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CHALLENGES AND VARIABILITY IN BUILDING SOFTWARE
PRODUCT FAMILIES: CASE RAILWAY ENERGY SETTLEMENT
SYSTEM

Master of Science Thesis

ABSTRACT

IIRIS SAARENPÄÄ: Challenges and variability in building software product families: case railway energy settlement system
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According to European Union, all member countries shall have a settlement system in use by 2020. The settlement system shall receive energy consumption data from meters installed in trains, validate the data and allocate it for the right user. In this way, the energy consumption can be invoiced from the right user precisely. Erex is a such energy settlement system. The system needs to be adopted for each country to meet their different needs with regards to laws, systems and practices. This means that the system shall allow at least some flexibility. When new partners have entered the partnership and new instances have been created and modified for them with ad-hoc methods, the manageability of the systems has decreased. For this reason, a need to improve the management of the systems as whole has been raised. It would be easier, if the systems would have a shared core and systematically managed variability. This would mean creating a product family with systematically managed commonality and variability.

The objective of this thesis was to study, what are the challenges of creating such product family, where all systems share the same principles but some degree of flexibility is allowed. To achieve these objectives, experts from partner countries and the administration and developers of the systems were interviewed. Thereafter, challenges related to product families and their variability were studied from the literature. Then, the challenges found in empirical and theoretical parts were compared. The objective was to see if the results of empirical study support the current literature.

The comparison had three key results. Firstly, many of the current challenges are rather typical for software that is derived with ad-hoc methods. These challenges were found both in empirical and theoretical parts. Secondly, there were a group of challenges that were found only in the theoretical part and did not appear in the interviews but were considered as potential for this case. Thus, these challenges can be of great worth when the product family is developed. Lastly, there were challenges discovered only in the empirical part. These challenges are highly case and domain specific and were not investigated in the theoretical part due to their subjects. Experience from domain should be used to address these case specific challenges as they may not be found from any literature. There were only three challenges that could have been addressed in theoretical part by their subject. Compared to the whole amount of challenges found, these three challenges had only little role. Overall, this means that challenges found in the case are rather typical for product families. Thus, experience from the literature and industry can be used to solve these challenges.

TIIVISTELMÄ

Euroopan Unionin säännösten mukaisesti, kaikilla jäsenmailla tulee olla käytössä rautateiden sähköenergian selvitysjärjestelmä vuoteen 2020 mennessä. Järjestelmä vastaanottaa kulutustietoja juniin asennetuista mittareista, validoi tiedot ja kohdistaa ne oikeille käyttäjille. Näin energia voidaan laskuttaa tarkasti oikeilta käyttäjiltä. Tässä tutkimuksessa tarkasteltu Erex on tällainen selvitysjärjestelmä. Sen eri käyttäjämailla on erilaisia tarpeita lainsäädäntöön, järjestelmiin ja käytäntöihin liittyen. Siksi selvitysjärjestelmä täytyy sopeuttaa maassa olemassa olevaan viitekehykseen. Kun uusia maita on tullut mukaan yhteistyöhön, heille on luotu oma järjestelmä hyödyntämällä vanhoja olemassa olevia järjestelmiä. Käytetyt toimintatavat ovat johtaneet siihen, että järjestelmäkokonaisuuden hallittavuus on laskenut. Kokonaisuutta olisi helpompi hallita, jos järjestelmillä olisi yhteiset ydintoiminnot ja muunneltavuutta hallittaisiin järjestelmällisesti yhteisten toimintojen ulkopuolella. Tämä tarkoittaisi systemaattisen ohjelmistotuoteperheen rakentamista.

Tämän tutkimuksen tavoitteena oli tutkia, mitkä ovat ohjelmistotuoteperheen rakentamisen haasteet. Näiden tavoitteiden saavuttamiseksi asiantuntijoita haastateltiin eri maista. Myös järjestelmän omistavan organisaation henkilökuntaa ja järjestelmän kehittäjiä haastateltiin. Tämän jälkeen ohjelmistotuoteperheitä ja niiden muunneltavuutta tutkittiin kirjallisuudessa. Lopuksi empiirisessä tutkimuksessa ja kirjallisuudesta löydettyjä haasteita vertailtiin. Tarkoituksena oli nähdä, tukevatko haastatteluissa esiin tulleet haasteet kirjallisuuden näkemyksiä.

Vertailun tuloksena tehtiin kolme päätulosta. Ensinnäkin, nykyiset haasteet ovat varsin tyypillisiä tapauksissa, joissa ohjelmistotuoteperheitä rakennetaan ilman jäsenneltyjä menetelmiä, kuten kopioimalla. Nämä haasteet tulivat esiin sekä haastatteluissa että kirjallisuudessa. Toisessa ryhmässä oli haasteita, jotka ilmenivät vain kirjallisuudessa. Niitä ei otettu esille haastatteluissa, mutta siitä huolimatta tutkimuksessa todettiin, että ne voisivat potentiaalisesti olla haasteita myös Erexin tapauksessa. Tieto näistä haasteista voi olla hyvin arvokasta, kun tuoteperhettä kehitetään. Kolmas ryhmä koostui haasteista, jotka ilmenivät vain haastatteluissa. Nämä haasteet liittyivät vahvasti tähän tapaukseen ja sen toimintaympäristöön ja siten eivät kuuluneet kirjallisuuskatsauksen piiriin. Kokemusta toimialalta tulisi käyttää näiden haasteiden ratkaisuun, sillä niitä ei välttämättä löydä kirjallisuudesta. Kolmannessa ryhmässä oli vain kolme haastetta, jotka olisivat voineet löytyä kirjallisuudesta niiden aihepiiristä johtuen. Näiden rooli oli kuitenkin kaikkien haasteiden määrään verrattuna hyvin pieni. Voidaan siis todeta, että haasteet tässä tapauksessa ovat hyvin tyypillisiä ohjelmistotuoteperheille. Siksi kokemusta kirjallisuudessa ja teollisuudesta voidaan hyödyntää haasteiden ratkaisussa.

PREFACE

CONTENTS

TERMS AND DEFINITIONS

CEBD	Compiled Energy Billing Data. Compiled dataset that is suitable for energy billing. (The European Commission 2014a)
CENELEC	European Committee for Electrotechnical Standardization. CENELEC is responsible for standardization of electrical engineering in Europe. (Eress n.d.c)
Common model	Products share artefacts, structures, modules. Having a common model enables building of a software product family. The process of aiming at common model can be called as "harmonization" of the systems.
Configuration	A configuration is characterized by a set of parameters. Each system with its different parameter values is different. This means that the functionality of a system may be modified directly based on the parameters. (Asikainen, Männistö & Soininen 2007)
DCS	Data collection system (DCS) collects data from on-board Energy Measurement Systems and sends this data to be validated or to settlements systems. The protocol, in which the DCS shall be able to receive data is defined in LOC&PAS TSI. (The European Commission 2014a) All member countries of European Union shall have a DCS in use in 2022 (Eress 2018).
DG Energy	The Directorate-General for Energy is responsible for the development and implementation of European energy policy. DG Energy works under political guidance of the European Commission.
DG Move	The Directorate-General for Mobility and Transport is responsible for development and implementation of European policies on mobility and transport. DG Move works under political guidance of the European Commission.
Directives	Directives are prepared by the EU Commission, who consult their own and national experts. Directives aim at achieving a common solution to be used in each country of European Union. Together with the intended outcome, there will be a timetable when the fulfillment is mandatory. (Eress n.d.c)
EIM	European Rail Infrastructure Managers (EIM) represents the common interest of infrastructure

managers in Europe, specially towards European Commission.

Energy billing system	Energy billing system makes the financial transaction inside the supply chain, based on accountancy. Energy billing system takes data from the energy settlement system. (Lis et al. 2011)
Energy settlement system	Energy settlement system is the process of acquisition and allocation of energy data. (Lis et al. 2011) Settlement system is a system that is capable to receive compiled energy billing data (CEBD) from a data collecting system (DCS) to be used for billing. (Eress n.d.c) According to Commission Regulation 1301/2014 (The European Commission 2014), the settlement system shall be capable of exchanging data with other settlement systems, validate the data and allocate the data for right user.
ENTSO-E	European Network of Transmission System Operators for electricity. ENTSO-E has been given the mandate to develop and liberalize the European energy market. (ENTSO-E 2015)
EMS	Energy Measurement System (EMS) measures electric energy taken from or returned to the overhead contact line by an electric train. EMS produces and transmits complied energy billing data (CEBD) to an on-ground energy data collection system (DCS). (The European Commission 2014b)
ERA	European Union Agency for Railways (ERA) is responsible for the development, revision and updating of Technical Specifications for Interoperability (TSIs). ERA will also support the sector in their application by guiding, communication and training. When needed, the ERA may draft new TSIs on a mandate from the European Commission. (Eress n.d.c)
Eress	Eress is a partnership for infrastructure managers in Europe. The business idea of Eress is development, implementation and supply of energy settlement solution called Erex. (Eress n.d.a)
Eress Change Advisory Board	Change Advisory Board (CAB) is responsible for the management of requirements coming from the partners. CAB decides whether requirements will be implemented and when.

Eress Steering Group	Eress Steering Group consists of representatives from partner countries. Steering Group is responsible for the strategic guidance of Eress and Erex.
Erex	Erex is a software that is made for billing accurately the energy consumed by trains. Energy meters are installed in electric trains and energy consumption data is imported to Erex. Erex validates the data and allocates energy for the right trains. Thus consumed energy can be settled and billed from the right user. (Eress n.d.a)
Erex Exchange	According to the European Commission (2014a), members of the European Union shall be able to collect and exchange energy data consumed by electric trains. Moreover, the data shall be validated and allocated to the correct end user. (The European Commission 2014a) Erex Exchange is a solution that fulfills these requirements.
GPS	Global Positioning System (GPS).
Grid	An electrical grid is an interconnected network. The network delivers electricity from suppliers to consumers. It consists of product plants, high-voltage transmission lines, which carry power from distant sources to where it is consumed, and distribution lines that connect customers. (Eress n.d.c)
Infrastructure manager	National entity responsible for the railway network in a country (Eress n.d.c).
Network statement	Network statement present in detail all the general rules, procedures and criteria that is relevant for railway undertakings. The topics include charging and allocation of capacity. (The European Parliament and the Council of the European Union 2012, chapter 1, article 3)
Pantograph	Pantograph is placed on the roof of an electric train. The pantograph collects power through a contact to an overhead catenary. (Eress 2013)
Railway package	European Commission has directed railway packages to be adopted between 2001 and 2016. The objective of the railway packages has been to open rail transport services for competition and making the railway systems interoperable but also defining conditions for single European railway area. (The European Commission 2018)

Railway undertaking	Train company or a train operator (Eress n.d.c).
Settlement of energy	Allocation and billing of energy costs.
Shunting	Shunting refers to processing of sorting rolling stock into complete train or traction unit sets (Eress n.d.c).
Stabling	Parked trains are stabled. Even though the trains are not moving, they can consume energy during stabling for example for the purposes of heating or cooling the rolling stock. (Eress n.d.c)
Traction unit	A locomotive or electric multiple unit (Eress n.d.c).
Traffic Management System	A Traffic Management System manages the information about, i.e. the distance travelled, the time, the traffic type (cargo/passenger), the weight and the composition of traction units. This information is used by Erex system to compound metered data with train runs, and to decide whether or not to use the metered data or the reported payload for a train metering point in the settlement. (Eress n.d.c)
Train run	Train run is a single run made by a train with start and endpoint. Train run can be identified with EVN-number identifying the traction unit, operating day and train number.
TSI ENE	Technical specification for interoperability related to energy. Most importantly, TSI ENE includes the requirements for on-ground data collection system (DCS) that receives data from on-board energy measurement system (EMS). (Eress n.d.c)
TSI LOC&PAS	Technical specification for interoperability related to locomotives and passenger rolling stock. Most importantly, TSI LOC&PAS defines the requirements for energy measurement system (EMS). (Eress n.d.c)
TSO	Transmission System Operator (TSO) is responsible for ensuring a long-term ability for the transmission of electricity. TSO is also responsible for managing electricity flows on the system and ensuring a secure, reliable and efficient electricity system. (The European Parliament and the Council of the European Union 2009)
UIC	International Union of Railways (UIC) is a worldwide organization for railway co-operation for railway undertakings and infrastructure managers. UIC is

active in all aspects of the development of rail transport. (Eress n.d.c)

UTILTS   Utilities time series message (UTILTS) is a message format utilized e.g. in railways. For this purpose, the message includes time series for metering values.

XML   Extensible Markup Language (XML) is a message format. EN-50463 of CENELEC has defined XML as a new format into exchange function. Similarly, UIC leaflet defines XML as a format out from the exchange function.

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1. INTRODUCTION

What are the challenges when product family is being built with a bottom-up approach? Bottom-up method means that there are already existing few product variants that are wanted to be managed and structured better as a product family. What are these challenges specially in Case Erex? Erex is a railway energy settlement system operating in railways and energy industries. These are the main topics that will be discussed in this Master's thesis. This study provides and overview of railway energy settlement systems used in Northern, Central and West European countries but also analyses more generally the challenges that can obstruct efforts for finding a common model for information system variants.

In the first chapter, the background for the study is presented. Moreover, the research problem and research questions but also the limitations for the study are introduced. Next, the philosophical and strategical choices of the study are presented and rationalized. Last, the outline for the thesis is presented.

