional materials that need improvement.
- Revise instruction
  To identify poor test items and to identify poor instruction
- Design and conduct summative evaluation

6.4.2.5 Suggested e-learning tools and methods

We suggest to implement a learning environment that refers to a combination of several teaching and learning tools:

- E-learning tools:

Massive open online course	Moodle	Long Tail Learning
Internet	Online training	On-demand training
Audio seminars	Podcasting	Wikis
Blogs	Collaboration tools/sites	
Mobiles applications	Social media	Portable course-ware formats
Cell phones as personal learning devices		Microblogging
Flip cameras	Youtube	Student oriented portfolio
Digital storytelling	Geotagging	Social bookmarking
Blended learning	Hybrid courses	Blackboard
Virtual world	Webcasting	Iphone mobile outreach
Small screen learning objects	Screen casting	e-Book textbooks
High definition video conferencing	Massive Open Online Courses (MOOCS)	
Social media for education	Open Source e-Portfolio software	
Cloud based Learning Management Systems (LMS)		Simulation

...

- Constructivist learning methods:

Cognitive Apprenticeship	Discovery Learning	Goal-based scenarios
Anchored instruction	Situated learning	Guided instruction
Cooperative learning	Problem-based learning	
Inquiry-Based Learning	Peer teaching	

…

6.5 Financial framework

The financing of the CdC GTB and CdC PAR have been organised through the logics of a mutualised training fund, based on an interprofessional agreement following the article 165 of the Luxembourg Labour law, obliging as a result the companies of the concerned crafts sector to invest a certain amount of the emoluments granted to their employees into a fund, which would then supply the training centres.

However, from several discussions with relevant ICT representatives in Luxembourg, it has emerged that this compulsory model can hardly be applied to the ICT sector. First of all, the ICT sector is with regards to continuing vocational training a mature sector, as it disposes of numerous and various training offers that are used by the ICT companies. Second, it will be uttermost difficult to decide what companies are belonging tot he ICT sector: only vendors and consulting forms, or also banks or even industries?

6.5.1 Financial models

Therefore, several other financing options should ne analysed in more depth:

- Financing by the Government

One of the obvious models of financing of a Virtual e-Skills Training Centre relates to Government financing. This option could be argued by the fact that the ICT plays a major role in the Luxembourg economy and will be even more relevant and strategic in the future. Similarly, as the Government supports already at this point strategically and financially the development of the ICT sector, especially in terms of ICT infrastructure (data high ways and data centres...), one could also consider investing in e-skills under the same terms: a government strategy to support institutions of continuing vocational training that enhance the development of e-skills.

However, it is doubtful that the Government is willing to subsidise one particular economic sector over another. So far, the Government has supported initiatives from the private sector in the field of continuous vocational training by co-financing infrastructure, as for example the training centre of the labour unions in Remich, the IFSB or the Centres de Compétences de l'Artisanat or others.

But as the Government is already co-financing vocational training through its legislation (loi 1999, loi congé individuel), it can be doubted that the Government will review its policy in that respect.

- Financing by ADEM

Of course, one of the routes for financing could be seen in the ADEM. It is true that ADEM has certain financial possibilities at its disposal, in conjunction with the Fonds pour l'Emploi, to finance vocational training measures. Furthermore, it would certainly be interesting for ADEM to elaborate an overall training plan for its target groups to develop new skills and thus reinforce their opportunities on the labour market.

Although such an initiative would be highly recommendable and useful with regard to the still high unemployment rate in Luxembourg, one must consider that one of the major reasons for unemployment in Luxembourg is related to the gap between the skills that are required form industry and the skills available with in the population of unemployed people.

It is doubtful that an e-skill initiative with unemployed people will provide the numbers and quality of trained people in a reasonable lapse of time to overcome significantly the e-skills gap in Luxembourg.

A cooperation with the ADEM makes sense in re-positioning unemployed ICT practioners, for unemployed people seeking job opportunities in the levels EQF 1-4 and is best-suited for enhancing the general capacities of jobseekers in relationship with social networks and co-related skills. The initiatives of Webforce 3 and of the Media House have already been identified in that perspective and a public impulse financing for developing a largely replicable integration scheme of such initiatives into the CDC ICT framework would definitely make sense

- Financing by European Funds

The financing of an e-skills training centre could be potentially co-financed via European funds, such as the European Social Fund. For that purpose, the e-skills sector, or one of its institutions, could conceive an appropriate project, ensure the necessary national counter-part funds (50%) and manage a potentially successful application.

However, the reliance upon European projects should only be considered as an upfront or impulse investment or as additional financial means for specific innovative projects or specific target-groups. It is not advisable to build a long term sustainable business strategy on European funds, as they are limited in time and complex in their management. Furthermore, one cannot be sure to prolongate European projects, and thus the risk exists that any given project dies with the funding.

The funding by European projects should only be considered as an additional funding for specific projects and developments, but not as a long term financial strategy.

- Financing by the ICT sector

Over the last years, several sectorial vocational training centres (financial sector, building and crafts in sectors, health sector, ...) have been created. Their major characteristic in terms of financial structuring relates to the fact that they have developed specific financing models: compulsory financing through trades agreements, through interprofessional agreements, membership financing, ... Furthermore, their financing relies on participation fees by participants and on national and/or European projects.

Their specific features are to be seen in the fact that their financial models are mixed models, as they rely on a mixture of financial sources to guarantee their sustainability and the variety of their offer.

But let's not forget that the ICT sector finances its vocational training for the moment all by itself, or in other terms:

First, the ICT sector is confronted by a large number of compulsory trainings to which their providers oblige them in order to guarantee that their third party services are up-to-date. For that reason, local ICT providers must follow norms, which they acquire via trainings provided for by the software or hardware providers. ICT providers finance these training costs by themselves and convey those in a generalised form to their customers.

Secondly, it can be assumed that the ICT sector is a heavy user of vocational training measures outside the normative range and is not limited to technical trainings, but also includes non technical-training, such as soft skills development, managerial, financial and administrative skills, etc. (second highest training effort of all sectors in 2013, INFPC, Formabref 7.2015[98]).

In any case, the ICT sector is actually financing its numerous training activities by itself and it will be eventually very difficult to conceive that this training effort could be delegated to public funding of any sort.

A mutualisation of existing training measures with large scale effects and a better adequation and a faster adaptation to the changing needs should nevertheless become both the driver and the economical backbone of the financing of the Virtual e-Sills Training Centre.

The setting up of specific training programmes on an individual, company or sectoral level could be another revenue stream, as well as the innovation monitoring and continuous adaption of the training schemes. Big vendors like Cisco, IBM, Oracle …. or the big four consulting companies as well as the specialist law firms could even act as sponsors: by increasing the number of competent employees in the ICT sector in Luxembourg, they can enlarge the size of the domestic market for their innovative solutions or their consultancy services.

[98] http://www.lifelong-learning.lu/bookshelf/documents/l_acces-a-la-formation-des-salarieés

6.5.2 Recommendation

We therefore suggest to establish a mixed financial model for the Virtual e-Skills Training Centre, in a three-stage approach:

- **First stage: Setting up of the centre**
  - Upfront investment of the shareholders
  - Public impulse financing
  - EU Funds (Interreg, FSE…)
- **Second stage: Operational phase**
  Creation of financial revenues through consulting activities such as:
  - Analysis and assessment of needs
  - Skills matching activities
  - Setting up of training plans
  - Coordination of trainings
  - Innovation monitoring
  - Fees from providers
  - Sponsoring
- **Third stage: Special projects**
  - Public funding (RDI….)
  - EU projects
  - Philanthropy
  - Fonds pour l'emploi
  - ADEM

In any case, it will essential to elaborate a concise business plan and budget in order to put the project on sound and sustainable grounds. The cost structure of the Centre should be very lean, as no expensive training modules have to be developed.

7 Action plan for of a Virtual e-Skills Training Centre

The following work packages have been identified in order to guarantee a quick set up of the CDC ICT:

- **Work package 1: Business Plan**
  - Define overall strategy of the Virtual e-Skills Training Centre.
  - Create Virtual e-Skills Training Centre as an institution under the GIE legal form.
  - Define cost structure and organigram
  - Define service packages to be offered.
  - Definition of strategic partnerships, membership and sponsoring packages
- **Work package 2: Educational Framework**
  - Elaborate precise ICT job profiles for different ICT professions and activities in different professional sectors in the form of a database.
  - Realise the adaptation and the fine-tuning of the EQF/e-cf/SFIA skills classification models
  - Define the specific skills frameworks
  - Elaborate a training needs assessment and evaluation system.
  - Identify and select ICT training providers and anayse their offer.
- **Work package 3: Implementation of infrastructure**
  - Extrapolate an e-skills framework from the job profiles in the form of a database.
  - Elaborate an e-skills assessment and evaluation system.
  - Create an observatory of ICT provision, national and international.
  - Implement an Internet based matching platform.
  - Initiate activities as an ICT matching, consulting and coaching institution.
- **Work package 4: expansion of project**
  - Realise technology and innovation watch
  - Set up *Fit for ICT* programme
  - Initiate grand coalition in ICT for Luxembourg
- **Work package 6: Marketing and stimulating of stakeholders and interested parties**
- **Work package 7: Launch of activities**

8 Conclusions

8.1 EU policy

As stated by the European Commission in its initiative **e-Skills for growth and jobs**[99] and as we have pointed out through our analysis of the trends and developemnts within the worldwide ICT market, competitiveness, innovation and job creation in European industry are increasingly being driven by the use of new information and communication technologies (ICT).