1.1 Background

The inspiration for this subject came from a project, where an information system for settlement of railway electricity was introduced in Finland. The objective of the system is to validate meter data received from meters from trains on board and allocate this energy for right train and its operator to be invoiced. This system will provide infrastructure manager the possibility to invoice actual amount of energy used by the railway undertaking. There is also the possibility to report the consumption timely to energy markets. Identified electricity consumption gives incentives to save energy and easier management of electricity of multiple railway undertakings and international traffic.

This system is in use in a number of European countries but has been customized for each country to meet their specific needs. This collaboration is open for growth, which makes the system more complex to handle as the number of users is growing. Different implementations make the introduction of systems longer. The complexity of the system increases, which increases the possibility of errors and makes the maintenance more challenging and time consuming.

On this basis, a need for standardizing the system has been raised. To make this type of standardized system possible, operations require some standardization. When looking for a standardized model, it is needed to study what sort of challenges there are that might

obstruct standardizing the systems and operations and systems behind them. Each of the countries have their own history in railway transport, laws, agreements between infrastructure managers and railway undertakings, different business models but also different solutions how they have solved practical issues in their everyday operations. These challenges are to be found in this thesis.

Finding a common model for Erex and thus being able to create a software product family, will bring about lot of benefits. The benefits include easier maintenance and development, shorter time for introduction of such system for new users, less customization work, less misunderstandings from using several parallel systems but also improved tradability as a product. The future benefit will also be fair and more affordable pricing for the members and for the member countries' railway undertakings.

The topic is significant as the world is full of different software. There are lot of general software that can be provided to the customers without any heavy needs for adaptation, but there must be a lot of software that needs to be adaptable to meet the different needs of customers. Moreover, the way how Erex has expanded during years may not be unique. The question is, how to make this a well-managed entity?

The aim of this thesis is to find the challenges that can obstruct building product family and their variability when few implementations already exists. This thesis studies product families and their variability from a general perspective too. This means finding out what is usually challenging when building a product family. The focus will be on defining the variability and commonality of the product family, i.e. what is different in the systems and thus challenging. The aim of the study is find challenges in current state of things in the Case. As many of the challenges are domain related, background research needs to be done on how railway systems function in Europe and in different countries that are partners of Erex.

1.2   Research problem and research questions

The primary research question is: What are the challenges that must be tackled when product families and their variability is being developed: case Erex?

This question can be answered by answering the following sub research questions:

- What sort of major differences there are in implementations of Erex currently and what are the major reasons to these differences?
- What things have an impact on the development of the system?
- What are the country specific obstacles that hinder standardization of the system?
- What is challenging when deciding variants and variation points for product family and few instances are already existing?

1.3 Limitations

The goal of the study is to find challenges that can obstruct standardization of this settlement system and building of product family from the existing systems. In other words, the thesis will list issues that shall be considered when building the product family with a bottom-up approach. Thus, the focus of this thesis is on studying the current state of things. The goal is not to give recommendations about priorities or solutions how to solve those problems. It is also not in the scope to decide about the measures towards the standardized model and their schedule.

The thesis will study the laws, network statements, practical domain, practices and business models. The study will not deeply study the current technical implementations of Erex or other information systems. It will neither study the electricity systems of the railway systems and their technical details and differences in the countries. The thesis will not interpret law. Experts in each country have already done their interpretation of laws and their understanding is utilized in this thesis.

Empirical study and background information will be collected from Belgium, the Netherlands, Finland, Switzerland and Norway, which are all Erex partners. Some information is also being collected from Denmark and Sweden. Also, the perspective of future prospect countries is included in some parts.

According to the research strategy chosen, the theoretical part will study topics that pop up in the empirical part. However, in the theoretical part, the focus will be on product family literature. Special attention is paid to development of product families bottom-up, when few implementations exists already. The focus will be on publications that discuss variability of the product family and challenges of building a product family. The thesis will not study literature about railways, energy market, regulations, standards or politics that may pop up in the empirical part as they are closely tied to the specific case of building the product family. Thus, in the analysis part, they will be considered separately.

1.4 Research strategy and research process

In this section, the methodological decisions of the study are introduced and rationalized. This study is exploratory by its nature which will affect the choice of the methods. It is typical for exploratory research to tackle new problems on which no or little previous research has been done. (Brown 2006) The choices of research methods are presented in Figure 1 below.
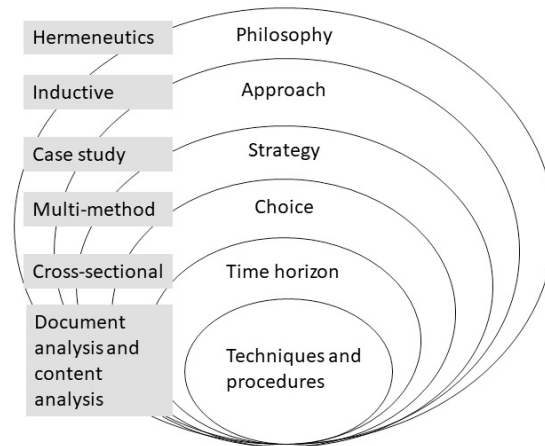
Figure 1. *Research methodology of the thesis. Adapted from* (Saunders et al. 2009)

This study utilized hermeneutical philosophy, inductive approach, case study strategy, multi-method choice, cross-sectional time horizon and document analysis and content analysis. These choices are explained in the following chapters.

Neilimo and Näsi (1980) have introduced research approaches in Business and Management. Their classification distinguishes four different approaches: nomothetic, decision-oriented, action-oriented, and conceptual approach. These research approaches have been identified by studying the purpose of research and information retrieval method. According to Olkkonen (1994), scientific research can be either descriptive or normative. Descriptive studies aim to describe the phenomena, while the normative studies tend to find results that can be used as guidelines for the development of operations in the future. Subject to data acquisition mode the study can be either theoretical or empirical. The aim of theoretical research is to develop new theories from the well-known and already sufficiently proven theories. The empirical study, in turn, starts from observation and measurement of individual cases. Then dependencies and causalities will be studied. (Olkkonen 1994) In addition to the four research approaches represented by Neilimo and Näsi (1980), Kasanen et al. (1993) have introduced constructive research approach. Here, the action-oriented research approach is used.

In the following sections, the philosophical commitments and the research approach are discussed. After that, research method and information gathering and analysis methods are introduced.

1.5   Research philosophy

According to Kasanen et al. (1993), research strategy is a result of the researcher's methodological choices, which are based on the methods and philosophical commitments used in the study. Research strategy includes also researcher's general world view and perception of science. Perception of science guides acquisition of information in the research process as it describes the beliefs of certain time but also the philosophical

understanding of science and traditions and targets of different disciplines. (Olkkonen 1994)

According to Olkkonen (1994), the most significant perceptions of science are positivism and hermeneutics. Positivism refers to scientific approach that is based on realism, alias confirmed facts. Typical to positivism is to reject all questionable factors that are not verifiable such as estimates obtained by pondering. Positivism studies and analyses phenomena, where they actually happen. (Olkkonen 1994) Positivism emphasizes collecting and processing of quantitative research material. Regularities and formulas are sought from the material while making the research. (Pitkaranta 2010, pp. 77–78) Accuracy and exact analysis are part of positivism and therefore issues and phenomena are processed with numbers if possible. The method is aiming to be objective and independent of researcher. (Olkkonen 1994) Hence the result is repeatability and it is possible for a different researcher to verify the result of the study by repeating it with the same data sources and methods (Olkkonen 1994, pp. 35-36).

Hermeneutic research aims to understand the target phenomena comprehensively and its internal connections in a situation, where a extensive data analysis based on statistical review can't be carried out (Olkkonen 1994). Hermeneutics bases on interpretation and understanding of meanings. It is attached to studies, which examine new areas of research or situations, where data for statistical analysis is not available. (Olkkonen 1994, pp. 50-54) Pitkäranta (2010, p. 78) says that hermeneutics emphasize qualitative data and approach of understanding. Hermeneutic studies are unique and not easy to repeat. Thus, they do not guarantee general results. On the other hand, the studies want to create a comprehensive picture of the target phenomenon. (Olkkonen 1994, pp. 50-54)

In positivistic researches, the research material is usually quantitative such as metering results whereas in hermeneutic researches the information is being created with the help of induction from the empirical material (Olkkonen 1994). Choice of methods is dependent from the disciplines that have their established comprehension of the scientific methods and the results that the methods obtain. In the field of business and management, both positivistic and hermeneutic methods are used. (Olkkonen 1994, p. 40)

This study will be a hermeneutic research as the target is to understand a specific single phenomenon in certain context. The goal of the study is to list challenges as they are not known yet. Thus, there is no quantitative data available. Moreover, it would be difficult to create such quantitative data from this type of challenges.

1.6   Approach

Research approach describes the relation of the research to theory. According to Saunders et al. (2009, p. 106), inductive or deductive approaches are generally used in studies. Inductive reasoning is typical for empirical research, where generalization is done from

a crowd of individual cases. Phenomena and features affecting the entire population are found statistically. In this way, the claim is reasoned from special known facts. Deductive approach emphasizes reasoning of specific claims from generalized truths. Therefore, it often appears in theoretical research. (Olkkonen 1994, pp. 29-30) This research uses inductive reasoning, as the study will be in close contact with the context and its findings.

Abductive approach could have been an option for the approach. In abductive approach, empirical research and theoretical understanding alternate. However, in this study inductive approach suits very well as the subject has not been studied a lot. Therefore, a better way is first to search for empirical findings and then compare it with literature.

1.7 Research strategy

Research strategy is a combination of methodological decisions done in the research (Hirsjärvi 2007, p. 128). Research strategy guides the setting of research questions and research problem but gives also guidance for setting the targets of the research (Saunders et al. 2009, p. 141). Case study has been selected as research method here. Other traditional research strategies include surveys and experimental researches (Hirsjärvi et al. 2007, p. 130).

The case study research method is particularly suited for researches that seek to understand in-depth the examined phenomenon and processes related to it. Case studies are often used as research tools in exploratory and descriptive studies. The method is especially well suited to answer questions beginning with words why, what and how. (Saunders et al. 2009 p. 146) This study is by its nature related to a single special case, its processes and the phenomenon in its entirety. Thus, case study method suits this research very well.

According to Yin (2009, p. 18), a case study investigates and illuminates a phenomenon in certain context. The context is the currently existing surroundings, where the boundaries between the phenomenon and the context aren't always clearly evidently to be seen. Hirsjärvi et al. (2007) say that case study processes detailed and intensive information about a single case or about a small group of cases which are related to each other.

1.8 Research choice

While making a case study research, various data collection methods and their combinations can be used. Typical methods include interviews, examining documents and perception. Usually combining various methods is justified, because by using different methods, the accuracy of the previous results can be obtained. (Saunders et al. 2009, p. 146)

In this research, document analysis will be used as data collection method. Moreover, semi-structured individual and group theme interviews will be made and thus content analysis of the interview material will be used as a second data collection method. Thus, the choice will be multi method. In the first place, documents available will be studied. Secondly, Erex managers in partner countries, Eress administration and Erex developers will be given a chance to express their views in focused interviews to find out tacit knowledge and get more information about the practical challenges. It is recognized that not all information is written in official documents and tacit knowledge exists. Erex developers will be interviewed as a group. Other interviews with Eress administration and Erex managers in partner countries will have only one or two participants in addition to the researcher.

Semi-structured interview is discussion-like situation, which will review pre-designed themes. The speaking order is free of choice, and not necessarily all the interviewees talk about all the issues to the same extent. Themes and some questions and keywords will be written for feeding the debate.

1.9   Time horizon

According to (Saunders et al. 2009, p. 155), time horizon of a study can be either longitudinal or cross-sectional. Longitudinal studies are repeated over an extended period. Thus, it describes development of the situation with respect to time. On the other hand, cross-sectional studies are limited to a specific time frame. They describe the situation at a certain time. (Saunders et al. 2009, p. 155) This research is limited to a time frame and hence the cross-sectional time horizon is used. This research doesn't have dimension of time whereas it describes the challenges at the time of the study.

1.10 Outline of the thesis

In the first chapter, background for the thesis is presented. Moreover, the research problem and questions, limitations and philosophical choices of the study are presented.

In the second chapter, the operating environment of the product family case are presented. This means introducing the relevant background information from both railway and energy domains. The legal framework and country specific factors are presented too. Moreover, the section describes the system of this case.

In the third chapter, the methods for empirical research are presented. The fourth chapter will reveal empirical findings.

The fifth chapter focuses on theoretical study of literature about product families. In the sixth chapter, the results of the study are presented. This means comparing the results from the empirical and theoretical parts. The results and their meaning are discussed more

in chapter seven. This chapter will include also assessment of the study and suggestions for future research. The results are concluded in chapter eight.

The conclusion for the first chapter is that now the needs and objectives for the study are expressed together with the theoretical means how the objectives will be achieved. This means that the choices made have been motivated from the perspectives of both the empirical case and the theoretical study. In the next chapter, the operating environment of the case software is presented. The operating environment includes the legal basis for the subject, introducing the markets but also country specific systems and regulations.

2. OPERATING ENVIRONMENT OF EREX: RAILWAY SYSTEMS IN EUROPE

In this chapter, the railway systems in Europe are familiarized. The railway domain is the operating environment of the case. The operating environment includes the laws, regulations, markets and systems, in which the software needs to adapt.