As a consequence, the workforce, may it be the ICT practitioner or the ICT specialist, the general worker and employee, or even puipils and students, they all must at one moment of their career and to different nut yet high level extends master these new technologies efficiently. Therefore, they must dispose of the necessary qualifications and skills, which supposes again that adequate, permeable, systematic and easily attainable education and training oppurtunities exist.

However, the actual situation on the ICT labur market seems to hint at a shortage or gap and at mismatches in the field of e-skills. This quantitative and qualitative disproportion between the offer and the demand on the ICT labour market risks eventually to hinder the development and progression of the European economies, while affecting negatively growth, competitiveness, innovation, employment and social cohesion in Europe, and even enlarge so so-called digital divide between people and between countries.

As the new ICT (and others) technologies develop at a very fast pace, it is essential for all economies that wish to play an active role in this area to make the required e-skills available adequately, i.e. in terms of time and of space, to all concerned players and persons.

These e-skills do not only need to be developed, but also to be updated constantly and expanded systematically to other realms of skills.

This desiderata then needs adequate support measures in the framework of wider policies and in terms of education, training, research and development, as neither the industry nor the employees ought to be left alone in this complexity.

In order to confont these challenges, the European Union has set up a series of policies, strategies and action programmes on the topic of e-skills that are documented in different publications.[100] In particuler, the European Commission has launched to further initiatives, the **European e-Competence Framework**[101] and the **The Grand Coalition for Digital Jobs**[102], which constitutes a multi-stakeholder partnership that is meant to facilitate collaboration between businesses, education providers, and public and private actors to attract young people into ICT education, and to retrain unemployed people.

8.2 Luxembourg policy

It is without any doubt that the European challenges are also valid for the situation in Luxembourg and that a similar policy is also needed for the Grand-Duchy. Of course, Luxembourg would not have appeare on the Europan or even worldwide ICT map, if its different Governements had not acknowledge the urgency of the situation. Therefore, a series of initiative have been launched over the recent years, as we have described them in the relevant chapter: heavy investment in high level ICT infrastructure, the launching of Digital Lëtzeburg or the recent inititiave of ICT Luxembourg, etc.

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[99] http://ec.europa.eu/growth/sectors/digital-economy/e-skills/index_en.htm
[100] Digital Agenda for Europe
e-Skills for the 21st Century
Competitiveness and Innovation Framework Programme (CIP)
Competitiveness of Enterprises and Small and Medium-sized Enterprises (COSME)
[101] http://www.ecompetences.eu/
[102] https://ec.europa.eu/digital-agenda/en/grand-coalition-digital-jobs-0
e-Skills for Jobs
e-Skills for Jobs High-Level Conference
e-Skills for Jobs Grand Event

However, these intiatives need to be further developed in the near future in order to keep pace with the actual evolution, preceding even trends and developments in certain areas.

- **Necessity to elaborate a long term national ICT vision and strategy**

In order to be successful, however, Luxembourg needs to further develop its vision and strategy in the field of ICT (and beyond) and for that reason we recommend that this overall strategic vision and implementation should be organised on a larger scale under the auspices of the Luxembourg Government and in conjuntion with the ICT stakeholders in Luxembourg.

While being perfectly aware of the real political situation of the country, we nevertheless think that it would be a good idea to have a very close look at the strategic vision of **Singapur**[103], developed by its Economic Development Board (EDB) representing the lead government agency that plans and executes economic strategies that enhance Singapore's position as a global hub for business, investment and talent. It would be worth while thinking about establishing such an institution for Luxembourg as well.

- **Necessity to review the structure of the ICT stakeholders**

But for once in Luxembourg, the relevant ICT and other economic stakeholders, representative bodies, players and actors should overcome their individualistic or even atomistic attitudes of defending permanently and vigourously their own particular interests and opinions against other national stakeholders. Instead, they should strive to come up with new ideas and new policies – and would thus not need to rely on foreign expertise that risks to be outdated by the time it reaches Luxembourg.

It seems that Luxembourg is in the presence of too many players, actors and institutions active in representing the ICT sector in its diverse forms, but that in the end, the whole sector does not speak with one voice, does not have an overall and accepted strategy and furthermore has no professional back office to implement this (not yet commonly approved) strategy.

For this purpose, Luxembourg needs to set up one strong professional steering committee that can act fast and consequently, and that can make policy proposals that are being implemented practically without hesitation.

But also for this purpose, Luxembourg should review its approach towards managing its ICT sector. As can be seen from our analysis of the ICT stakeholders in Luxembourg, there are very many (too many?) institutions that indiviually do not have the means or resources, nor are they organized in a sufficiently professional manner in order to develop and implement such strategies. In order to elaborate and implement a national ICT vision and strategy, Luxembourg needs to create a very efficient development and collaboration scheme between all actors, that is organized professionally and that disposes of all the means necessary – even under the risk hat existing institutions should be merged into larger, stronger and more proactive institutions. The Luxembourg ICT eco-system is simply too complex and too multi-layered to be efficient and proactive. One should reflect about the slogan *less is more* in this context

And, it will be necessary to confide the role of this *e-leadership* to a charismatic personality that is able to make things go ahead.

- **Necessity to establish a real Luxembourg grand coalition for and by all ICT stakeholders**

Luxembourg would therefore need not only a grand coalition for Digital Jobs (as proposed by the European Commission), but a multi-stakeholder partnership to tackle the digital challenges with which Luxembourg is confronted across all industry sectors.

[103] https://www.edb.gov.sg/content/edb/en/about-edb/our-strategy/mission-vision.html

8.3 e-Skills policy

As a first step and in order to implement at least on the level of e-skills a national grand coalition, it is suggested by this study to create a **Virtual e-Skills Training Centre (Centre de compétences ICT, Luxembourg Institute for Digital Education and Training LIDIET)** which combines a series of functionalities in order to structure, systemize and professionalize the Luxembourg ICT vocational training market market.

In the preceding chapters, we have largely described the roles and functions that we want to attribute to this institution.

But furthermore, this institution could also play the role of an **operator of the Luxembourg grand coalition for the ICT sector**, assembling and managing under the auspices of the Luxembourg Government the relevant stakeholders.

The policy outlined for the Virtual e-Skills Training Centre is meant to contribute to the development of Luxembourg as an ICT hub, at least on the level of initial and continuing vocational training. The Virtual e-Skills Training Centre is meant to be more than a training provider, it should also function as an initiator, facilitator, launcher, coordinator and producer of new activities, products and services that should contribute thorougly and sustainably to the development and enhancement of Luxembourg's ICT model.

For that reason, the Virtual e-Skills Training Centre wishes and needs to collaborate fruitfully (and without the attidude of competition or ownership) with all concerned actors, ranging from the Government, ministries, semi-public institutions, representative bodies, ustomers and providers, as well as the interested and concerned individuals, in ordert o achieve this common goal of maintaining and expanding Luxembourg on the international ICT map.

Therefore, the Virtual e-Skills Training Centre has as an objective to develop and implement all the necessary infrastructure, products and services needed at least in the framewrok of initial and continuing vocational training, and this on the basis of scientifically sound concepts, of professionalism and high quality acievements, of practicality and viability.

In other words:

Luxembourg has been constructing over the recent years a great deal of physical infrastructure with performant Internet highways, state-of-the-art data centres and hubs with top security standards, …

<u>But the first question is: What cars will drive on these highways?</u>

In order to answer this question, there needs to be a second phase.

Therefore, Luxembourg also has to build appropriate cars that can run on these Internet highways.

For that reason, Luxembourg needs to produce permanently new ICT solutions, services and products through established companies and new start-up initiatives.

<u>And the second question is: Who will drive these cars on these highways?</u>

In order to answer this question, there needs to be a third phase.

Therefore, Luxembourg needs to attract potential drivers nationally and internationally and to train thm initially and continuously in order to drive these new cars on these new highways efficiently and productively.

For that reason, Luxembourg needs to create new driving schools with eminent trainers and teachers that teach people how to drive better and more securely.

We wish to believe that the proposed Virtual e-Skills Training Centre will be able to become the mastermind of the ICT driving schools.