2.1 European laws and systems

When railways in European countries are discussed, laws and directives of European Union are a basis for the railway operations in the European countries. Thus, European council effects how railways operate. The vision of European Union is to create a Single European Railway Area. To have a such area, it requires abolishment of technical, administrative and legal obstacles that obstruct entering the whole area at a time. (European Commission 2011)

There are several directives given at the European Union level that guide railway operations. Directive 2012/34/EU (The European Parliament and the Council of the European Union 2012) is a recast of the first, second and the third railway packages. The Directive discusses development of the Community's railways, licensing of railway undertakings, allocation of infrastructure capacity and collection of fees for the use of railway infrastructure. (The European Parliament and the Council of the European Union 2012)

European Parliament and the Council have governed that European Union Agency for Railways ensures that the specifications for interoperability (the TSIs) are updated to meet technical progress, market trends and social requirements. Energy subsystems have been accepted as one interoperative systems. (The European Commission 2014b) There are different TSIs for rolling stock, energy, infrastructure and similarly for other subsystems.

Commission regulation number 1301/2014 (The European Commission 2014a) is a technical specification for interoperability focusing on the energy subsystem. Regulation 1302/2014 (The European Commission 2014b) relates to the interoperability of rolling stock, which includes passenger rolling stock and locomotives. The directives are referring to each other.

2.1.1 Establishing a single European railway area

One of the major themes of the Directive 20122012/34/EU is the improvement of the railway systems to a single competitive market (The European Parliament and the Council

of the European Union 2012) The role of the countries here is to make sure that the railway undertakings have the roles of independent commercial operators so that it is possible for them to adapt to the needs of the market (The European Parliament and the Council of the European Union 2012).

To make sure improvements and efficient use, transportation services and managing infrastructure need to be separate in accounting matters. The railway undertakings can be owned or controlled by governments but they need to have an independent status and separate assets, budgets and accounts, which are separate from the ones of the country. (The European Parliament and the Council of the European Union 2012, chapter 2, section 1, article 4). The countries may decide that this separation requires distinct divisions or that they shall be managed by separate entities (The European Parliament and the Council of the European Union 2012, chapter 2, section 2, article 6). The objective of these requirements is to provide non-discriminatory operation environment and improve competitiveness. The most essential functions, such as decision making regarding train route allocation or infrastructure charges need to be made by such bodies or undertakings that do not operate on railways themselves. However, the railway undertakings can have responsibilities for contributing to the development of the railway infrastructure, which can include investing, maintenance and funding. Nevertheless, the member states shall keep the overall responsibility on the development of the infrastructure. (The European Parliament and the Council of the European Union 2012, chapter 2, section 2, article 7)

It has been prescribed that any railway undertaking dealing with rail transport services shall conclude agreements with the relevant infrastructure managers (The European Parliament and the Council of the European Union 2012, chapter 4, section 1, article 28) The infrastructure managers shall ensure that their charging of railway undertakings is equivalent and non-discriminatory. Applied charges shall follow the criteria that is agreed in the network statement. (The European Parliament and the Council of the European Union 2012, chapter 4, section 2, article 29)

Sharing costs between railway undertakings needs to be based on best information available about cost causation. Based on this knowledge, the costs should be shared for the railway undertakings based on different services. (The European Parliament and the Council of the European Union 2012) As electricity plays a big part in costs for railway undertakings, getting energy consumption metered accordingly and exactly is a big improvement. Getting paid for energy that is actually used, not only estimated, is also a huge incentive on energy savings. It is said that there can be relatively big differences on same routes depending on the transport situation and driver.

2.1.2 On-board energy measuring system

TSI for locomotives and passenger rolling stock (LOC&PAS TSI) contains the requirements for on-board Energy Measuring Systems (EMS), which is a system for

measuring electricity taken from the overhead contact line by the train. The system also observes returned electricity during regenerative braking. This system is suitable for billing purposes and should be accepted by all European Union countries. (The European Commission 2014b, appendix 4.2.8.2.8) On-board energy measurement system. The EMS is mandatory for new, upgraded and renewed rolling stock that intend to operate on networks that have on-ground data collecting system (DCS) (The European Commission 2014b, article 3). The specifications for these energy meters are presented in European Energy measurement standards EN 50463 1-5 written by CENELEC, European committee for Electrotechnical Standardization. The intend of EMS is to produce and transmit the compiled energy billing data (CEBD) to an on-ground energy data collecting system (The European Commission 2014b). CENELEC prepares specifications for meters on board. The EN 50463:2017 has been published in the beginning of 2018. The major changes of EN 50463:2017 relate to standardized communication protocol. (Eress 2017)

The on-board energy measurement system has three main functions. The first function is energy measurement that measures the voltage and calculates energy and produces energy data. The second function of the system is data handling system (DHS) that produces compiled energy billing data sets to be used for energy invoicing. The system stores the data so that it can be sent to on-ground data collection system (DCS) by a communication system. The third functionality gives geographical position of the traction unit. (The European Commission 2014b) The measured energy data shall have a reference period of 5 minutes. Shorter time period can be used if the data can be aggregated on-board into 5 minutes time periods. The data for each time reference period shall include identification number pointing at specific vehicle and its particular meter, time, location and consumed and regenerated energy. (The European Commission 2014b, appendix D)

TSI for energy subsystem (ENE TSI) contains requirements for on-ground energy data collecting system (DCS). The DCS shall receive, store and export compiled energy billing data (CEBD) without corrupting it. (The European Commission 2014b) The deadline for having a DCS in use is 2022. The deadline for DCS was postponed by DG Move but the request came from the members of European Union. (Eress 2018) The relations of LOC&PAS TSI and ENE TSI are presented below in Figure 2.
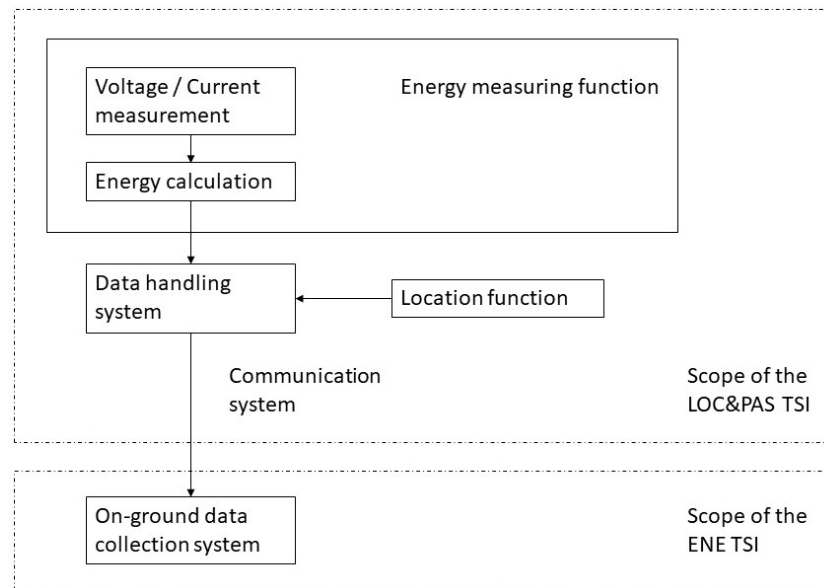
Figure 2. *Scope of LOC&PAS and ENE TSIs. Adapted from* (The European
Commission 2014b)

As data collecting systems gather data from on-board energy measuring systems,
European countries shall ensure that they have a system that is capable to receive such
data and accept it for billing purposes. (The European Commission 2014a) The system
shall be in use from the beginning of 2020. Moreover, the settlement system shall be able
to exchange CEBD with other such settlement systems, validate CEBD and allocate the
consumption to the correct users of the energy. Relevant legislation concerning the energy
market shall be taken into account when doing this. (The European Commission 2014a,
article 9) This means that international trains can be then billed the right amount from the
right country. Countries can also manage the total balance of their network with the help
of settlement system. Thereby, in few years all European Union partner countries shall
collect and exchange energy data consumed by electric trains. The countries shall be able
to collect and exchange energy data, including validation and allocation of energy
consumption to the correct end user. (The European Commission 2014a)

UIC refers to International Union of Railways. UIC started development of railway
energy settlement standard already in 2004-2005. UTILTS was chosen as a standard for
data exchange back then. The idea was that everyone would use UTILTS format from
data collection system to settlement systems but also between settlement systems. This
was a basis for UIC leaflet 930, which official name is UIC Codex 930 "Exchange of data
for cross-border railway energy settlement". However, following the standards of UIC is
not mandatory as it is not a legal document. The UIC leaflet 930 is being updated, which
includes for example the update of role model. There are also discussions whether
validation, estimation and allocation processes should be standardized. One of the most
important updates is also standardizing of exchanges and their change into xml format.
(Van Der Spiegel 2017)

2.1.3 Energy market in Europe

Directive 2009/72/EY (The European Parliament and the Council of the European Union 2009) defines the requirements for the separation of networks and operating activities that include supply and generation of electricity. This separation shall be done to prevent discrimination and encourage investing in the networks. The other major requirement from the point of view of railways is the possibility of large customers to choose their supplier. They can also make an agreement with more than one suppliers to secure their requirements. The objective is to improve competition in the market. (The European Parliament and the Council of the European Union 2009) In the railways, however, the members of European Union have not yet been obliged to apply this to the railways. Still, the application of the directive on railways is only a matter of time.

Nordic countries are known as forerunners in the energy market. They have been most successful in Europe in implementing shared energy market. This shared market may encourage competition and can reduce price fluctuation by having a larger market. Nord Pool was the first multinational platform for trading electric power. Nowadays it offers both day-ahead and intraday trading platforms. Nord Pool operates in Norway, Denmark, Sweden, Finland, Estonia, Latvia, Lithuania, Germany and the UK. In 2016, 505 TWh of power was traded in Nordpool. 391 TWh of the whole amount was traded in Nordic and Baltic day-ahead market. (Nord Pool Group 2017)

Imbalance refers to the difference of consumption and production, which comes from the uncertainties in consumption and failures in production. Transmission System Operators are using balancing power to equalize the situation within an hour that is the smallest time period for trading. Imbalance settlement refers to calculating the difference and invoicing the costs from the right participant and making possible refunds. In Finland, Norway and Sweden, imbalance settlement is carried out by eSett, a company providing imbalance settlement services to electricity market participants. Its operations started in 2017 but it is already serving more than 1000 electricity market participants. ESett is jointly owned by Transmission System Operators Fingrid, Statnett and Svenska kraftnät, who were responsible of the imbalance settlement earlier but wanted to develop a harmonized model for it. (eSett 2017)

2.2 Country specific factors

National laws, regulations, business models and network statements are defining the operation environment for energy settlement system. However, they should not contradict with TSI's (Technical Specifications for Interoperability) or EN 50463 (EU norm that describes the specific requirements for on-board Metering Systems). After the adoption of the requirements described European documents, they are considered as national rules. Then, conflicting national regulation need to be adjusted. The easiest way is to clarify that

some national regulation is not applicable or that conformity to the TSI is an accepted alternative to the national rules. (Eress 2017)

2.2.1 Finland

In Finland, Finnish Transport Agency (FTA) operates as infrastructure manager and rail maintenance authority. Railway undertakings have a right to use the FTA's electricity power supply network for their operation of trains. However, FTA does not provide electricity for the railway undertakings. This means that the traffic operator shall make an agreement with an external service provider. (Liikennevirasto 2015, p. 61) The cost of transmission of electric power transmission in the railway network will be divided between all electricity consumers according to the amount they consume. (Liikennevirasto 2015, p. 60)

Directive 2009/72/EC (The European Parliament and the Council of the European Union 2009) has been put into force in Finland with electricity market law 588/2013 (FINLEX 2013). FTA is thus performing according the directive even though it is not yet obligated in the railways. The railway undertakings have been allowed to buy their own electricity under certain terms since the railway undertaking and infrastructure manager were separated. FTA only provides the service of transmission of energy, but does no sell electricity for the railway undertakings. The service includes balance management of electric energy and reporting to the energy market. This allows the railway undertakings to purchase their own energy according the directive 2009/72/EC (The European Parliament and the Council of the European Union 2009).

More detailed information can be found from Appendix A.

2.2.2 Switzerland

Swiss Federal Railways (SBB) is responsible both in operating the trains and managing infrastructure in Switzerland. (SBB n.d.b) However, not all parts of infrastructure are managed by SBB. BLS Netz AG and SOB Infrastructure are other smaller infrastructure managers in Switzerland. However, SBB Infrastructure is the responsible party for energy settlement in the whole country. Switzerland has agreed with European Union that it shall separate infrastructure management and operating in accounting terms (European Community & Switzerland 2002).

European Community and Switzerland have made an agreement, which defines the common rules for rail transport whit a result that the both parties have access to both markets (European Community & Switzerland 2002). Switzerland is not part of European Union and thus it is not obliged to implement laws of EU. Switzerland adapts its regulations to EU laws when it is in their own interest. (Intergration Office FDFA/FDEA 2009) In Railways, however, it is beneficial for all parties that Switzerland follows

European regulations because Switzerland is located in the middle of Union partners. Switzerland has made an agreement that they will follow the regulations in railways even though it is not obligatory for them. For their own benefit, they are following the rules. Thus, the rules for energy settlement are in line with European Union countries.