9 Bibliography

Ant, M.; Nimmerfroh, M.C. & Reinhard, C. (2013). *Effiziente Kommunikation*. Berlin: Spinger.
Arbesman, S. (2013). *The Half-Life of Facts*. London: Aurum.
Bauerlein, M. (2011). *The digital divide*. New York: Tarcher/Penguin.
Brown, M. (2014). *Data Mining For Dummies*. Hoboken, NJ: Wiley.
Brynjolfsson, E. & McAfee, A. (2014). *A Second Machine Age: Work, Progress, and Prosperity in a Time of Brilliant Technologies*. New York: Norton.
Buckminster Fuller, R. (1981). *Critical Path*. New York: St Martin's Press.
Campbellkelly, M. et al. (2013). *Computer: A History of the Information Machine*. 3rd ed. Oulder: Westview.
Carr, N. (2004). *Does IT Matter? Information Technology and the Corrosion of Competitive Advantage*. Cambridge (MASS): HBS Publishing Corporation.
Ceruzzi, P.E. (2003). *A History of Modern Computing*. 2nd ed. Boston (Mass.): MIT Press.
European Commission. (2014). *Digital agenda for Europe*. Luxembourg: Publications Office of the European Union.
Greengard, S. (2015). *The Internet of Things*. Boston: MIT Press.
Händeler, E. (2011). *Kondratieffs Gedankenwelt - Die Chancen im Wandel zur Wissensgesellschaft*. 5. vollst. überar. Aufl. Moers: Marlon.
Hüsing, T. & Korte, W.B. (2010). *Evaluation of the implementation of the communication of the European Commission E-skills for the 21st century*. Bonn: Empirica.
ICT (2014). Development Trends - Embracing the Era of Mobile-ICT ZTE COPORATION
IDC. (2014). ICT trends 2020 – Main trends for information and communication technologies (ICT) and their implications for e-Leadership skills.
ITU (2014). *Measuring the Information Society. Report 2014*. Geneva: ITU.
Kurzweil, R. (2005). *The Singularity Is Near*. New York: Viking.
Latour, B. (2005). *Reassembling the Social: An Introduction to Actor-Network-Theory*. Oxford: Oxford Univerity Press.
Lethbridge, L. (2001). *Ada Lovelace - The computer wizard of the victorian England*. London: Faber&Faber.
Luskin, B. (2010). Think "Exciting": E-Learning and the Big "E". *Educause Review Online*.
Mayer-Schönberger, V. & Cukier, K. (2013). Big Data: A Revolution That Will Transform How We Live, Work and Think. New York: Houghton, Mifflin, Harcourt.
McLaughlin, S. et al (2014). *e-SKILLS: the international dimension and the impact of globalization*. European Commission.
Moore, G.E. (1965). Cramming more components onto integrated circuits. *Electronics*, 38, 8, p. 114–117.
Neumann, J.v. (1958/2000). *The computer and the brain*. New Haven: Yale University Press.
OECD. (2002). *Measuring the Information Economy*. Paris: OECD.
OECD. (2011). *OECD Guide to Measuring the Information Society 2011*. Paris: OECD.
Papert, S. (1993). *Mindstorms: Children, Computers, and Powerful Ideas*. 2nd ed. New York: Perseus.
Perrenoud, P. (2001). *Construire un référentiel de compétences pour guider une formation professionnelle*. Genève: Université de Genève.
Schiller, R. (2015). *Irrational Exuberance*. 3rd ed. Princeton: Princeton University Press.
Skinner, B.F. (1958). Teaching machines. *Science*, 128 (3330), 969-977.
Swade, D. (2001). *The Difference Engine: Charles Babbage and the Quest to Build the First Computer*. New York: Viking.
Turing, A. (1937). On Computable Numbers, with an Application to the Entscheidungsproblem. In *Proceedings of the London Mathematical Society*. 42, 230–265.
Wooldridge, A. (2015). *The Great Disruption: How business is coping with turbulent times*. London: The Economist.
Dick, W.; Carey, L. & Carey, J.O. (2005). *The Systematic Design of Instruction*. 6th ed. Boston: Allyn & Bacon.

10 Annexes

10.1 ICT job profiles

10.1.1 European ICT professional profiles

10.1.1.1 Example of a job profile

Profile title	ACCOUNT MANAGER (1)		
Summary statement	Senior focal point for client sales and customer satisfaction.		
Mission	Builds business relationships with clients to facilitate the sale of hardware, software, telecommunications or ICT services. Identifies opportunities and manages sourcing and delivery of products to customers. Has responsibility for achieving sales targets and maintaining profitability.		
Deliverables	Accountable • Sale	Responsible • Business Relationship	Contributor • Sales Forecast • Technical proposal • Production Forecast
Main task/s	• Maintain overall customer satisfaction with products and/or services • Identify opportunities to propose new products or services to client(s) • Be the primary contact point for client executive management • Deliver value added presentations related to products and services to customer executive management • Lead negotiations to establish profitable contracts with client(s) • Maintain and enhance business relationships		
e-competences (from e-CF)	D.5. Sales Proposal Development	Level 4	
	D.7. Sales Management	Level 5	
	E.1. Forecast Development	Level 3	
	E.4. Relationship Management	Level 4	
	D.6. Channel Management	Level 4	
KPI area	Sales quota achievement		

10.1.2 Internet professions by the Portail des Métiers de l'Internet

Programmation et développement
Architecte web
Développeur / animateur Flash
Développeur multimédia
Développeur web
Développeur web mobile
Directeur de produit Internet
Gestionnaire de base de données
Intégrateur Web
Webdesigner

Production et gestion de contenu
Animateur de Communauté (Community Manager)
Architecte de l'information
Assistant de valorisation des usages numériques responsables
Assistant de valorisation numérique du territoire
Chargé de production vidéo
Consultant en référencement naturel
Consultant en référencement payant
Consultant SMO
Documentaliste
Gestionnaire de base de données
Gestionnaire de documents audiovisuels
Gestionnaire des médias sociaux
Illustrateur 3D
Journaliste en ligne
Knowledge manager
Modérateur
Rédacteur web
Responsable éditorial online
Responsable emailing
Veilleur stratégique
Webmestre

Interfaces et creation numérique
Chargé de production vidéo
Designer d'interaction
Designer sonore
Designer web mobile
Développeur / animateur Flash
Développeur multimédia
Directeur artistique Web
Ergonome Web
Graphiste Web
Illustrateur 3D
Webdesigner

Infrastructures et réseaux
Administrateur réseaux
Architecte réseaux
Architecte web
Consultant IT
Consultant SaaS
Expert en cybersécurité
Forgeur Numérique - #EAVNUM
Gestionnaire de base de données
Ingénieur réseaux
Technicien réseau

Formation et assistance
Animateur de Communauté (Community Manager)
Animateur multimédia
Assistant de formation aux usages mobiles - #EAVNUM
Chef de projet e-formation
Consultant IT
Consultant SaaS
Formateur TIC
Régisseur Multimédia - #EAVNUM
Responsable de laboratoire de Fabrication Numérique (FabManager)
Spécialiste de l'accessibilité numérique

Conception et gestion de projet
Architecte de l'information
Architecte web
Chargé de production vidéo
Chef de projet de jeux web
Chef de projet e-CRM
Chef de projet e-formation
Chef de projet fonctionnel web
Chef de projet technique web
Chef de projet web mobile
Concepteur de niveaux de jeux web
Consultant en maîtrise d'ouvrage web
Consultant IT
Consultant SaaS
Correspondant Informatique et Libertés (CIL)
Designer d'interaction
Designer web mobile
Directeur de produit Internet
Ergonome de jeux web
Ergonome Web
Game designer web / Concepteur de jeux web
Juriste Internet
Responsable qualité web
Spécialiste de l'accessibilité numérique
Webdesigner

Communication et marketing

Acheteur d'espaces publicitaires web
Animateur de Communauté (Community Manager)
Assistant Vidéoludique - #EAVNUM
Chargé de communication Web
Chargé des RP digitales
Chef de projet e-CRM
Consultant en référencement naturel
Consultant en référencement payant
Consultant SMO
Consultant web analytique
Directeur de produit Internet
Gestionnaire des médias sociaux
Ingénieur commercial Web
M-marketeur
Média planner
Rédacteur web
Responsable de l'affiliation
Responsable du trafic (Traffic manager)
Responsable emailing
Vendeur d'espaces publicitaires web
Webmarketeur
Webmestre

10.1.2.1 Exemple d'un profil

Développeur web (Analyste-programmeur, Développeur back office, Développeur back-end)

Le développeur web effectue la réalisation technique et le développement informatique d'un site web. A l'aide ducahier des charges réalisé par le chef de projet, le développeur web programme les fonctionnalités qui correspondent aux besoins du client pour son site web. Le développeur web peut exercer dans une ESN (Entreprise de Services du Numérique), dans une agence Web, en tant que travailleur indépendant ou directement chez le client. Certains développeurs web sont également bénévoles dans le cadre de projets liés à l'informatique libre.

Familles de métiers : Programmation et développement
Mots-clés : analyse de besoins, programmation, qualité, spécification technique, veille

- Présentation

Le **développeur web** est un informaticien qui réalise l'ensemble des fonctionnalités d'un site internet. Le profil du développeur web est celui d'un technicien ou d'un ingénieur capable d'analyser les besoins des clients consignés au préalable dans un cahier des charges par le chef de projet. Il préconise et met en oeuvre une solution technique pour concevoir des sites sur mesure ou adapter des solutions techniques existantes.

A ce titre, le développeur est en charge de :

- L'analyse des besoins
- Le choix de la solution technique
- Le développement de toutes les fonctionnalités techniques du site
- Le respect des bonnes pratiques de codage
- Les tests et la validation des fonctionnalités développées

De façon complémentaire, il participe aussi à :

- La formation du client lorsque le site internet lui est livré
- Support technique tout au long de la vie du site internet
- Corrections des problèmes remontés par le client

Après quelques années d'expérience, le développeur web peut évoluer vers le poste de directeur technique ce qui l'amènera à asseoir son niveau d'expertise en développement et éventuellement à encadrer une équipe de développeurs.

- Missions

Lors de la phase de conception, le développeur web analyse le projet qui lui est confié, en fonction des besoins des utilisateurs, consignés dans un cahier des charges techniques. Il étudie les étapes de fonctionnement du site, puis détermine une solution technique. Il peut alors décider de réaliser l'ensemble du site à partir de zéro, ou bien choisir d'adapter une solution existante de type Framework ou CMS (Content Management System).