Network statement of Switzerland (SBB 2017) states that new and renewed rolling stock need to be equipped with meter in accordance to European regulations EN-50463 and TSI LOC&PAS. Network users transmit their energy measurements to the infrastructure manager in accordance UIC leaflet 930. Railway undertakings are responsible for implementing the relevant interfaces with Erex Exchange. The interfaces are used for reporting energy measurement. If there are no meters on-board or the data is not transferred correctly, invoices will be based on the relative consumption values per train type, which are published by the infrastructure manager. The relative consumption is used also in conditions where not all the requirements are met. This includes situations where the energy measurement systems fail, the readings are incorrect or implausible, readings for individual sections of a train run are missing or the data is not received within three days as defined in the network statement. (SBB 2017, pp. 102-106)

The Federal Electricity Supply Act, has provided an opening of the electricity market. During the first years ending in 2013, large end users had access to the market. After this period, smaller consumers can freely choose their electricity supplier. (Swiss Federal Office of Energy SFOE 2017) However, the liberalization has not yet reached closed railway grid. Currently, 90% of the whole consumption of SBB is hydro power that comes mostly from its own power plants (SBB n.d.a).

More detailed information can be found from Appendix A.

2.2.3 Belgium

In Belgium, infrastructure manager Infrabel is the body that is responsible for the energy supply and settlement. Infrabel provides the supply of traction current for the railway undertakings as an additional service. Transport and distribution of traction current are considered as basic service. Currently, the infrastructure manager supplies electricity to all the applicants for the powering of units if they require. The electricity is bought in advance with a mandate of their expected consumption given by the railway undertakings. When electricity directive 2009/72 will be adopted into Belgian law, the applicants are free to choose their own electricity supplier. All traction units, for which the railway undertaking is choosing its own supplier, must be equipped with an energy meter. (Infrabel 2016, pp. 67-68) In addition, such railway undertaking must also appoint a balance responsible party who reports daily forecasts for transmission system operator, compensates for energy losses in the transmission grid but also pays the costs of imbalances. (Infrabel 2017, p. 5)

More detailed information can be found from appendix A.

2.2.4   The Netherlands

In the Netherlands ProRail is responsible for management of Netherlands' railways. ProRail is a private company, but the only shareholder is the State of the Netherlands through Railinfratrust BV. Railinfratrust is the owner of the closed distribution system, which is the railway network. ProRail performs all the management tasks for this private network. (Prorail 2017, p. 7)

The energy market of the Netherlands is fully liberalized in accordance of the energy market directive 2009/72/EC (Bouchez & Bos 2014, p. 315). However, the liberalization has not yet proceeded into railways. In the Netherlands, the electricity for trains is purchased by VIVENS, a co-operation of Dutch railway undertakings. VIVENS is authorized by ProRail, the infrastructure manager of the Netherlands. Vivens has made an agreement for electricity supply for the following years. Thus, the freedom to choose own supplier is not going to be implemented in the railways in few years. (Lo 2015)

VIVENS is a co-operation of railway undertakings. VIVENS arranges cost allocation of the electricity and the purchasing of electricity. The benefits of VIVENS are transparency in costs and tariffs, easiness for railway undertakings, lower surcharge on commodity price and joint interest representation such as introduction of energy meters on trains. (VIVENS n.d.b)

More detailed information can be found from appendix A.

2.2.5   Denmark

Rail Net Denmark is responsible for managing the infrastructure in Denmark (Transport- og Bygningsministeriet 2015). However, according to network statement 2018 (Rail Net Denmark 2017), there are some smaller infrastructure managers too. Rail Net Denmark may manage other railway infrastructure according to agreement with the infrastructure owner (Transport- og Bygningsministeriet 2015). So far, Rail Net Denmark is purchasing and buying all electricity for the railway undertakings.

More detailed information can be found from appendix A.

2.2.6   Sweden

In Sweden, there are two infrastructure managers: Swedish Transport Administration and Inlandsbanan AB. Swedish Transport Administration procures electricity and supplies it to all railway undertakings in need. The cost of electricity is invoiced from the end users

but no profit or loss is made on this trade. However, the cost includes the cost for electricity certificate. (Swedish Transport Administration 2016, pp. 76-88)

More detailed information can be found from appendix A.

2.2.7 Norway

In Norway Bane NOR is responsible for planning, building and maintaining railway infrastructure since 2017. Norwegian Railway Directorate has the strategic responsibility of railways. Earlier these two commissions were tasks of Norwegian National Rail Administration. (Jernbanedirektoratet 2016) Norway is not part of European Union but as a member of European Economic Area, it has approved majority of the EU directives. In railways' energy settlement, similar rules to European Union partners are followed.

Bane NOR provides power supply for railway undertakings for their train operations including purchasing of energy and sale of this energy for the railway undertakings. The energy is provided to all railway undertakings requesting it. (Bane Nor 2017) According to Stortingsproposition nr. 64 1996/97 (Samferdselsdepartementet 1997), the cost of electrical energy for the transport of trains is charged from the railway undertakings. Bane NOR as infrastructure manager is required to purchase the energy and resell this energy for the railway undertakings at cost price with addition of possible administrative costs and brokerage fees. As accounting officer, Bane NOR is assigned to the settlement of energy. (Samferdselsdepartementet 1997)

More detailed information can be found from appendix A.

2.3 Eress and Erex

Erex is an on-ground settlement system as defined in the directives of European Union. It is a software that is made for billing accurately the energy consumed by trains. Energy meters are installed in electric trains and energy consumption data is imported to Erex. Erex validates the data and allocates energy for the right trains. Thus, consumed energy can be settled and billed from the right user. (Eress n.d.b)

Eress is a partnership for infrastructure managers in Europe. It is a non-profit organization owned by its partners. Eress is developing, implementing and supplying energy settlement solution called Erex. The current Eress partners are Rail Net Denmark, Belgian Railway Infrastructure Manager, Bane NOR, Swedish Transport Administration, Finnish Transport Agency, Swiss Federal Railways and Dutch Railway Energy procurement cooperative. (Eress n.d.a)

2.3.1 Current implementations

At the moment, there are basically two different models: train run based and traction unit based settlement. Train run based model is used in Finland, Switzerland, Belgium and will also be used in the Netherlands. This model is a primary objective for using standardized solution. The Scandinavian countries Denmark, Norway and Sweden are using traction unit based settlement. In the traction unit based settlement the bills are directed to each traction unit based on the meter in each traction unit of rolling stock. It can be a locomotive or a composition which can be a set of wagons that have no separate locomotive but is a fixed set of wagons. In the train run based settlement, consumption of traction units is split for each train run reported to the traffic management system. The train run based settlement is more advanced way of settlement.

Eress has been growing during the years partner by partner. Similarly, the Erex solution has been developed and improved for each partner to fit their national requirements. In the past few years, it has been growing above such limit where handling separate instances is getting more challenging. Maintaining these diffused implementations has been getting more difficult. From this basis, the idea of common model has been raised by Eress and its partners and the developers of the Erex system. In literature, the ideology of products sharing a common model is usually referred as a product family.

Inside these two models there are still differences in the implementations. These are results of the way how Erex is developed and improved for each partner. In short time, the objective is to have similar implementation for Finland, Belgium and the Netherlands. Later Switzerland might join. In more longer perspective, the objective could be also to adapt Scandinavian countries to have a similar system, even though it might be built from modules and include a lot of configuration if the base for settlement is still different. It would require more development and changes in the practices than the harmonization of the current train run based implementations. If the countries would leave behind traction unit based settlement and start using train run based settlement, development would be needed in the traffic management systems and their interfaces to Erex.

Finnish Erex is the newest and the most mature Erex solution. It came an example for other Eress but also for possible future partners. Both Eress and Finnish Transport Agency paid attention to developing a general and common train run based model from the beginning. This solution fulfils all the European Union requirements.

2.3.2 Foundation of Erex

Development started from the traction unit based settlement model. The purpose was to develop as generic solution as possible. For example, it has support for different energy types (5 minutes interval, 1 hour, 1 week, meters that are read only few times a year and so on). The exchange function for sending data to other countries was built as part of the

system. It checks GPS-position and verifies if the data is from the right country or from some other countries, in which case the data is sent to that country's settlement system. In the beginning, there was the supposition that metering data is already exchanged, validated and corrected by using some kind of smart DCS. However, this supposition was proved wrong and this needs to be done in exchange function. For the newest meters, the traction unit based settlement model uses common Erex Exchange module, that is standardized and used in all the countries utilizing train run based settlement too.

When a new country (Belgium) entered this partnership, it was found out that they will not settle traction units but train runs. This changed the system quite a lot how it handles metering data and allocates it for trains. Train run data and its validation was introduced in Erex for allocating the energy and combine energy data and train run data. Because this model was very different from the previous one, calculation of settlement was also updated. At the same time, specifications for sending train run data for international trains to other countries was introduced by UIC.

After few more members, it was found out that there had been no incentive to make the system smaller. The objective had been to make the system flexible to use for all parties which made the system grow. It was found out that improvements need to be done on both software and hardware side to enable cost effective maintenance. At that time, it was seen that two more partners will start to use train run based settlement model. Their systems were somewhat different due to different needs and their provided input and needed output data. At this point it was decided, that this model will be developed to be as standardized as possible. This is still an on-going work.

2.3.3 Erex processes

Erex is built from various processes. The Figure 3 below explains the processes and procedures of Erex but as well the environment in which Erex is used.
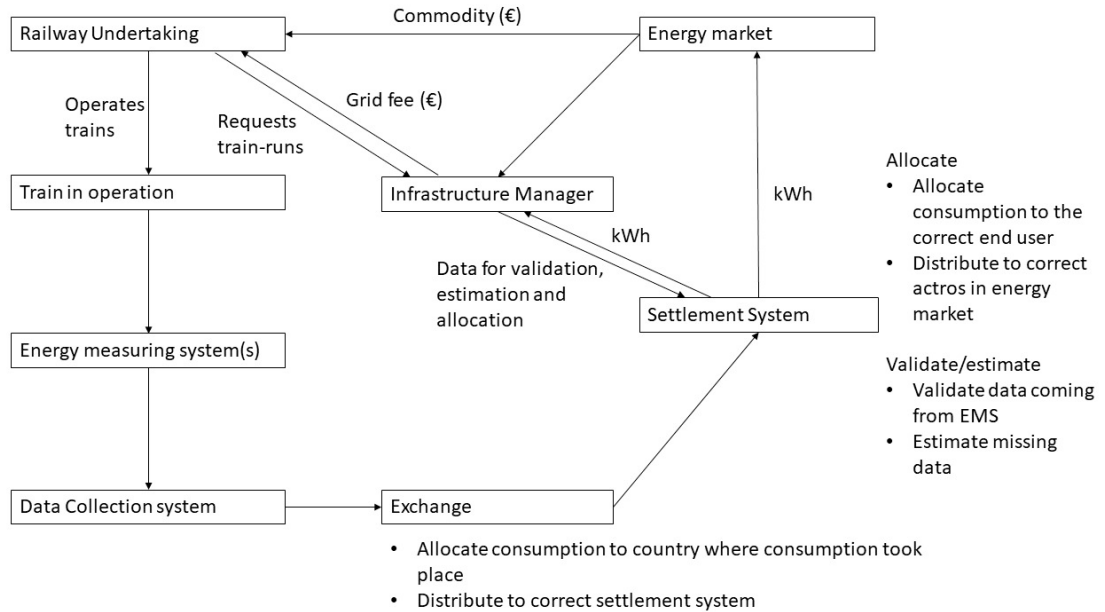
Figure 3. *Erex and its operation environment*

Railway undertakings operate trains and report their consumption to energy measurement systems (EMS) introduced in LOC&PAS TSI (The European Commission 2014b). This information is sent to data collection systems (DCS) defined in ENE TSI (The European Parliament and the Council of the European Union 2009). The data is sent from DCS to exchange function of Erex that allocates the consumption and distributes it to right settlement systems. The settlement system validates and allocates the data and sends it to the infrastructure manager and to energy market if required. Infrastructure manager may also send data to settlement system from their fixed consumption and from their substations. Infrastructure manager invoices grid fees from the railway undertakings who operate in countries with agreements made with the infrastructure manager.

In this chapter, the legal and system frameworks for the case software are introduced. This includes the structures and regulations on European level but also in countries, where the European framework is put into practice. Moreover, the case organization and software were introduced. In the next chapter, the means and methods for empirical research are presented.

3. EMPIRICAL RESEARCH

In the following chapter, the research techniques and procedures for empirical research are introduced. On their basis, the research material was selected, collected and analyzed. The process for collecting data and its analysis are also explained in the chapter.

3.1 Research material and data collection methods

Research material consists of documents, qualitative interviews and their material together with theoretical material. Documents include laws, network statements, company brochures that explain business models, documents about current implementations that explain the practical domain issues and some other relevant top-level documents about Eress' partner countries operating environments. The selection of research material has largely been influenced by the constraints and targets of the research project.

Further data was collected face to face from Eress administration, Erex developers and from Erex responsible in each of the countries. The framework of questions for the focused interviews includes questions from many topics such as current implementation, processes and practices, laws, agreements and network statements, roles and partners, energy market and interfaces. More than half of the questions were same for each interviewee and will be adapted for their know-how and field of specialty. In addition, there were specific questions for some interviewees about specific country or field of specialty such as marketing and communications or development of the system. The interview questions can be found from appendix B.

These interviews were recorded. The interviews were replayed and important parts and found challenges were written down. This was the basis for content analysis. Only the manifest content was analyzed as hidden messages are not important for the interpretation of interviews. The latent content would not have affect the answers to research questions.

The selection of research material has been affected by the project client organizations requirements and propositions but also the findability of appropriate data and researcher's own subjective interpretation of the suitability of material.

Theoretical material was utilized to support research. Database searches have been done to find relevant research material. In addition to found relevant articles, references and articles that have referred to this article, were taken into account. The focus was on articles that have received the most referrals and on the latest research results. However, the material was limited and thus there was no need to limit the material particularly.