Dans le premier cas, il devra concevoir et réaliser dans sa totalité l'architecture technique du site alors que dans le deuxième cas il se chargera principalement d'écrire ou d'adapter une ou plusieurs parties de la solution technique retenue. Pour ce faire, il programme les lignes de codes informatiques. Ensuite, il participe aux phases d'essai, essentielles pour tester les fonctionnalités développées.

Enfin, il réalise les notices techniques d'installation, ainsi que les guides destinés aux utilisateurs. Il est parfois amené à apporter à ceux-ci un soutien technique ou à les former à l'utilisation de l'application. En l'absence de technicien de maintenance en informatique, il peut assurer lui-même le suivi technique du site.

- Domaine et périmètre d'intervention

Le développeur est rattaché de façon fonctionnelle au chef de projet technique. Il intervient sur l'ensemble des fonctionnalités techniques du site.

Sous la houlette de ce dernier, il travaille sur des projets toujours différents, dans des secteurs d'activité très variés : télécommunications, transports, banque, assurance, industrie automobile, commerce ou encore grande distribution.

Les nouveaux CMS facilitent l'écriture des sites web et font évoluer l'activité du développeur vers plus d'analyse et moins de programmation. Avec l'usage croissant de solutions existantes, il s'implique davantage dans des opérations de paramétrage et de retouche. Parallèlement, la durée de vie des sites se raccourcit. Confronté à de multiples changements, le développeur doit sans cesse s'adapter.

- Activités & tâches

Activité 1: Analyse technique
Tâches

Identifier comprendre et analyser les besoins du client :

- Appréhender les besoins client
- Rédiger les spécifications détaillées

Benchmark des solutions existantes :

- Lister les fonctionnalités demandées dans le cahier des charges
- Répertorier les solutions existantes
- Vérifier pour chaque fonctionnalité si elle existe ou non dans les solutions répertoriées

Apporter son avis sur la solution technique la plus pertinente :

- Réalisation totale du site
- Utilisation d'une solution existante

Activité 2: Conception
Tâches
Structurer la base de données :

- Ajout éventuel de tables si utilisation d'une solution existante
  ou
- Création de l'ensemble des tables qui contiendront les données

Architecture technique du site :

- Prise en main de l'architecture de la solution retenue si utilisation d'une solution existante
  ou
- Création de l'architecture

Activité 3: Programmation
Tâches
Développement :

- Respect des bonnes pratiques
- Choix du langage utilisé si le site est totalement développé
  ou
- Réalisation des évolutions ou adaptation sur la solution retenue

Activité 4: Tests et Validation
Réalisation d'un ensemble de tests :

- Tests unitaires pour vérifier chaque fonctionnalité
- Tests d'intégration pour vérifier que l'ensemble des fonctionnalités développées fonctionnent bien ensemble

Validation exhaustive du site :

- Ecrire un plan de test qui permet de valider l'ensemble des fonctionnalités attendues
- Conduite des tests de validation

Activité 5: Support technique
Tâches
Réalisation de documentation :

- Documentation technique
- Documentation fonctionnelle

Suivre l'évolution du site dans la durée :

- Corrections des problèmes remontés
- Dépannage des utilisateurs

Activité 6: Veille technologique
Tâches
Veille sur la technologie existante

- Evolution des langages de programmation
- Evolution des solutions techniques existantes
- Vérifier la pérennité des technologies existantes

Veille sur les nouvelles technologies :

- Nouveaux langages de programmation
- Nouvelles solutions techniques
- Nouveaux outils

* Compétences

Savoirs
Compréhension des contraintes du projet :

- Délais

- Budget
- Fonctionnalités attendues

Conception et développement de site :

- Techniques de conception, modélisation et architecture d'applications
- Méthodes, normes, langages et outils de développement
- Langages de programmation web
- Algorithmique
- Environnement de développement
- Culture générale informatique
- Environnement web et XML
- Normes et procédures de sécurité

Savoir-faire

Réaliser une analyse des besoins fonctionnels du projet et préconiser une solution technique
Maîtrise des langages utilisés pour le développement web :

- PHP
- SQL
- Java
- ASP

Maîtrise opérationnelle des outils suivants :

- CMS (Content Management System)
- Framework
- Outils d'édition de code

Solutionner les problèmes détectés dans un site :

- Trouver l'origine des problèmes
- Effectuer les corrections nécessaires
- Mise en ligne de ces corrections sans interrompre le fonctionnement du site

Savoir-être

Autonomie :

- Assimilation des objectifs du projet
- Respect des délais
- Rapidité d'exécution

Adaptabilité :

- Polyvalence
- Force de proposition
- Compréhension des métiers des autres membres de l'équipe

Capacité à travailler en équipe :

- Écoute
- Ouverture aux problématiques des autres

Auto-formation continue :

- Nouveaux concepts de programmation
- Evolutions / Nouveaux langages de programmation web
- Evolutions / Nouvelles solutions techniques (CMS et Framework)

10.1.3 G3 Web Skills Profiles

Exemple d'un profil

Profile WSP-G3-001. Web Community Manager

Summary statement	Professional position in the digital Marketing & Communication sector that manages virtual communities on the Web.
Mission	The Web Community Manager creates and helps strengthen relationships among members of a Web virtual community and between the community and the customer organization through effective communication within the group; in particular he or she promotes, controls, analyses, and evaluates the conversations that take place on various Web resources (Websites, blogs, social networks). He or she builds and manages relationships with online stakeholders. He or she may work as a freelancer, for specialized Web marketing agencies, or as part of an organization. In the latter case, the term Internal Community Manager is also often used in English. He or she is also known as a Community Manager.
Deliverables	Accountable (A) • Strategic community management plan. Responsible (R) • Document describing topic trends and related critical points and opportunities. Contributor (C) • Report on the produced assets and results obtained.
Main tasks	• Control, evaluate, and manage online conversations, always using the appropriate language for the medium used • Promote new topics for conversation/connection • Stimulate the productive involvement of users and stakeholders • Assume a role of institutional representative within the community • Evaluate online sentiment • Create periodic reports.
E-CF competences	• B.1. Application Development: Levels e-2, e-3. • C.1. User Support: Levels e-2, e-3. • D.12. Digital Marketing: Levels e-2, e-3. • E.4. Relationship Management: Level e-3.
Skills / Knowledge Technical	Technical • Unconventional marketing. • Organization of online events (e.g. Chat, Webcast). • Technical Writing/Reporting. • Copyright management on the Internet. • Web content accessibility. • Marketing. • Web analytics. • Effective communication, mediation. Informatics • Mark-up and style sheets (e.g. XHTML, HTML and CSS). • Web publication tools (e.g. CMS, Blog and Editor). • Use of the primary Social Networks. Strengthening • Public relations. • Organization of offline events (e.g. Meeting, Camp).
Key Performance Indicators (KPIs)	• Audience engagement. • Advocacy impact. • Satisfaction score. • Topic trends.
Qualification / Certifications (this section is informative)	• Master's degree/Special training courses on the characteristics of Web communication and/or online community management. • University degree in: Communication sciences and technologies, Public and corporate communication, Journalism.
Attitudes (non ICT) (this section is informative)	Interpersonal and Organizational • Virtual group management. • Active listening and empathy. • Conflict management/Balance and stress management. • User/customer focus. • Problem solving. Linguistic • Good knowledge of the national language or the language used by the working group - minimum level: B1 QCER. • Good knowledge of spoken and written English - minimum level: B2 QCER.
Relationships / Reporting line (this section is informative)	Interacts with: • Web Account Manager • Search Engine Expert • Web Advertising Manager

• Web Content Specialist
• Web Accessibility
Expert
• Mobile Application Developer
• Reputation Manager
Reports to:
• Digital Strategic Planner

10.2 EQF Framework

10.2.1 Description of EQF levels

EQF Level	Knowledge	Skills	Competence
Level 1	Basic general knowledge	Basic skills required to carry out simple tasks	Work or study under direct supervision in a structured context
Level 2	Basic factual knowledge of a field of work or study	Basic cognitive and practical skills required to use relevant information in order to carry out tasks and to solve routine problems using simple rules and tools	Work or study under supervision with some autonomy
Level 3	Knowledge of facts, principles, processes and general concepts, in a field of work or study	A range of cognitive and practical skills required to accomplish tasks and solve problems by selecting and applying basic methods, tools, materials and information	Take responsibility for completion of tasks in work or study; adapt own behaviour to circumstances in solving problems
Level 4	Factual and theoretical knowledge in broad contexts within a field of work or study	A range of cognitive and practical skills required to generate solutions to specific problems in a field of work or study	Exercise self-management within the guidelines of work or study contexts that are usually predictable, but are subject to change; supervise the routine work of others, taking some responsibility for the evaluation and improvement of work or study activities
Level 5[1]	Comprehensive, specialised, factual and theoretical knowledge within a field of work or study and an awareness of the boundaries of that knowledge	A comprehensive range of cognitive and practical skills required to develop creative solutions to abstract problems	Exercise management and supervision in contexts of work or study activities where there is unpredictable change; review and develop performance of self and others
Level 6[2]	Advanced knowledge of a field of work or study, involving a critical understanding of theories and principles	Advanced skills, demonstrating mastery and innovation, required to solve complex and unpredictable problems in a specialised field of work or study	Manage complex technical or professional activities or projects, taking responsibility for decision-making in unpredictable work or study contexts; take responsibility for managing professional development of individuals and groups
Level 7[3]	Highly specialised knowledge, some of which is at the forefront of knowledge in a field of work or study, as the basis for original thinking and/or research. Critical awareness of knowledge issues in a field and at the interface between different fields	Specialised problem-solving skills required in research and/or innovation in order to develop new knowledge and procedures and to integrate knowledge from different fields	Manage and transform work or study contexts that are complex, unpredictable and require new strategic approaches; take responsibility for contributing to professional knowledge and practice and/or for reviewing the strategic performance of teams
Level 8[4]	Knowledge at the most advanced frontier of a field of work or study and at the interface between fields	The most advanced and specialised skills and techniques, including synthesis and evaluation, required to solve critical problems in research and/or innovation and to extend and redefine existing knowledge or professional practice	Demonstrate substantial authority, innovation, autonomy, scholarly and professional integrity and sustained commitment to the development of new ideas or processes at the forefront of work or study contexts including research