3.2   Methods of data analysis

Content analysis was selected as an analysis method for the study, since the aim was to identify the content and find existing differences that cause challenges for standardized system. Based on the qualitative research method, unstructured material and open research questions, content analysis has been selected as analysis method. The method can analyze documents systematically and objectively. Content analysis seeks to organize the research material clear and concise format without losing the information value of the material. (Tuomi & Sarajarvi 2009, pp. 103-108) Content analysis is a basic analysis method that can be used in all traditions of qualitative research. Most of the different analysis methods in qualitative research are based on content analysis to some extent. Content analysis can be seen as a loose theoretical framework for the analysis of content that is written, heard or seen. (Tuomi & Sarajarvi 2009, p. 91)

According to Tuomi & Sarajärvi (2009, p. 108), qualitative data processing is based on logical reasoning and interpretation in which the research material is broken up into parts, conceptualized and reassembled into a logical entity. In practice, it means that the classifications will rise purely from the research material and the material will be classified. Then, similarities and differences are searched from the classification so that the classification can be combined to create a set of upper and lower level categories. (Tuomi & Sarajarvi 2009, p. 109) This process provides a logical entity which can answer research questions. The analysis is based on interpretation and inference, which provides new views of the phenomenon. Finally, the empirical data is connected to the theoretical concepts and a theme or concept model formed from the material is presented. (Tuomi & Sarajarvi 2009, pp. 95-113)

After the interviews were concluded, challenges were listed while replaying the interviews. The analysis was primarily based on transcripts of the interviews. However, additional information was taken into account, including the impressions of the researcher who was present at the interviews. Also received documentation, and written notes of the interviews were utilized. The challenges found out from the interviews were given a category and importance (scale 1-3). After this, categories were approached as whole. The most important challenges were copied to a second sheet and written in a more understandable form. They were also given a category name. These categories were again analyzed and their groupings revisited, which resulted the challenges that are the main result of the empirical part. According these groups, supporting material and challenges found a search from the literature was done for similar themes. When search and analysis of the theoretical part and challenges found there a comparison was made to see if the challenges are similar in both empirical and theoretical part. The challenges were combined and categorized into three categories: the challenge was found in both empirical and theoretical parts of the study or the challenge was found only from the literature or the challenge was found only in the empirical research.

This chapter has concluded the methods and techniques used in empirical research. In the following chapter, the results based on these procedures and techniques are presented.

4. EMPIRICAL FINDINGS

In this chapter, the empirical findings are presented. The topics discussed in interviews are manifold and include topics like laws, standards, railway and energy markets, data, practical domain, business models and partners and many other.

4.1 General findings and observations

It has been widely noticed that the national requirements prevent using one fully standardized system that could be adopted to new countries without any adaptation. The requirements vary in relation to railway and energy markets, business models and daily practices. This means that the system needs to take into account all the relevant differences such as differences in input data, different practices for accepting data and different needs for reporting the results. The general challenge in this domain is that energy market is meeting railway market for the first time. Electric trains have been running for decades, but their cost of electricity in delimited railway grid can have been assigned for the national railway undertaking. Market opening requires new methods for cost allocation and thus the markets are more closely bound than before. Both markets have existed for a long time and can't be directly adjusted to fit each other. They also have some contradicting requirements. Which one to follow in each situation?

The national environments and requirements do not enable 100% standard Erex solution. To have a fully standardized system, the domain environment should be standard too. If a 100% standard system would be built without having a standard environment, the system would get very complex and difficult to handle each situation. The challenge is to decide what is common, what is variable and what variability is not supported. Compromises shall be made to solve the challenges in one system. At this point, modular system is most admitted direction for the development. In that kind of system, countries could choose which modules they what. The modules should be easily compound. To enable such system, clever architecture is needed.

With regards to energy market, the practices are at least as varied across the countries as in the railway market. The countries have very different requirements for energy with respect to railway market as the European Union energy market directive has not been implemented on the railways yet. The requirements of what should be reported, when and expected quality vary. Also, the purchasing of electricity is different, specially on railways. Thus, the question is that should Erex be standardized with respect to energy market or only towards the railway market?

The general challenge with respect to the energy market is that the railways are the only energy users that are moving across the countries. Inside countries there is neither much

moving consumption. The challenge is to see how much a single user has used electricity from a single substation as it has been moving between the substations. Traditional consumption of electricity such as housing, has been widely standardized. Railways are a relatively big user of energy but still only one of the users and very specific kind. This limits the possibilities of railways to affect the ways of proceeding in energy market. This means that railways have to adapt in some way to the way in which the energy market operates.

Shared rules, standards and regulations aim at standardizing the domain and practices. This means that the very positive aspect of regulations of European Union is that all EU countries shall follow them. Besides that, most countries follow international standards written by UIC, which has built the basis requirements and processes for energy settlement in railways. These multinational requirements are the basis for Erex. However, apart from international regulations, country specific legal and system frameworks need to be respected when implementing a settlement system in a country. In addition to laws and regulations, all specialties such as price areas, calculation formulas of losses and fees and formulas for estimating energy consumption need to be noticed. These type of practical matters and processes are special for the countries. However, most of these practical domain challenges can be solved by configurations. The challenge in the practical matters is that they need to be known so that they can build into the system to be ready to be configured.

The incentive for finding a common Erex model is that common model enables cost-efficient development, maintenance and operations. The common framework fits the EU legislation and can be easier updated when the regulations and standards progress. To find a common model with reasonable number of variables, each partner needs to be flexible to gain benefits. If all countries wish to have huge number of specific functionalities, the gain of the common model might be smaller. In addition, the common model is difficult to achieve in such situation. According the experience of the experts, many of the wishes in the countries can seem very special at first glance. At the end, the needs are more or less the same in each country. The terms and ways of defining requirements are special. This is already recognized. Still, some may want to hear that they are special, the experts say. Accepting this and understanding the real differences is a key to success. To meet these objectives, a lot of communication between the partners and Eress administration is required. Even the Eress administration and Erex developers can see different problems and same problems in different ways. The process of standardizing Erex involves lot of stakeholders and parallel projects. This makes it more challenging to create a good overall picture. However, in such situation it is even more important to have a common understanding what this project includes and demands. Therefore, communication is crucial. It has been noticed that developing such a common model for the system is a big challenge but is also a huge opportunity for all.

4.2   European and country specific laws

The guidance and regulations of European Union form the basis for settlement systems in railways. However, not all current partners are members of European Union. Norway is part of European Economic Area (EEA), which means that it is not a member of EU but follows the rules and regulations set by EU. Switzerland is not a member of EEA either, but has bilateral agreements with EU and voluntarily adapts many of the EU laws. Still, some differences appear and many referendums are used. In railways, it has been seen that following EU regulations is requisite and very beneficial for Switzerland as it is surrounded by EU countries. What is most important, Switzerland does not have laws that contradict with EU laws in this area.

The laws and regulations of individual European countries follow the laws and directives set by European Community. The Directorate-General for Mobility and Transport (DG MOVE) and The Directorate-General for Energy (DG Energy) are departments in the European Commission responsible for setting the laws under this topic. As there are so many gross European rules, country specific laws and regulations do not have heavy input on the development of energy settlement and settlement systems as long the systems operate in European countries. Country specific differences appear in lower level issues and closer to the operational practices.

The risks and challenges related to European wide laws are presented next. Even though there can be risks with the laws and standards, it is a good trend having such common laws and standards on the European level so that such common development is possible at all. In the beginning, there were no common regulations in Europe about energy settlement in railways and the practices and maturity in the countries was varying a lot.

4.2.1   Challenges related laws, directives and country specific regulations

European regulations form general guidelines for the operations of energy settlement but do not assist in all details. The written regulations are not detailed enough, which results in all countries adjusting them in a different way. If the requirements of European Union would be tightened, there could be disharmony between European Union laws and national regulations. Even at this point, there can be some disharmony between national and EU laws. National laws can have been written when the laws of European Union were general or there were no such laws. The best way to prevent this challenge is a good knowledge of the law makers.

International Union of Railways (UIC) develops standards for practices and processes of energy settlement. This means that is a natural place of being present for infrastructure managers. However, being present there may not always be enough as the laws are written elsewhere. European Rail Infrastructure Managers (EIM) represents the common interests

of infrastructure managers in Europe, specially towards European Commission. EIM is an important way to influence the preparing process of TSI documents at European Commission. EIM is also the organization that can choose people into working groups under European Commission. If lobbying will fail at some point, it is possible that there could be unfavorable or new competing standards.

In addition, there are few political risks related to laws, regulations and standards that aim for standardization. Different political parties can push through their different political interests. There is a risk of governing something, where no practical solution has been developed or the solution is supposed without understanding the practices. A risk related to dealing with EU might be that several countries leave EU, when EU regulations and standards would not apply anymore and countries could choose their own systems and standards.

The challenges with country specific laws and regulations mainly relate to time when there were no common EU regulations. Later, international regulations have revealed contradicting country specific regulations. Moreover, many of the practices have been developed by the regulations so there may not have been much to be changed. Nowadays, there are more cases where EU regulations are too general and national regulations are needed to assist in the details. Therefore, the challenges appear often if the ministry in question or infrastructure manager itself have set many detailed requirements for the subject for example in network statement.

The challenges related to varying energy laws will be explained later.

4.3   Standards and standard making bodies

In addition to laws and directives, there are standards that are followed by infrastructure managers. European Union Agency for Railways (ERA) has given the task of developing standards for CENELEC. ERA has created the need for standard and European Commission and Parliament have accepted the need. CENELEC standards focus on metering systems and to interfaces on board. ERA communicates with European Commission and advises them when needed if something should be included in TSIs/laws.

UIC is an International Union of Railways. The members of the union are railway undertakings and infrastructure managers. UIC provides standards, which are not legal frameworks, but are suggested to be used. Most of the infrastructure managers follow this piece of advice. Standards provided by UIC are based on CENELEC standards. When CENELEC standards (such as EN-50463) or TSIs are updated, there will be pressure for updating the UIC norm, because the standards are highly dependent of each other. For example, in future a new format can be used for reading data from the meter without a

DCS. All the standards focus on billable CEBD data, validation of data and settlement of energy.

What has been accepted in CENELEC or UIC, will be implemented also in Erex. One of the coming updates is the change from UTILTS into XML format. For Erex and other settlement systems, it is important to accept the fact that standards evolve in each of the interfaces. On the other hand, the standards provide a standardized protocol that can be used for other demands as well. By this means, the data can be faster send to other systems for other use cases like energy efficiency.

4.3.1 Challenges related to standards

It has been admitted that Erex has been built on very close to existing standards like UIC Leaflet 930. Standards are a great help as they are multinational by their nature. However, the challenge is that standards can get outdated and after some time updated measurably. In those cases, it can be a challenge that the system and its architecture is build close to the standards, which makes the upgrade to the new standard challenging. The outdated and changed standards can increase technical depth of the system. Technical depth is caused by decisions made in the past. For example, in old UIC standard there used to be only one energy type in one energy consumption time series. However, meters collect four types of consumption. This means that there are different files for active consumption, active generation, reactive consumption and reactive generation. The new CENELEC standard has fixed this problem, but the implementation in the system needs to be upgraded and all the dependents shall be updated too.

As the directives of the EU and CENELEC standards are published lately, the UIC leaflet shall be next refreshed to meet the other regulation. The outdated leaflet causes some challenges. Last update of UIC leaflet was made when traction unit based settlement was more common than train run based settlement. For countries that use train run based settlement, the rules may cause challenges. For example, wrong GPS can be rejected even though later in the process, when train run data is imported, it could be verified where the train has been, based on the train run data. This can be a problem in areas, where GPS is easily lost such as tunnels. This may cause the data to be rejected. Later, some development has been done on the system side, but still the process does not fully support this challenge. Standards do not describe things how they should be but how they are now. If something new is being development, some wrong decisions can often be made. After some practice, it is seen how the standard should be.

The other challenge relates to standards is that they are not detailed. This means that often the last mile is accommodated case by case, usually defined in the network statement. This will result in differences in the implementation. Of course, the standards cope with the same challenges than settlement systems: it is difficult to develop something that fits 100% in all the countries. Moreover, standards are not detailed by their nature. But still,

if standard way for something is missing, it will lead to several ways of doing the same thing. In those cases, countries will make their own decisions, which should be avoided. This will also lead to cases where something is already implemented when new standards are developed.

Erex discusses with its regulatory partners preparing regulations and standards actively. In addition, there are good possibilities for infrastructure managers to participate in the work. Even though the relationship is good, there is always dependence on the standard making and regulatory bodies and their decisions. For example, it is not sure before the final acceptance what kind of things the new norms will include. The system developers should know, but they can't be sure and they need to wait for publication to see if renewed standards force something to be added or changed in the system.

4.4   Railway market

The vision behind European Union's directives is an open railway market across Europe. For this purpose, a common way of handling electricity has been developed. For example, similar practices for handling electricity of international trains contribute to openness of the market. This type of collaboration helps Europe also in competition with other large economies. Still barriers exist. Railway markets are very nationally oriented since they have been historically in military use. Regulations are looking for compatibility, but the industry is changing very slowly. This results in a non-standard domain across the Europe. Each infrastructure manager has its own infrastructure, systems, practices, processes and businesses. They have been developed separately and have different technical details but also in a more general sense. There are different laws and requirements, business models, systems and practices for using the systems, reporting train runs, owning the vehicles and so on.