10.2.2 Synoptical table of e-CF job profiles

Competence area	***ICT family***	***ICT Profile***	***Competences***	***e-1***	***e-2***	***e-3***	***e-4***	***e-5***
Plan	Design	Business Analyst	IS and Business Strategy Alignment					
		Systems Analyst	Service Level Management					
		Enterprise Architect	Business Plan Development					
		Systems Architect	Product/Service Planning					
			Architecture Design Specifies					
			Application Design Analyses					
			Technology Trend Monitoring					
			Sustainable Development					
			Innovating					
Competence area	***ICT family***	***ICT Profile***	***Competences***					
Build	Development	Developer	Application Development					
		Digital Media Specialist	Component Integration					
		Test Specialist	Testing					
			Solution Deployment					
			Documentation Production					
			Systems Engineering					
Competence area	***ICT family***	***ICT Profile***	***Competences***					
Run	Service and Operation	Database Administrator	User Support					
		Systems Administrator	Change Support					
		Network Specialist	Service Delivery					
		Technical Specialist	Problem Management					
		Service Desk Agent						
Competence area	***ICT family***	***ICT Profile***	***Competences***					
Enable		ICT Consultant	Information Security Strategy Development					
		Account Manager	ICT Quality Strategy Development					
		ICT Trainer	Education and Training Provision					
		ICT Security Specialist	Purchasing					
			Sales Proposal Development					
			Channel Management					
			Sales Management					
			Contract Management					
			Personnel Development					
			Information and Knowledge Management					
			Needs Identification					
			Digital Marketing					

Competence area	*ICT family*	*ICT Profile*	*Competences*					
Manage	Business management	Business Information Manager	Forecast Development					
		Chief Information Officer	Project and Portfolio Management					
		ICT Operations Manager	Risk Management					
	Technical management	Quality Assurance Manager	Relationship Management					
		ICT Security Manager	Process Improvement					
		Project Manager	ICT Quality Management					
		Service Manager	Business Change Management					
			Information Security Management					
			IS Governance					

10.3 E-skills profiles

10.3.1 European e-Competences Framework 3.0[104]

- Plan

The first, which is titeld by the term “Plan” includes all planning measures. This means that all added competences are based on a strategy. In general planning is the systematic procedure for the development of aims and processes. The following comptences are the content of the group “Plan”.

	Competences	Definition
Plan	IS and Business Strategy Alignment	• Anticipates long term business requirements, influences improvement of organizational process efficiency and effectiveness • Determines the IS model and the enterprise architecture in line with the organization’s policy and ensures a secure environment • Makes strategic IS policy decisions for the enterprise, including sourcing strategies
	Service Level Management	• Defines, validates and makes applicable service level agreements and underpinning contracts for services offered • Negotiates service performance levels taking into account the needs and capacity of stakeholders and business
	Business Plan Development	• Addresses the design and structure of a business or product plan including the identification of alternative approaches as well as return on investment propositions • Considers the possible and applicable sourcing models • Presents cost benefit analysis and reasoned arguments in support of the selected strategy • Ensures compliance with business and technology strategies • Communicates and sells business plan to relevant stakeholders and addresses political, financial and organizational interests
	Product/Service Planning	• Analyses and defines current and target status • Estimates cost effectiveness, points of risk, opportunities, strengths and weaknesses, with a critical approach • Creates structured plans • Establishes time scales and milestones, ensuring optimisation of activities and resources • Manages change requests • Defines delivery quantity and provides an overview of additional documentation requirements • Specifies correct handling of products, including legal issues, in accordance with current regulations .
	Architecture Design Specifies	• Specifies, refines, updates and makes available a formal approach to implement solutions, necessary to develop and operate the IS architecture • Identifies change requirements and the components involved: hardware, software, applications, processes, information and technology platform • Takes into account interoperability, scalability, usability and security Maintains alignment between business evolution and

s-du-secteur-prive-en-2013.pdf

[104] CEN ICT Skills Workshop. European e-Competences Framework 3.0: A common European Framework for ICT Professionals in

	Competences	Definition
		technology developments
	Application Design Analyses	• Analyses, specifies, updates and makes available a model to implement applications in accordance with IS policy and user / customer needs • Selects appropriate technical options for application design, optimising the balance between cost and quality • Designs data structures and builds system structure models according to analysis results through modelling languages • Ensures that all aspects take account of interoperability, usability and security • Identifies a common reference framework to validate the models with representative users, based upon development models (e.g. iterative approach)
	Technology Trend Monotoring	• Investigates latest ICT technological developments to establish understanding of evolving technologies • Devises innovative solutions for integration of new technology into existing products, applications or services or for the creation of new solutions
	Sustainable Development	• Estimates the impact of ICT solutions in terms of eco responsibilities including energy consumption • Advises business and ICT stakeholders on sustainable alternatives that are consistent with the business strategy • Applies an ICT purchasing and sales policy which fulfills eco-responsibilities
	Innovating	• Devises creative solutions for the provision of new concepts, ideas, products or services • Deploys novel and open thinking to envision exploitation of technological advances to address business / society needs or research direction

- Build

The next table presents the competences, which require to the group “Build”. This includes measures and operations that have an observable result. The term “Build” in general, covers all measures, which serve to manufacture for something. Then the results of the manufacturing are passed on to the group “Run”. This shows that there exists a connection between the individual groups.

	Competences	Definition
Build	Application Development	• Interprets the application design to develop a suitable application in accordance with customer needs • Adapts existing solutions by e.g. porting an application to another operating system • Codes, debugs, tests and documents and communicates product development stages • Selects appropriate technical options for development such as reusing, improving or reconfiguration of existing components • Optimises efficiency, cost and quality. Validates results with user representatives, integrates and commissions the overall solution
	Component Integration	• Integrates hardware, software or sub system components into an existing or a new system • Complies with established processes and procedures such as, configuration management and package maintenance • Takes into account the compatibility of existing and new modules to ensure system integrity, system interoperability and information security • Verifies and tests system capacity and performance and

	Competences	Definition
		documentation of successful integration
	Testing	• Constructs and executes systematic test procedures for ICT systems or customer usability requirements to establish compliance with design specifications • Ensures that new or revised components or systems perform to expectation • Ensures meeting of internal, external, national and international standards, including health and safety, usability, performance, reliability or compatibility • Produces documents and reports to evidence certification requirements
	Solution Deployment	• Following predefined general standards of practice carries out planned necessary interventions to implement solution, including installing, upgrading or decommissioning •Configures hardware, software or network to ensure interoperability of system components and debugs any resultant faults or incompatibilities •Engages additional specialist resources if required, such as third party network providers. Formally hands over fully operational solution to user and completes documentation recording all relevant information, including equipment addresses, configuration and performance data
	Documentation Production	• Produces documents describing products, services, components or applications to establish compliance with relevant documentation requirements • Selects appropriate style and media for presentation materials • Creates templates for document-management systems • Ensures that functions and features are documented in an appropriate way • Ensures that existing documents are valid and up to date
	Systems Engineering	• Engineers software and / or hardware components to meet solution requirements such as specifications, costs, quality, time, energy efficiency, information security and data protection • Follows a systematic methodology to analyse and build the required components and interfaces • Builds system structure models and conducts system behavior simulation • Performs unit and system tests to ensure requirements are met

- Run

The table “Run” presents service-oriented activities. This group gets the results of the group “Build” and brings them on the market. The term “Run” presents that there are physical activities and that there exist directly contacts between other persons. For this reason the following competences include mostly supporting measures.

	Competences	Definition
Run	User Support	• Responds to user requests and issues, recording relevant information • Assures resolution or escalates incidents and optimises system performance in accordance with predefined service level agreements • Understands how to monitor solution outcome and resultant customer satisfaction
	Change Support	• Implements and guides the evolution of an ICT solution

	Competences	Definition
		• Ensures efficient control and scheduling of software or hardware modifications to prevent multiple upgrades creating unpredictable outcomes • Minimises service disruption as a consequence of changes and adheres to defined service level agreement • Ensures consideration and compliance with information security procedures
	Service Delivery	• Ensures service delivery in accordance with established service level agreements • Takes proactive action to ensure stable and secure applications and ICT infrastructure to avoid potential service disruptions, attending to capacity planning and to information security • Updates operational document library and logs all service incidents • Maintains monitoring and management tools (i.e. scripts, procedures) • Maintains IS services • Takes proactive measures
	Problem Management	• Identifies and resolves the root cause of incidents • Takes a proactive approach to avoidance or identification of root cause of ICT problems • Deploys a knowledge system based on recurrence of common errors • Resolves or escalates incidents • Optimizes system or component performance

- Enable

The term “Enable” includes that a person has sufficient knowledge and experience to implement ideas and concepts. These are actions and activities that form the core of the ICT sector. The associated competences enable a liquid process on the market. The group “Enable” ensures that the potential of the sector can be used and problems can be eliminated.