This incoherence challenges for example freight that operates through Europe. Rail Net Europe works as one helping point that assists railway undertakings but there are still challenges existing. Specially for small railway undertakings the barriers are large as a great effort is needed to start the business internationally.

4.5   Energy market and energy laws

Energy market varies a lot across the Europe. Standardization has started on European level with regards to security of supply, energy flow between market areas and spot markets but still, these regulations are general from the perspective of a railway undertaking. For railway undertakings, it is challenging to fulfill all the varying national regulations. The situation is so difficult that some companies have started to work as service providers for railway undertakings and help them dealing with these multiple requirements.

European Union is working for common rules for energy markets. One of the working documents is network codes that is a draft made by an organization of transmission system operators (ENTSO-E). The document describes the different aspects and rules of energy market. The document will also set requirements for information exchange and balancing. Alike TSIs, this document will be applicable in all member states when it's being accepted. It is possible that the regulations apply only to new or upgraded installations.

DG MOVE and DG Energy work on their own agendas in the Commission. They co-work when such topics appear but as apprehensible, the co-work can sometimes be challenging. The problem is that implementing energy guidelines in railways is always a bit special. Thus, overlapping regulations can exist. In railway sector, specially infrastructure managers usually choose over railway laws instead of energy laws if they have the possibility to choose.

Third Energy Package will be implemented in different ways in different countries in respect how will railway sector relate to the regulation. The question on the railways and their specific networks is, which one is higher regulation, TSI or energy code? Which one will be followed if there are contradicting regulations? In railways, railway regulations usually overwrite. Will railways together lobby energy code in some way? For roles that act as transmission operators, following the energy laws is straightforward and mandatory. If the railway regulations do not describe how to proceed, then rules of a closest distribution system will be followed. Because not all countries have yet implemented all parts of third energy package, it is not yet sure how the regulations will be applied.

How railways fit in the roles defined in energy code depends on the role given for infrastructure manager. The network code defines actions for different roles. However, the roles given for infrastructure managers can vary. For example, in the Netherlands Vivens purchases all energy fulfilling some of the roles in grid settlement but at the same time, does not have access to all necessary data to fully fit the role. Vivens is a partnership of railway undertakings which means that Vivens can't have all classified business information of the railway undertakings.

So far, energy directive has not yet been affecting a lot. However, it will have a great effect when it is implemented everywhere. The directive will define how the meter should be and what happens when the costs have been divided for the consumers. The vision is that energy laws will be applied to these processes and railway laws will define only the metering part. Earlier infrastructure managers have sold the energy for railway undertakings and energy laws have controlled only the way how the infrastructure manager has purchased the energy. In the future, energy laws will have a greater role.

Most of the countries have a closed railway grid. In Finland, there is a specialty of handling railway grid as an internal network of a real estate group. It is not a separate grid as the railway grid is connected to the open distribution network through substations. This means that there are no responsibilities of a closed network and thus the regulators have decided that it is enough if only the railway regulator controls consumption within the railway grid and the energy regulator controls energy consumption only from substations onwards. Elsewhere, energy regulator can also participate in controlling the railway grid. In Finland, there is only one party managing the railway grid whereas at least in the Netherlands and Switzerland there are multiple infrastructure managers within the grid already. However, this may change in the future in Finland too. There might be a company responsible for transport network, which can have private parts. In those cases, railway grid would have separate parts and the energy regulator would start controlling this grid too.

The energy laws of each country define how long settlement data needs to be available. In Switzerland, the requirement is 3 months. In other countries, the time periods are longer. In Belgium and Finland raw train run import data needs to be kept for one year so that it is possible to reprocess settlement. In Norway, corrections need to be able to be done 3 years back which means also rerunning and correcting settlement.

Energy directive defines that all consumers have the right to choose their supplier. This is not yet implemented in railways in many countries. The activities and current situation will be explained in next section.

4.5.1 Purchasing energy

The energy market varies across European countries with respect to the possibility of railway undertakings to choose their own supplier. The possibility of choosing the supplier is called third party access.

Third party access has been implemented in Finland. In Belgium, it is theoretically possible for railway undertakings but the network statement says that all units need to be metered to enable third party access. As there are not that much meters installed for any railway undertaking, infrastructure manager buys all the energy so far. In the Netherlands choosing own supplier is not available because at the time of writing last contracts, third party access was not yet implemented in the Netherlands. There is also an incentive to purchase the electricity collectively as the tax structure is layered, which means that the higher the volume, the smaller tariff.

In Switzerland choosing own supplier is also not possible as the energy department of the national railway undertaking provides all energy for railways for the closed railway grid. Energy department sells the energy for infrastructure managers who sell the energy for railway undertakings. This is not going to change during next years but maybe one day.

In Switzerland, there is an own transport network including own transmission system and product plans. In Sweden and in Norway the grid is similar but they have much more converters between public grid and railway grid. To be able in practice to purchase the electricity freely from another grid, enough converters between the grids are required.

As Finland is the only Erex partner currently providing third party access, the functionality was first implemented in the Finnish instance. How standard the solution can be in the future, is depending on how the third-party access will be implemented in each country, legally and practically. Implementing new laws can be difficult. For example, in Sweden it has been discussed that if the railway undertakings are given the possibility to choose their supplier, then also the residents close to rails shall to be given the change to buy their electricity from the railway grid. Laws of countries can affect implementation of such new movement or at least such discussion can appear.

The higher the volume of operation and consumption of electricity is, the meaningful it is to operate in energy purchasing market itself. Buying the electricity without any helping organization requires electricity market knowledge. Therefore, with low volumes purchasing electricity from the infrastructure manager can be more reasonable. Even though the infrastructure manager may purchase a massive amount of electricity, it is not necessarily cheaper. The price depends on agreements, prediction and time of purchasing a price hedging. Dealing with price hedging is risk management as the maximum price is ensured.

Different perspectives to purchasing electricity exists. Some say that if a government owned railway undertaking purchases the energy in the pool of government, then all other railway undertakings should be able to purchase their electricity from that pool. But can the government purchase electricity for private companies? There are different conclusions of this in different countries. Discrimination is an important topic in the railway markets on TSI level and some countries like to avoid such cases more carefully than others.

To be able to enable third party access, the railway undertakings need to be able to report their consumption to the energy market. That is needed for balance management. Time intervals, where balance management need to be done, are different in different countries. In Nordic countries, where Nord Pool is used, the consumption is purchased and reported hourly. However, that will change into 15 in the coming years. In Belgium imbalance is reported every 15 minutes. Still purchasing of energy is done hourly. In Belgium, it is sufficient in some cases that the consumption is equal to used amount of energy every hour or even by day if the amount of consumption is low. Reporting to energy market is described more briefly in next section.

4.5.2   Reporting to energy market

From the perspective of a settlement system, freedom to choose the supplier requires some actions. The system needs to send the information to the right supplier, balance responsible but also to imbalance settlement party. Distribution operators define the formats for data exchange and they also evolve from time to time. For example, in Belgium UTILTS-messages will change into XML. The transmission system operators can provide a service where they exchange information between the market actors. Even though there would be actors taking care of the changing of data, the right data needs to be available.

Reporting to energy market has been started in Finnish Erex in autumn 2017. There are various actions that need to be done in the settlement system side for that purpose. One of the most evident needed process is the projection of moving consumption into fixed consumption, as energy market does not handle with GPS-data. The challenge is great specially in countries where there are multiple price areas. Communication of imbalance for the imbalance responsible eSett was something new too. Currently, there are different formats for reporting to eSett and electricity providers but next year this consumption data will be sent to a hub where relevant parties can collect the data they need. Because implementing these functions in Finland was the first exercise and other countries come behind, it is not yet sure how applicable the solution will be for other countries. The data contents and needs for reporting in other countries would be similar. However, the formats and rules come from the imbalance responsible and thus reporting in other countries might be different except the Nordic countries that are part of eSett. That is where the hub helps.

Exchange from grid users to energy market has not yet been standardized between the countries. Protocols exists within countries though. Railways are one of rare or only consumers who move between the countries. At the same time, railways are only one consumer on the market, which means that the energy market will not be developed only on their terms. The closer railways get integrated to the energy market, the more specific means are needed. This may require an additional service provider that prepares the data for energy market.

One of the biggest challenge when reporting to energy market are the SLA requirements for timing and deadlines. Energy markets are commercial and organized whereas in railways are new with the whole topic. If the information is used for energy purchasing in day-ahead market, the consumption for next day should be known by noon. Intraday market is a place for operators to trade their consumption for the next hours, which means that regulation prices and power are traded hourly between the consumers and transmission system operator. The laws require to report great deviations from the planned consumption or production too. Railways are new in this kind of market as they are used to purchase electricity and be invoiced long term. Now it is possible that the pace

is speeding up. From DCS the data can usually be send within an hour even though the requirement for DCS is to send the data within 24 hours. If the data is sent through exchange, processing takes some extra time compared to sending the data straight from DCS. Data available in DSC is not yet validated and thus some validation would be needed if the data won't go through exchange. When will the data be needed and what is the quality requirement? There is an obvious risk of delivering low quality data. This describes the challenges of operating closely with the energy market. Currently, only Nordic and Baltic countries have advanced energy market regarding SPOT, balancing and regulating markets whereas in other countries the energy markets are still much more primitive.

It has been recognized that SPOT-markets are very difficult markets for railway undertakings to operate. Current practices of purchasing the energy vary across the countries. Service providers are used to deal with energy market and infrastructure managers or railway undertakings often use long term agreements for energy purchasing with the help of service providers. However, variations are high between countries. For example, in Norway infrastructure manager purchases the energy and operates at SPOT and balance markets. In Sweden, energy supplier does this for infrastructure manager. Currently, in Switzerland the laws when billing data and corrections need to be available are tighter than in other countries. In other countries, settlement is done usually on monthly basis even though energy market itself is running a more frequent cycle.

4.6   Data

Lacking available data and its quality is a big challenge for settlement systems and their operation. The available data and interfaces obstruct the standardization efforts of the system. The reason is that usually a settlement system needs to be modified to meet the data available as it can be very difficult to request changes for example to large traffic management systems. Low train run data quality causes one of the biggest operational challenges. Challenges of train run data are discussed in next section.

4.6.1   Train run data

Train run data is received to settlement systems from traffic management systems of infrastructure managers. The systems tend to be old and complicated but more importantly, not standardized at all. Energy settlement is only one of their use cases and thus it can be challenging to request development for this purpose only. The systems include complex sets of subsystems but also multiple processes and practices behind them. Thus, requesting specific data or asking improvement to data quality can be very challenging. Some of the countries are working to improve their systems but it will take years of time, which can't be speeded up. However, one of the reasons for low quality

train run data are the reporting practices that are not precise. Assisting to sharp reporting can be challenging too but at least, that should be easier than instructing the systems.

If there is no right or high-quality input data available, train run data based settlement may not be a good option. The development of traffic management systems might help with both problems but before the development is done, the only thing to do is to improve the processes that create input data to traffic management systems. The same challenges complicate all the countries that are using train run data based settlement model.

The operational challenges with low quality data are such situations where data causes errors or is missing. There is also a question of what should be done when low data appears and something is missing or is wrong. Countries handle situations where for example EVN is missing differently. Some countries do not send the data to settlement system and somewhere the data is processed but not settled. Altogether, special knowledge is needed to understand if some low-quality data is real or is incorrectly reported. For example, in the middle of a train run there can be a stop of one hour where the train can consume energy or it can't. The real situation can be difficult to explain with the data. As the expectation is a right amount of energy settled, the realistic situations need to be recognized. The more automated the system and its validations get, the challenging it is to build in all special cases that can happen.

One of the biggest challenges of standardization is to find a shared format for train run data. Even within an infrastructure manager, there can be various forms for data depending on the railway undertaking. Typical examples of variations include waiting time, start and end points of train runs and expression of whether the starting point was in a different country or not. In addition, the granularity can vary whether every section or only the starting point and end-point are reported. These variations raise discussion even within some infrastructure managers. The more countries join the same system, the more challenges may arise. The challenge has been identified also in European level where a shared solution is being developed. The current standard for train run data is not detailed enough and countries have adopted it in different ways or have not adopted it at all. Currently, Erex has been developing a web service and format for train run input data to deal with different countries. The format defines entities that can uniquely define a train run. Currently, there are some differences in what is sent and how often.

4.6.2 Metering data

There are differences in the meters and the data that the provide. There are different types of metering resolutions that the system needs to handle. Modern meters have either five minutes or one-minute interval, whereas old generation of meters can send their data hourly or in some cases reading is done manually. However, those old meters are about to retire soon. CENELEC standard requires five minutes interval for new meters but in some countries, one minutes has been chosen as time interval as it allows more frequent

analysis. The meters that fulfill the requirements of standards, send CEBD in similar ways. However, meters can have some additional functionalities that can be used for additional purposes.

It has been recognized that if same traction unit set or even within a country there are both one-minute and five minutes interval meters, it causes some challenges for validation. For example, configured maximum power is higher for one-minute time than within five minutes, as the consumption evens out. These values are configurable and therefore it needs to be considered if both time intervals can be used within one country. Moreover, attention should be paid for trains and their meters that move across countries too. The challenging part with international trains is that metering data is sent to the visiting countries only if there is an agreement between the countries. Closing such agreement can be challenging.

One special difference related to data is that In Switzerland data protection laws do not apply only for persons but also for legal persons. Railway undertakings are considered as legal persons. This means that they have the same right to data collected from them as natural persons. Data protection laws are overall tightening in Europe when General Data Protection Regulation (GDPR) will be implemented in May 2018.