	Competences	Definition
Enable	Information Security Strategy Development	• Defines and makes applicable a formal organizational strategy, scope and culture to maintain safety and security of information from external and internal threats, i.e. digital forensic for corporate investigations or intrusion investigation • Provides the foundation for Information Security Management, including role identification and accountability • Uses defined standards to create objectives for information integrity, availability and data privacy
	ICT Quality Strategy Development	• Defines, improves and refines a formal strategy to satisfy customer expectations and improve business performance (balance between cost and risks) • Identifies critical processes influencing service delivery and product performance for definition in the ICT quality management system • Uses defined standards to formulate objectives for service management, product and process quality. Identifies ICT quality management accountability
	Education and Training Provision	• Defines and implements ICT training policy to address organizational skill needs and gaps • Structures, organizes and schedules training programmes and evaluates training quality through a feedback process and implements continuous improvement

Competences	Definition
	• Adapts training plans to address changing demand
Purchasing	• Applies a consistent procurement procedure, including deployment of the following sub processes: specification requirements, supplier identification, proposal analysis, evaluation of the energy efficiency and environmental compliance of products, suppliers and their processes, contract negotiation, supplier selection and contract placement • Ensures that the entire purchasing process is fit for purpose, adds business value to the organization compliant to legal and regulatory requirements
Sales Proposal Development	• Develops technical proposals to meet customer solution requirements and provide sales personnel with a competitive bid • Underlines the energy efficiency and environmental impact related to a proposal • Collaborates with colleagues to align the service or product solution with the organization's capacity to deliver
Channel Management	• Develops the strategy for managing third party sales outlets • Ensures optimum commercial performance of the value-added resellers (VARs) channel through the provision of a coherent business and marketing strategy • Defines the targets for volume, geographic coverage and the industry sector for VAR engagements and structures incentive programmes to achieve complimentary sales results
Sales Management	• Drives the achievement of sales results through the establishment of a sales strategy • Demonstrates the added value of the organization's products and services to new or existing customers and prospects • Establishes a sales support procedure providing efficient response to sales enquiries, consistent with company strategy and policy • Establishes a systematic approach to the entire sales process, including understanding customer needs, forecasting, prospect evaluation, negotiation tactics and sales closure
Contract Management	• Provides and negotiates contract in accordance with organizational processes • Ensures that contract and deliverables are provided on time, meet quality standards, and conform to compliance requirements • Addresses non-compliance, escalates significant issues, drives recovery plans and if necessary amends contracts. Maintains budget integrity • Assesses and addresses supplier compliance to legal, health and safety and security standards • Actively pursues regular supplier communication
Personnel Development	• Diagnoses individual and group competence, identifying skill needs and skill gaps • Reviews training and development options and selects appropriate methodology taking into account the individual, project and business requirements • Coaches and / or mentors individuals and teams to address learning needs
Information and Knowledge	• Identifies and manages structured and unstructured information and considers information distribution policies

	Competences	Definition
	Management	• Creates information structure to enable exploitation and optimization of information • Understands appropriate tools to be deployed to create, extract, maintain, renew and propagate business knowledge in order to capitalise from the information asset
	Needs Identification	• Actively listens to internal / external customers, articulates and clarifies their needs • Manages the relationship with all stakeholders to ensure that the solution is in line with business requirements • Proposes different solutions (e.g. make-or-buy), by performing contextual analysis in support of user centered system design • Advises the customer on appropriate solution choices • Acts as an advocate engaging in the implementation or configuration process of the chosen solution
	Digital Marketing	• Understands the fundamental principles of digital marketing • Distinguishes between the traditional and digital approaches • Appreciates the range of channels available • Assesses the effectiveness of the various approaches and applies rigorous measurement techniques • Plans a coherent strategy using the most effective means available • Understands the data protection and privacy issues involved in the implementation of the marketing strategy

- Manage

The last table presents the group “Manage”. Managing includes all leading tasks and operations. This group forms the frame of the ICT sector. The associated competences involve activities and operations that initialize improvements and developments of the sector. Moreover, the group “Manage” includes organizational and strategic measures.

	Competences	Definition
Manage	Forecast Development	• Interprets market needs and evaluates market acceptance of products or services • Assesses the organization’s potential to meet future production and quality requirements • Applies relevant metrics to enable accurate decision making in support of production, marketing, sales and distribution functions
	Project and Portfolio Management	• Implements plans for a programme of change • Plans and directs a single or portfolio of ICT projects to ensure coordination and management of interdependencies • Orchestrates projects to develop or implement new, internal or externally defined processes to meet identified business needs • Defines activities, responsibilities, critical milestones, resources, skills needs, interfaces and budget • Optimizes costs and time utilisation, minimizes waste and strives for high quality • Develops contingency plans to address potential implementation issues • Delivers project on time, on budget and in accordance with original requirements • Creates and maintains documents to facilitate monitoring of project progress
	Risk Management	• Implements the management of risk across information systems through the application of the enterprise defined risk

	management policy and procedure • Assesses risk to the organization's business, including web, cloud and mobile resources • Documents potential risk and containment plans
Relationship Management	• Establishes and maintains positive business relationships between stakeholders (internal or external) deploying and complying with organizational processes • Maintains regular communication with customer / partner / supplier, and addresses needs through empathy with their environment and managing supply chain communications • Ensures that stakeholder needs, concerns or complaints are understood and addressed in accordance with organizational policy
Process Improvement	• Measures effectiveness of existing ICT processes. Researches and benchmarks ICT process design from a variety of sources • Follows a systematic methodology to evaluate, design and implement process or technology changes for measurable business benefit • Assesses potential adverse consequences of process change
ICT Quality Management	• Implements ICT quality policy to maintain and enhance service and product provision • Plans and defines indicators to manage quality with respect to ICT strategy • Reviews quality measures and recommends enhancements to influence continuous quality improvement
Business Change Management	• Assesses the implications of new digital solutions • Defines the requirements and quantifies the business benefits • Manages the deployment of change taking into account structural and cultural issues • Maintains business and process continuity throughout change, monitoring the impact, taking any required remedial action and refining approach
Information Security Management	• Implements information security policy • Monitors and takes action against intrusion, fraud and security breaches or leaks • Ensures that security risks are analysed and managed with respect to enterprise data and information • Reviews security incidents, makes recommendations for security policy and strategy to ensure continuous improvement of security provision
IS Governance	• Defines, deploys and controls the management of information systems in line with business imperatives • Takes into account all internal and external parameters such as legislation and industry standard compliance to influence risk management and resource deployment to achieve balanced business benefit

10.3.1.1 e-CF

10.3.1.2 Example of the detailed description of one specific skill (e-CF):[105]

Dimension 1 e-Competence area	A. Plan
Dimension 2 e-Competence: Title + generic description	**A.1. IS and Business Strategy Alignment** Anticipates long term business requirements, influences improvement of organisational process efficiency and effectivenes. Determines the IS model and the enterprise architecture in line with the organisation's policy and ensures a secure environment. Makes strategic IS policy decisions for the enterprise, including sourcing strategies.
Dimension 3 e-Competence: proficiency levels e-1 to e-5, related to EQF levels 3 to 8	e-1: – e-2: – e-3: – e-4: Provides leadership for the construction and implementation of long term innovative IS solutions. e-5: Provides IS strategic leadership to reach consensus and commitment from the management team of the enterprise.
Dimension 4 Knowledge examples *Knows/aware of/ familiar with*	K1 business strategy concepts K2 trends and implications of ICT internal or external developments for typical organisations K3 the potential and opportunities of relevant business models K4 the business aims and organisational objectives K5 the issues and implications of sourcing models K6 the new emerging technologies (e.g.distributed systems, virtualisation, mobility, data sets) K7 architectural frameworks K8 security
Skills examples *Is able to*	S1 analyse future developments in business process and technology application S2 determine requirements for processes related to ICT services S3 identify and analyse long term user/customer needs S4 contribute to the development of ICT strategy and policy, including ICT security and quality S5 contribute to the development of the business strategy S6 analyse feasibility in terms of costs and benefits S7 review and analyse effects of implementations S8 understand the impact of new technologies on business (e.g. open/big data, dematerialisation opportunities and strategies) S9 understand the business benefits of new technologies and how this can add value and provide competitive advantage (e.g. open/big data, dematerialisation opportunities and strategies) S10 understand the enterprise architecture S11 understand the legal & regulatory landscape in order to factor into business requirements

all industry sectors, S.12 ff.

[105] /profiletool.ecompetences.eu/" http://profiletool.ecompetences.eu/
http://ecompetences.eu/wp-content/uploads/2014/02/European-e-Competence-Framewor

10.3.1.3 European e-CF and EQF level correspondance table

EQF levels	EQF Levels descriptions	e-CF Levels	e-CF Levels descriptions	Typical Tasks	Complexity	Autonomy	Behaviour
8	Knowledge at the most advanced frontier, the most advanced and specialised skills and techniques to solve critical problems in research and/or innovation, demonstrating substantial authority, innovation, autonomy, scholarly or professional integrity.	e-5	**Principal** Overall accountability and responsibility; recognised inside and outside the organisation for innovative solutions and for shaping the future using outstanding leading edge thinking and knowledge.	IS strategy or programme management	Unpredictable – Unstructured	Demonstrates substantial leadership and independence in contexts which are novel requiring the solving of issues that involve many interacting factors.	Conceiving, transforming, innovating, finding creative solutions by application of a wide range of technical and/or management principles
7	Highly specialised knowledge, some of which is at the forefront of knowledge in a field of work or study, as the basis for original thinking, critical awareness of knowledge issues in a field and at the interface between different fields, specialised problem-solving skills in research and/or innovation to develop newknowledge and procedures and to integrate knowledge from different fields, managing and transforming work or study contexts that are complex, unpredictable and require new strategic approaches, taking responsibility for contributing to professional knowledge and practice and/or for reviewing the strategic performance of teams.	e-4	**Lead Professional/ Senior Manager** Extensive scope of responsibilities deploying specialised integration capability in complex environments; full responsibility for strategic development of staff working in unfamiliar and unpredictable situations. contributing to professional knowledge andpractice and/or for reviewing the strategic performance of teams.	IS strategy/Holistic solutions		Demonstrates leadership and innovation in unfamiliar, complex and unpredictable environments. Addresses issues involving many interacting factors.	
6	Advanced knowledge of a field of work or study, involving a critical understanding of theories and principles, advanced skills, demonstrating mastery and innovation in solving complex and unpredictable problems in a specialised field of work or study, management of complex technical or professional activities or projects, taking responsibility for decision-making in unpredictable work or study contexts, for continuing personal and group professional development.	e-3	**Senior Professional/ Manager** Respected for innovative methods and use of initiative in specific technical or business areas; providing leadership and taking responsibility for team performances and development inunpredictable environments.	Consulting	Structured –	Works independently to resolve interactive problems and addresses complex issues. Has a positive effect on team performance.	Planning, making decisions, supervising, building teams, forming people, reviewing performances, finding creative solutions by application of specific technical or business knowledge/skills.
5	Comprehensive, specialised, factual and theoretical knowledge within a field of work or study and an awareness of the boundaries of that knowledge, expertise in a comprehensive range of cognitive	e-2	**Professional** Operates with capability and independence in specified boundaries and may supervise others in this environment; conceptual and abstract	Concepts/	unpredictable	Works under general guidance in an environment where unpredictable change	Designing, managing, surveying, monitoring, evaluating, improving, finding non standard

	and practical skills in developing creative solutions to abstract problems, management and supervision in contexts where there is unpredictable change, reviewing and developing performance of self and others.					occurs. Independently resolves interactive issues which arise from project activities.	solutions. Scheduling, organising, integrating, finding standard solutions, interacting, communicating, working in team.
4	Factual and theoretical knowledge in broad contexts within a field of work or study, expertise in a range of cognitive and practical skills in generating solutions to specific problems in a field of work or study, self-management within the guidelines of work or study contexts that are usually predictable, but are subject to change, supervising the routine work of others, taking some responsibility for the evaluation and improvement of work or study activities.		model building using creative thinking; uses theoretical knowledge and practical skills to solve complex problems within a predictable and sometimes unpredictable context.	Basic principles			
3	Knowledge of facts, principles, processes and general concepts, in a field of work or study, a range of cognitive and practical skills in accomplishing tasks. Problem solving with basic methods, tools, materials and information, responsibility for completion of tasks in work or study, adapting own behaviour to circumstances in solving problems.	e-1	**Associate** Able to apply knowledge and skills to solve straight forward problems; responsible for own actions; operating in a stable environment.	Support/Service	Structured – predictable	Demonstrates limited independence where contexts are generally stable with few variable factors.	Applying, adapting, developing, deploying, maintaining, repairing, finding basic-simple solutions

10.3.2 SFIA competence framework

10.3.2.1 List of SFIA Skills

Category	Subcategory	Skill	Levels						
Strategy and architecture	Information strategy	IT governance **GOVN**					5	6	7
		IT strategy and planning **ITSP**					5	6	7
		Information management **IRMG**				4	5	6	7
		Information systems coordination **ISCO**						6	7
		Information security **SCTY**			3	4	5	6	7
		Information assurance **INAS**					5	6	7
		Analytics **INAN**			3	4	5	6	7
		Information content publishing **ICPM**	1	2	3	4	5	6	
	Advice and guidance	Consultancy **CNSL**					5	6	7
		Technical specialism **TECH**				4	5	6	
	Business strategy and planning	Research **RSCH**		2	3	4	5	6	
		IT management **ITMG**					5	6	7
		Financial management **FMIT**				4	5	6	
		Innovation **INOV**					5	6	
		Business process improvement **BPRE**					5	6	7
		Enterprise and business architecture **STPL**					5	6	7
		Business risk management **BURM**				4	5	6	7
		Sustainability strategy **SUST**				4	5	6	
	Technical strategy and planning	Emerging technology monitoring **EMRG**				4	5	6	
		Continuity management **COPL**				4	5		
		Sustainability management **SUMI**					5	6	
		Network planning **NTPL**					5	6	
		Solution architecture **ARCH**					5	6	
		Data management **DATM**		2	3	4	5	6	
		Methods and tools **METL**				4	5	6	
Change and	Business change	Portfolio management **POMG**					5	6	7

transformation	implementation	Programme management **PGMG**						6	7
		Project management **PRMG**				4	5	6	7
		Portfolio, programme and project support**PROF**		2	3	4	5	6	
	Business change management	Business analysis **BUAN**			3	4	5	6	
		Requirements definition and management**REQM**		2	3	4	5	6	
		Business process testing **BPTS**				4	5	6	
		Change implementation planning and management **CIPM**					5	6	
		Organisation design and implementation**ORDI**					5	6	
		Benefits management **BENM**					5	6	
		Business modelling **BSMO**		2	3	4	5	6	
		Sustainability assessment **SUAS**				4	5	6	
Development and implementation	Systems development	Systems development management **DLMG**					5	6	7
		Data analysis **DTAN**		2	3	4	5		
		Systems design **DESN**		2	3	4	5	6	
		Network design **NTDS**					5	6	
		Database design **DBDS**		2	3	4	5	6	
		Programming/software development **PROG**		2	3	4	5		
		Animation development **ADEV**			3	4	5	6	
		Safety engineering **SFEN**			3	4	5	6	
		Sustainability engineering **SUEN**				4	5	6	
		Information content authoring **INCA**	1	2	3	4	5	6	
		Testing **TEST**	1	2	3	4	5	6	
	User experience	User experience analysis **UNAN**			3	4	5		
		User experience design **HCEV**		2	3	4	5	6	
		User experience evaluation **USEV**		2	3	4	5	6	
	Installation and integration	Systems integration **SINT**		2	3	4	5	6	
		Porting/software configuration **PORT**			3	4	5	6	

		Hardware design **HWDE**				4	5	6	
		Systems installation/decommissioning **HSIN**	1	2	3	4	5		
Delivery and operation	Service design	Availability management **AVMT**				4	5	6	
		Service level management **SLMO**		2	3	4	5	6	7
	Service transition	Service acceptance **SEAC**				4	5	6	
		Configuration management **CFMG**		2	3	4	5	6	
		Asset management **ASMG**				4	5	6	
		Change management **CHMG**		2	3	4	5	6	
		Release and deployment **RELM**			3	4	5	6	
	Service operation	System software **SYSP**			3	4	5		
		Capacity management **CPMG**				4	5	6	
		Security administration **SCAD**	1	2	3	4	5	6	
		Penetration testing **PENT**				4	5	6	
		Radio frequency engineering **RFEN**		2	3	4	5	6	
		Application support **ASUP**		2	3	4	5		
		IT Infrastructure **ITOP**	1	2	3	4			
		Database administration **DBAD**		2	3	4	5		
		Storage management **STMG**			3	4	5	6	
		Network support **NTAS**		2	3	4	5		
		Problem management **PBMG**			3	4	5		
		Incident management **USUP**		2	3	4	5		
		Facilities management **DCMA**			3	4	5	6	
Skills and quality	Skill management	Learning and development management**ETMG**			3	4	5	6	7
		Learning assessment and evaluation **LEDA**			3	4	5	6	
		Learning design and development **TMCR**				4	5	6	
		Learning delivery **ETDL**			3	4	5		
		Teaching and subject formation **TEAC**					5	6	
	People management	Performance management **PEMT**				4	5	6	

		Resourcing **RESC**				4	5	6	
		Professional development **PDSV**				4	5	6	
	Quality and conformance	Quality management **QUMG**				4	5	6	7
		Quality assurance **QUAS**			3	4	5	6	
		Quality standards **QUST**		2	3	4	5		
		Conformance review **CORE**			3	4	5	6	
		Safety assessment **SFAS**					5	6	
		Digital forensics **DGFS**				4	5	6	
Relationships and engagement	Stakeholder management	Sourcing **SORC**		2	3	4	5	6	7
		Contract management **ITCM**				4	5	6	
		Relationship management **RLMT**				4	5	6	7
		Customer service support **CSMG**	1	2	3	4	5	6	
	Sales and marketing	Digital marketing **MKTG**		2	3	4	5	6	
		Selling **SALE**				4	5	6	
		Sales support **SSUP**	1	2	3	4	5	6	
		Product management **PROD**			3	4	5	6	