4.6.3 Interfaces

Under the circumstances it has been seen that varying interfaces provided by traffic management systems prevent a fully same system. Different meters require also some flexibility from the interfaces provided. Further, not only input interfaces are different but specially the output interfaces to settlement systems are very different. Also, the availability of interfaces varies. For example, in Denmark no interface to substation data is available and thus adding substation data to the settlement system requires some manual work. Having standardized interfaces at least to some extent would help the overall situation. The logics of the interfaces should be same at least the same for everyone. This would help in finding a common model for the settlement system.

In the future, if several countries start to use same interface, the interface shall be well defined. Also, the communication and versioning of the changes need to be well managed. If the countries use shared interface, more updates can be expected. Specially in Switzerland, where an internal software system is closely bound to Erex, changes need to be very well informed so that deployment processes are simultaneous, which is very critical in production. Next, the specialties of input and output interfaces are reviewed in more detail.

An objective of Erex is getting a standard form for input data, which would help when creating the interfaces. At this point, there are still differences in the inputs and their contents. Especially, Switzerland has a totally different input compared to other users as

they send estimated consumption instead of travel information and weight from which Erex calculates the estimates. From the standardization point of view, it would be an objective to receive trains' travel information and weight in a standard way. Most of the countries send gross ton kilometers, whereas the Netherlands uses carriage kilometers, which take note the possible number of passengers and their weight. This kind of differences can be configured, but the logics should be the same.

Besides the different contents, the interfaces can be very different and this may not fully change in coming years. Countries have developed complicated traffic management systems where provided interfaces vary. It can be a difficult task to persuade infrastructure managers to develop standard solutions that would enable standard communication between the systems. The persons responsible for the development of the systems do not participate in energy settlement. The challenge with the traffic management systems is that they have complicated background systems. They vary as well and almost each railway undertaking has its own systems for planning train compositions, which then report the information to traffic management systems. The possibility of having standard interfaces would be best realized if it would be set in some norm. However, similar logic for input would help too.

If the possibilities of standardizing input interfaces seem problematic, standardizing output of the system can be even more challenging. Invoicing systems are large systems used for all types of invoicing at infrastructure managers. Energy efficiency systems are similar by their nature. They are large and many different systems exists on the market. The reality with these large commercial systems is that the software providers tell the possible interface or interfaces. Similar types of challenges are related to reporting to energy market, which were discussed already earlier in section 4.5.2. This all means that no standard interface is expected to the settlement end in few years.

Currently, there are various interfaces for settlement results. Current selection includes automatic and reloadable XML, invoice appendixes, excel sheets and PDF files. The result of the settlement can be somewhat similar but the final implementation is not the same even for few countries. The reasons are different accounts, structuring of accounts, taxes, fees and so on. For example, In Finland, gross energy needs to be reported separately so that transmission of electricity can be invoiced separately according to laws. Even tough variabilities exist, generation of files can be similar.

4.7   Current and future modules of Erex

Currently, there are two different models of Erex, which are kind of two separate software systems. The models are train run based and traction unit based settlement, which refer to the billing object. In addition, there is a separate model for exchange, which receives meter data, validates it and sends it to right country's settlement system. In traction unit

based model, there is included also an old exchange part. However, new and advanced meters send the data to shared exchange module of Erex.

The main standardization objectives focus currently on the train run based model, which is a more developed model. Still, also the traction unit based model also has variations between its implementations. The traction unit based model will be alive and used at least for the next years so possibly some standardizing efforts should be addressed there as well. However, it is possible that after some years, the current users start to use train run based settlement instead of traction unit based settlement. The reasons might be laws or practical challenges. Practical challenges may appear for example if multiple railway undertakings use same traction unit. In those cases, it would be challenging to know, who should be invoiced. Political decisions may change the business models of who is operating and who owns the vehicles. However, to be able to change into train run bases settlement, there should be a possibility to report train run data from the traffic management system. Still, it is not yet known what will be the future of the countries using the model nowadays. One of the possible would be a modular system, where billing objects would be traction units but the module would have some benefits of the train run based model such as automatic input of train run data into the system to be used for validation. This input would bring in the ton kilometers for trains with no meter or having errors in the meter data, which requires nowadays manual tasks. If the system would get closer to train run based model, should they be combined or kept separate in two different environments? Is it possible to use same core and have different validation, estimation and allocation methods for different billing objects? That is a decision to be made by the architect.

Because the billing objects can be different and change, in an ideal world a standard solution should not define the billing object. Therefore, in the long run, the objective might be a standard system that is not restricted to any specific model that exists nowadays. Such ideal standardized and common model is presented in the next section.

4.7.1 Common model

As explained in previous section, there are different visions for the targeted model. One of the possibilities is a common model that is not restricted to either train runs or traction units as billing objects. The target might be a standardized core solution where additions could be made. The better would be, if there was a standard set of building blocks offered including different functions, where requisite parts could be chosen. From the point of view of new partners, they could review the offered superset and choose functionalities that they do not want to have. Still, it shall be remembered that the system has to meet some differing requirements like laws but it should neither fulfill all nice to have features.

The knowledge how the system should work, grows over time and experience. Naturally, a clever solution and basis for the system is needed. When specifications for the basis are

agreed, the system can start to evolve. When having a common solution, all instances can be changed at a time. This helps maintenance and development of the system. When same code exists in different instances without shared modules, changes need to be copied and tested in all instances to make everyone benefit. Testing gets difficult because in addition to testing each functionality, they need to be tested in each of the instances as long they are separate. Complex implementation causes that unexpected implications can occur when changes are done elsewhere. These are the challenges of clone-and-own practice, where new instances are built in ad-hoc method applying code used elsewhere.

4.7.2 Strategic guidance

There are many definitions for common model. Different persons may understand standard Erex and its common model in many ways. What it does mean to have a standard Erex? It may not be 100% same for every country, but in which way it should be standard? It has been agreed that totally same system might not be an option as the country specific requirements need to be met. If such system would be built, it would get very complex. However, standardization is not only a technical or an architectural exercise. Business case for standardization should be defined first. What are the objectives of standard solution and what kind of standardization is intended? What are the key performance indicators (KPIs)? They are something what the steering group needs to decide.

Developers can analyze which building blocks can be customized enough to meet the needs of the different partners and which building blocks need to be built from scratch for each partner. This is very useful in technical sense but still, the group needs to have a leading vision that someone else provides. Technical objectives can't overwrite business objectives.

The meters can provide data for other purposes as well than just energy settlement. Is there a role for Erex in this? What kind of services might be related? Examples of other application areas are energy efficiency or measuring performance of contact line. The opinions whether any services should be provided vary and they can relate to business models in which the infrastructure manager is operating. The organizations that are both infrastructure managers and railway undertakings, can be more interested in additional services than others. One of the important matters is that Eress can't sell anything directly to private businesses due to its company model as public-public co-operation. Nevertheless, the meter data can naturally be used for other purposes also without Erex and its validations.

4.7.3 Architecture and technical aspects of the common model

To be able to have a standard solution, a clever system architecture is needed. Part of the standardization work are the definitions of input and outputs. The architecture shall support standardization in a way where country specific solutions should be

architecturally as far from the core of the system as possible. To be able to fulfill all the needs of different users, the system needs to allow flexibility in multiple ways. However, not all wishes can't be fulfilled because there is always a balance between flexibility and both size and cost of the system.

There are various architectural possibilities in how to build a such standardized common model. Common for all plans is that the core of the system would be standardized and no country specific adaptations would be accepted there excluding configurations. Country specific variations would be placed as far from the core as possible. The question would be, what is the relation of size of the core and other parts of the system? There can be a large core and only little additional functionalities or vice versa.

Structuring and building a such system is a big challenge, but it is also a great opportunity. Wise decisions are needed to build a viable entirety and avoid just creating an extremely large and complex model. Therefore, knowing how the infrastructure managers work and why they do it that way, is crucial. One of the important decisions include which parts are common and how many different needs can be met by configuring and parameterizing. The interesting thing to be noticed is that to be able to configure and parameterize, the variations need to be recognized in forehand. One more important thing is to analyze how different requirements and compulsories affect the system.

Development of a common, modular system requires also a lot of technical work. After recognizing the different modules of the system, they need to be separated in technical means. An example of such development is exchange module that is totally separate from the settlement module. Exchange module is also standard for each country.

Old technical choices and technical depth make the development of a common model more challenging. Previous choices will affect future decisions. Since the beginning of the development, technology has been evolved and visions of systems logical and technical future have also been improving constantly. When common model is being developed, technical depth should be addressed properly so that as part of the project, larger existing technical challenges could be solved. This means that technical development can't be bypassed when developing the common model. In the future, the objective might be to have as little need as possible to customize the system for new users by creating new solutions. How much work is accepted when new country enters, is a business decision to be made.

4.7.4 Requirements for the common model

As said earlier, the system may not ever be 100% standard. That would require forcing everyone to use the same functionalities, which is not wanted as long all countries need something special. There will always be different needs if international standards allow that flexibility. Thus, the objective is to unify everything that is possible. Some flexibility

needs to be allowed but only to an extent, where using the same common model is still possible.

Management of change requests is a success factor for the standardization of the system. Eress has lately implemented Change Advisory Board (CAB) that is responsible for handling requirements coming from the users. CAB decides whether they are accepted or not. Thus, there needs to be a clear vision how the system is like. Partners and new partners propose functionalities and earlier, they can have been implemented because they sound logical and nice. CAB has the responsibility of the strategic development of the system and it should avoid accepting unfavorable requirements.

The success of the system family depends not only about successful implementation of new requests. One of the most important things is the ability to see what has already been implemented for other countries. The countries have somewhat similar needs regardless of the differences. When partners know well existing solutions and possibilities it may decrease requests that are similar or only little bit different. This can help countries to improve their system with little additional work. If the existing implementations are not listed and communicated clearly, there may be requirements that are close to the existing functionalities. The implemented and requested requirements might be close to each other but it is possible that the both will be implemented if not communicated clearly.

4.8   Standardization of Erex processes

Standardization of Erex processes has started with standardization of exchange that is used by all the countries. The countries that utilize traction unit based settlement are moving towards shared exchange as new meters in the countries send the data to the common solution. Information collection and exchange is being defined in standards, which made the first step of the process easier to standardize.

In the next phase, standardization efforts focus on the settlement module, which varies across the countries. The settlement module consists of a few main processes. It has been recognized that preprocessing, train preprocessing and combine could be standardized. This would mean that information exchange, collection and validation principles would be similar for all. Moreover, the interfaces to settlement systems would be as much similar as possible. The difficult part comes after these processes. The actual settlement process differs across the countries and therefore it is not currently subject of main standardization effort. It has been seen that configurations can help to gain needed variability for countries inside preprocessing, train preprocessing and combine processes but settlement remains too different.

4.8.1 The core processes

Preprocessing, train preprocessing and combine are considered as core processes that are part of each system and could be standardized. Potentially, preprocessing could be same for each of the country as all the countries import meter data to the system. Standards do define requirements for meters and for processing the data. Thus, preprocessing is easiest process to standardize. If the process would be modular part of Erex, also the countries using settlement based on traction units, could join standardization of this process. Currently, there are only some small differences in preprocessing within the countries using traction unit based model.

To be able to have a standard train preprocessing process, the input train run data should preferably be in a same format. The following questions are how the data will be applied, validated and reported. Currently, there are differences with respect to train pre-processing process. In Switzerland, train run data is imported but instead of distance and weight, estimation is provided whereas in other systems, estimate is being calculated by Erex. The countries that use train run data, have few smaller differences in their train preprocessing but still, this process could be standardized, experts say. Currently, the formats are different but the principles are the same. The countries that have traction units as their billing objects, do not import train run data at all.

The biggest reason for different activity in Switzerland is that they have a system that has consumption factors for different routes and rolling stock. They also have their timetable in the system. This system was integrated with Erex. The reporting format is more or less the same as in other countries even though the content is a bit different. However, the special implementation causes some challenges for standardization. Still, standardization is an objective, at least for some parts of the system. For example, the validation of train run data could be shared.

The combine process takes the outputs of preprocessing and train-preprocessing. When metering result and estimate based on train run are combined, the settlement result of individual train is created. Thus, output of combine process is used in settlement process. It has been seen that the combine process could be standardized as the validation and allocation parts are roughly similar when train run based model is used for settlement. However, the implementation is currently quite different especially in Switzerland. The objective is to use a solution more like the common combine solution. Regardless of the objective of having a shared solution, maybe few different input and output scenarios should be supported. In addition, the combine process includes a lot of procedures that may require further variability. For example, calculation of losses is included here and the formulas and rules are bit different.

4.8.2 Validation rules

Validation rules are rules used in validation in several processes. Validation is done for meter and train run data but also during combine process. Validation rules are also called as business and validation rules, which explains the fact that they are defined by business decisions how different situations with data are handled. From the perspective of railway undertakings, it would be an advantage and fair that the rules for validation would be similar in all countries. In exchange, the validation rules are configurable but same for each country. For example, different meters may require different validation rules to be chosen from the set of rules defined. The way how the rules are configured, varies a lot.

The validation rules for train run data are similarly more and less the same but configurable. The engine can be the same and the configurations vary, but validation rules are not a great problem from the standardization point of view. Thus, all specialties should be able to be solved by configurations and parameters. Configurability is a huge advantage. The downsides are that configuring can change things to be very different from each other, which means that not all configuration possibilities can be combined as they do not make sense or there can be other logical or technical dependencies.