10.3.2.2 Structural levels of e-skills

SFIA Levels	
Level 1	Strategy and architecture
Level 2	Information strategy
Level 3	It Gouvernance
	The establishment and oversight of an organisation's approach to the use of information, digital services and associated technology. Includes responsibility for provision of digital services; levels of service and service quality which meet current and future business requirements; policies and practices for conformance with mandatory legislation and regulations; strategic plans for technology to enable the organisation's business strategy; transparent decision making, leading to justification for investment, with appropriate balance between stakeholder benefits, opportunities, costs, and risks.
Level 4	
	Leads development and communication of the organisation's policies for corporate governance of information. Contributes to strategic plans, which satisfy the current and ongoing needs of the organisation's business strategy, and the current and future capabilities. Promotes clear decision making, leading to valid reasons for technology-related acquisitions. Monitors provision of services, levels of service and service quality. Assures that the organisation's business processes are compliant with relevant legislation, and that the organisation operates according to the principles embedded in relevant standards. Promotes policies, practices and decisions which recognise the current and evolving needs of all the stakeholders.
Additional precision Levels	
Level 5	General operational skills
Example Microsoft Word	• Explain the functions of the word processing software as used by the legal team. • Navigate in word processors and use menus and commands. • Find online and program resources for learning how to use the program and its features. • Create and save a document in a word processor. • Be able to identify the document format by reference to the file extension. • Understand the ethical issues in saving word processing documents.
Level 6	Specific operational skills
Example Microsoft Word	• Enter text and correct mistakes. • Change the look of the text, e.g. font, alignment, line spacing, and very simple formatting including bold, italic and underlining. • Save their work. • Select text and cut, copy, and paste it. • Create bulleted and numbered lists. • Perform spell checking. • Close, reopen and create a new document. • Know how to print. • Use the online help. • Exit from Word.
Level 7	Content description

10.3.2.3 SFIA skills framework

SFIA Skills Framework V 6			1 Follow	2 Assist	3 Apply	4 Enable	5 Ensure, Advise	6 Initiate, Influence	7 Set strategy, Inspire, Mobilise
Strategy and architecture	Information strategy	IT governance					x	x	x
		IT strategy and planning					x	x	x
		Information management				x	x	x	x
		Information systems coordination						x	x
		Information security			x	x	x	x	x
		Information assurance					x	x	x
		Analytics			x	x	x	x	x
		Information content publishing	x	x	x	x	x	x	x
	Advice and guidance	Consultancy					x	x	x
		Technical specialism				x	x	x	
	Business strategy and planning	Research		x	x	x	x	x	
		IT management					x	x	x
		Financial management				x	x	x	
		Innovation					x	x	
		Business process improvement					x	x	x
		Enterprise and business architecture					x	x	x
		Business risk management				x	x	x	x
		Sustainability strategy				x	x	x	
	Technical strategy and planning	Emerging technology monitoring				x	x	x	
		Continuity management				x	x		
		Sustainability management					x	x	
		Network planning					x	x	
		Solution architecture					x	x	
		Data management		x	x	x	x	x	
		Methods and tools				x	x	x	
Change and transformation	Business change implementation	Portfolio management					x	x	x
		Programme management							
		Project management				x	x	x	x
		Portfolio, programme and project support		x	x	x	x	x	
	Business change management	Business analysis			x	x	x	x	
		Requirements definition and management							
		Business process testing							
		Change implementation planning and management					x	x	
		Organisation design and implementation					x	x	
		Benefits management					x	x	
		Business modelling		x	x	x	x	x	
		Sustainability assessment				x	x	x	

Development and implementation	Systems development	Systems development management				x	x	x	x
		Data analysis							
		Systems design		x	x	x	x	x	
		Network design					x	x	
		Database design		x	x	x	x	x	
		Programming/software development		x	x	x	x		
		Animation development			x	x	x	x	
		Safety engineering			x	x	x	x	
		Sustainability engineering				x	x	x	
		Information content authoring							
		Testing	x	x	x	x	x	x	
	User experience	User experience analysis			x	x	x		
		User experience design		x	x	x	x	x	
		User experience evaluation		x	x	x	x	x	
	Installation and integration	Systems integration		x	x	x	x	x	
		Porting/software configuration			x	x	x	x	
		Hardware design		x	x	x			
		Systems installation/decommissioning	x	x	x	x	x		
Delivery and operation	Service design	Availability management				x	x	x	
		Service level management		x	x	x	x	x	x
	Service transition	Service acceptance				x	x	x	
		Configuration management		x	x	x	x	x	
		Asset management				x	x	x	
		Change management		x	x	x	x	x	
		Release and deployment			x	x	x	x	
	Service operation	System software			x	x	x		
		Capacity management				x	x	x	
		Security administration	x	x	x	x	x	x	
		Penetration testing				x	x	x	
		Radio frequency engineering		x	x	x	x	x	
		Application support		x	x	x	x		
		IT Infrastructure	x	x	x	x			
		Database administration		x	x	x	x		
		Storage management			x	x	x	x	
		Network support		x	x	x	x		
		Problem management			x	x	x		
		Incident management		x	x	x			
		Facilities management			x	x	x	x	
Skills and quality	Skill management	Learning and development management			x	x	x	x	x
		Learning assessment and evaluation			x	x	x	x	
		Learning design and development				x	x	x	
		Learning delivery			x	x	x		
		Teaching and subject formation					x	x	

	People management	Performance management				x	x	x	
		Resourcing				x	x	x	
		Professional development				x	x	x	
	Quality and conformance	Quality management				x	x	x	x
		Quality assurance			x	x	x	x	
		Quality standards		x	x	x	x		
		Conformance review			x	x	x	x	
		Safety assessment					x	x	
		Digital forensics				x	x	x	
Relationships and engagement	Stakeholder management	Sourcing		x	x	x	x	x	x
		Contract management				x	x	x	
		Relationship management				x	x	x	x
		Customer service support	x	x	x	x	x	x	
	Sales and marketing	Digital marketing		x	x	x	x	x	
		Selling				x	x	x	
		Sales support	x	x	x	x	x	x	
		Product management			x	x	x	x	

10.3.2.4 Desciption of profile and skills: IT governance

The establishment and oversight of an organisation's approach to the use of information, digital services and associated technology. Includes responsibility for provision of digital services; levels of service and service quality which meet current and future business requirements; policies and practices for conformance with mandatory legislation and regulations; strategic plans for technology to enable the organisation's business strategy; transparent decision making, leading to justification for investment, with appropriate balance between stakeholder benefits, opportunities, costs, and risks.

- IT governance: Level 7

Leads development and communication of the organisation's policies for corporate governance of information. Contributes to strategic plans, which satisfy the current and ongoing needs of the organisation's business strategy, and the current and future capabilities. Promotes clear decision making, leading to valid reasons for technology-related acquisitions. Monitors provision of services, levels of service and service quality. Assures that the organisation's business processes are compliant with relevant legislation, and that the organisation operates according to the principles embedded in relevant standards. Promotes policies, practices and decisions which recognise the current and evolving needs of all the stakeholders.

- IT governance: Level 6

Puts in place, or confirms, staffing structures to support the work of the governing authority (board, trustees, etc) and proper relationships between the organisation and external parties. Takes responsibility for review of management processes (and decisions) and confirms that they are compliant with the organisation's strategy for corporate governance of information. Is familiar with relevant standards and the principles embedded within them. Reviews new business proposals and provides specialist advice on compliance issues. Acts as the organisation's contact for relevant regulatory authorities. Establishes policy and standards for compliance with relevant legislation.

- IT governance: Level 5

Reviews information systems for compliance with legislation and specifies any required changes. Responsible for ensuring compliance with organisational policies and procedures and overall information management strategy.

10.3.2.5 Combination of the the SFIA skills framework and the EQF

EQF Level	SFIA Professional level	SFIA category	SFIA Description
Level 1	Assistant	1. Follow	Basic capability to complete tasks under close supervision. Not expected to use much initiative. Should be organised.
Level 2	Assistant	2. Assist	Uses some discretion and has a wider circle of interaction than level 1, especially in speciality. Works on a range of tasks, and proactively manages personal development.
Level 3	Associate professional	3. Apply	Complete work packages with milestone reviews only. Escalates problems under own discretion. Works with suppliers and customers. May have some supervisory responsibility. Performs a broad range of tasks, takes initiative, and schedules own and others work.
Level 4	Professional	4. Enable	Works under general direction in a framework. Influence at account level, works on a broad range of complex activities. Good level of operational business skills.
Level 5	Senior professional	5. Ensure and advise	Broad direction, supervisory, objective setting responsibility. Influences organisation. Challenging and unpredictable work. Self sufficient in business skills.
Level 6	Lead professional	6. Initiate and influence	Authority for an area of work. Sets organisational objectives. Influences policy, significant part of organisation, and customers and suppliers at a high level. Highly complex and strategic work. Initiates and leads technical and business change.
Level 7	Principal professional	7. Set strategy, inspire, and mobilise	Authority includes setting policy. Makes decisions critical to organisation, influences key suppliers and customers at top level. Leads on strategy. Full range of management and leadership skills.
Level 8			