The instances based on the settlement of traction units do not have train run data automatically available in the system. If there are errors in meter data or it is missing for some period, gross ton kilometers need to be asked from the railway undertakings to create an estimate of the consumption. Thus, validation without train run data is more challenging. One of the expressed possibilities would be to import train run data for validation purposes even though it might not be used for settlement in most cases. However, this vision requires development in the system side plus available train run data with required quality. The approach is very different from the systems using settlement of train runs and thus only some validation rules in the combine part can be shared between these two models.

Combine validation rules are currently a bit different in different instances using settlement of train runs. However, the differences have been addressed and the rules are getting closer of each other. The differences have been evolving over time and as the experience grows, validation rules are adapted in best possible way. Currently, the biggest difference in validation rules in combine process is that in Switzerland, partially metered trains are not allowed. However, there has been discussions that this might change.

The foundations for validation rules are being defined by UIC. Thus, the rules applied are approximately the same. However, some challenges exist. The validation rules have been built to settle traction units, which was the case some years ago. An example of the challenges relates to GPS. The rules check if the GPS has been right between measurements and if the GPS has been wrong, the data can be rejected. However, when train run data is available, it is known that the unit has been on that rail. Meter data will

be rejected before comparing it with train run data that are based on operation control point codes. In Switzerland there are those codes, which location is defined in the system. The definition is a little bit different from Finland and Belgium, where location can be ensured at each traffic place. In Switzerland, the operation control points have a code in addition to the GPS-coordinates. Anyhow, rejecting the data based on uncertain or wrong GPS rejects meter data especially in areas where there are lot of tunnels or hills causing GPS failures. Hence, some of the interviewees hope that the standard will update.

4.8.3 Settlement process

Settlement process is currently not in the center of main standardization efforts as the requirements for settlement process differ too much within the infrastructure managers. As long there is no one shared energy market in Europe, the settlement may not be 100% standard and that reduces the scope of standardization. The settlement process is the most complicated process to standardize on, as each partner's settlement result is commonly driven by local regulatory law.

Currently, the best cut-off point has been seen to be after combine process when price categories and kilowatt hours have been allocated to the right railway undertaking and train run. After this cut-off point, the process is very different for each of the countries. Settlement is different everywhere, because it is most dependent on country specific factors as taxes and fees, which are added in this point. The settlement reports do also vary with regards to data and its presentation.

Besides the procedures, also the interfaces should be as similar as possible so that similar basic output could be used. As the invoicing systems differ, the requirements for formats of output data differ. This means that there should be a basic output from the system, which would be conversed for each country to their desired format.

In Switzerland, there no actual settlement process at all. When combine of estimate and metered values is done, the chosen one is sent back to their own system in a train run file with allocation to a price category. Neither any reports are created. Their own system takes care of settlement process and adds taxes and maintenance costs to the invoice. The close integration back to their own system creates new SLA requirements for Erex. This means that all metering data and train run data need to be sent in time. The data needs to be processed within four hours and railway undertakings are invoiced within three days in Switzerland.

The time frames for settlement vary in different countries but none of the other countries has such a tight schedule than Switzerland. In other countries, where settlement is based on train runs, the settlement is run once a month. In countries where settlement is based on traction units, there are some specialties within the implementations. In Norway invoicing is done in the middle of the month so that half of the invoicing is done in

advance. In Sweden, there are some old meters where data is collected every three months, which requires re-evaluation of the settlement. At least in Belgium, Finland and Norway, there are fixed tariffs for invoicing. In Belgium, last invoice of the year works as balancing invoice. In Norway, the next years tariff will be adjusted depending of the realized costs during past year. In Finland, balancing invoice is sent twice a year. However, the balancing invoice concerns only the transmission of electricity, as the IM does not sell electricity.

One of the challenges related to settlement process are the requirements of automatism. Automatized invoicing should be an objective for the use of the system but at the same time it creates new requirements for quality. As said earlier, data quality can be seen as the biggest challenge in the operation of the system. If the invoice is sent automatically, it needs to be sure that the invoice is having the right invoiced amount for right party without any manual check.

In Norway, Sweden and Denmark, where settlement is based on traction units, the settlement process is not standard either even though there are standard parts in it. For example, accumulating consumption to hourly consumption and to railway undertakings are similar. Basic procedures are similar but in the end, different tax and fees need to be added to the settlement result. Currently the way how data is added together and fees and taxes are added is a little bit different. Various fees and taxes exists. For example, In Denmark, there is a special transmission tax and different loss calculation in different parts of the grid. Energy taxes, environmental fees and grid feed vary also across the three countries.

With respect to all partner countries, there are many aspects that vary in the settlement result. Settlement needs to follow the existing laws and regulations and take into account systems where the result is used. For example, implementation of price and grid areas, calculation of losses, price categories and third-party access vary. Some countries report money whereas the preferred way is to report consumption of energy. In addition, there are different practices in what is done if there is no train run input for the meter data. To be able to handle all these different practices in a more standardized way, lot of work is needed to be able to use the same solution.

All these little aspects may also change due to updates in laws or network statements. One of the examples are price areas that used to exists only in the Scandinavian countries. Now they are getting more popular in Europe. One of the reasons is increased wind power, which may cause imbalance of supply and demand between different areas of the countries. The reasons for changes can be many and the system needs to adapt to any change in railway or energy market that is related.

Despite of all the mentioned differences, interest of standardizing the settlement process has been expressed by some partners. Even though the practices are very different at this

point, exchanging best practices and sharing experiences across the partnership might provide standardization possibilities to a certain extent. It is certainly possible to standardize some aspects of cost settlement, such as calculation of losses and reconciliation. Also, the mechanisms for adding taxes and fees are roughly the same. Thus, standardization of settlement process as much as possible should be also an objective, some interviewees have said.

There are some special needs with regards to reporting the settlement results. For example, in Belgium there is a special payload report, which tells metered and non-metered kilometers daily per railway undertaking. When experience with the system grows, also the requirements for reports may change. For example, new report has been requested in Finland. They would like to have consumption per traction units reported. As the needs evolve, the future objective is to develop analytics solution rather than static reports. In the optimal situation, the user could choose which information is wanted to be seen. The development has started and in the future, there may be dashboards and queries, which can be used to build one's own report. For this purpose, the data structure might have to evolve. However, the development of reporting and analytics is rather a separate development task than part of the standardization.

4.9   Practical domain

Practical domain refers to the environment where railway undertakings operate. There are few special subjects that cause some harm for the system. They seem not to obstruct standardization work of Erex but are aspects that need to be taken into account when system is being built.

Standardization work needs take into account all the specialties in all countries but also prepare for new partners. Each infrastructure manager has their special infrastructure, systems, practices and businesses. As long the differences are defined early enough, they can be parametrized and configured. If some specialty is not recognized when building the system, it can create challenges afterwards. Thus, the specialties need to be well understood to make right conclusions. The conclusions to be made include if the factor is special or it is just named and explained in a different way. As railways have been very nationally oriented, each new partner will create various practical challenges to be solved.

4.9.1   Positioning and GPS

In the daily operations of the system, one of the most visible challenges relate to uncertain GPS. Many challenges appear especially in areas where GPS is lost often and the train is crossing a border. UIC has defined uncertainty zones in UIC leaflet 930. Uncertainty zones are areas near borders where GPS is often uncertain. Examples include a bridge between Sweden and Denmark, where electricity can come from both countries, and Luxembourg where there are borders of three countries very close and GPS-location is

often lost. UIC provides a decision table, which helps to see if the start and end points of metering are in or outside a specific country. The challenge is that the zones are accepted and defined only by UIC. For example, Simplon tunnel from Switzerland to Italy was discussed as one uncertainty zone and now causes problems without that notation. When the train comes from Switzerland and out of the tunnel, it is already in Italy and has been there for a while.

To solve the challenges, Erex Exchange includes some solutions for uncertainties. The biggest challenges relate to border trains in mountains, where GPS is not working right. To solve uncertainties in borders and within countries, Exchange module of Erex interpolates the GPS with an assumption that speed has been linear. Reality is likely something different and thus GPS is still a challenge. To fully solve the GPS-challenges, there is a dependency of what the meter providers provide. Some of the causes might also relate to the way how settlement and invoicing is being organized. For example, one-minute time interval compared to five minutes has an effect as it is more probable to have right GPS within five minutes than one.

One possible solution might be uncertainty areas agreed bilaterally between corresponding countries. The challenge comes from the fact that countries want to invoice all electricity consumed in the country but at the same time, they do not want to invoice electricity consumed in other countries. Except the GPS-challenges international trains work well, as long no double data appears. GPS is not an obstacle for standardization, but obviously the system needs to have means to solve the challenge.

4.9.2 Estimation

There are some differences in what are the factors when making estimates. In the Netherlands, calculating of estimated consumption for passenger trains will be based on carriage kilometers instead of ton kilometers. Carriage is a fixed mass, describing the weight of passengers that can fit the train composition. Thus, it is means adding a constant to calculation formula so that the result is described in ton kilometers. Ton kilometer reflects the reported weight and reported distance.

The metered consumption in comparison to estimates can vary a lot in areas where there are many uphill and downhill areas. For this purpose, different consumption factors are used for different routes in Norway. This or an alternative solution would probably help also Switzerland. These two countries have lot of ground height variation compared to other countries.

Seasonal variation in consumption has been taken into account in Belgium and in the Netherlands. Both countries use degree days in their estimation and Belgium has defined also cooling days. For other countries, this configurable value is zero. However, it has been noticed in Finland that the solution would suit well in there as well because the

consumption varies a lot depending on the month and its temperature. Depending on the temperature, there can be a need to warm or cool down the rolling stock. Due to these reasons, for example, the seasonal variation in consumption can be relatively high. With degree and cooling days these variations can be addressed in estimations.

In some of the countries, there are different price areas. There are different energy prices for different areas currently in Norway, Sweden and Denmark based on their grid areas. Thus, they need to be reported separately to be invoiced differently. The areas can also change according to a decision of transmission system operator, but currently, areas have been same for several years already. Price areas will be implemented also in Belgium in 2018. Moreover, there can be other specialties within grid areas and tariff areas. For example, in Denmark, there are different taxes and grid fees for different grid areas. Average price is used if the area can't be identified.

In Switzerland, there are no area based differences but their pricing depends on the time of the day. The price time categories are normal day time price, rush hour price and lower tax during nights.

4.9.3 Stabling and shunting

Stabling and shunting is a new functionality implemented in Erex. Shunting refers to the process of assembling or disassembling traction units and wagons into a train, or to change the composition of a train. (i.e. remove or add traction units/wagon). Stabling refers to the consumption used when train is standing still and consuming electricity for the purposes such as heating, cooling or lightning. The procedure implemented, is common solution for countries using train run based settlement. When traction units are considered as settlement objects, there is no such intermediate consumption to be settled. Meter is always paired with a traction unit who has its owner. When settlement is based on train runs, there is consumption between the train runs and earlier, it is not clear for which train run or owner the consumption belongs to.

The challenge related to stabling and shunting is that they are reported to traffic management systems in different countries in very different ways or not reported at all. The data quality is poor in respect to stabling and shunting compared to train runs. The challenge related to stabling and shunting is to validate what happened. When stabling train is planned, there is required knowledge, but in other situations everything is unknown. The maturity of the countries to follow stabling and shunting is in different levels. Thus, it needs to be reasoned with the help of previous and following train run data if there has been stabling or shunting meanwhile.

One problematic related to stabling and shunting is that there are different practices and contracts how railway undertakings use rolling stock. The rolling stock can also be leased. This means that it might be possible that railway undertakings change during shunting.

In those cases, it is important to know who is invoiced from the electricity used and to which point. Who is responsible if the pantograph stays up, the heating is on and train is still using energy and next train run will be operated by a new railway undertaking? In Switzerland, there is specific rolling stock for shunting and they are not reported as train runs with train number. Due to these challenges, finding a solution in Erex was needed.

4.10 Network statement

The rules and practices applied in settlement in each country are defined in network statements. Network statement is a legal framework that tells how laws are interpreted and expected to be implemented in practice. The settlement system is expected to fulfill the requirements given in the network statement. The network statements are yearly documents that need to be published well in forehand. From the Eress point of view, infrastructure managers can sometimes ask for changes in short time period. Therefore, the need of having network statement available well in forehand is a good thing for Eress. There is enough time for change advisory board to prioritize the requirements and there is still plenty of time to implement the needed changes. However, the network statements follow the regulations and no big changes are usually requested.

From the perspective of infrastructure manager, it can be challenging to change something when needed if it needs to be told in the network statement. There is variation between the countries how detailed the statement is. For example, in Switzerland price catalog is part of network statement and thus prices and consumption factors have a similar change schedule. In some other countries, the practice is more flexible to adjust consumption factors. From the railway undertakings perspective, the network statement can be difficult to understand. Some say that the railway undertakings may also not read it carefully enough. Specially for new operators, it is difficult to understand all the requirements. The operators should understand what is needed on top of installing meters that is regulated by European Union.

As said earlier, in Switzerland, price catalog is part of network statement. Similarly, in Sweden, network statement includes all information about energy settlement. In Belgium and Norway there are separate documents for such details. The Netherlands are also considering a separate brochure, which could have a more flexible publishing schedule. The challenge with a fixed schedule is that energy price is changing constantly. Neither can consumption factors be changed. There is always a risk that is some of the factors is too high, then some other may probably be too low. Thus, there is a risk of adjusting the factors only yearly if something goes wrong.

Usually the persons who write the about energy settlement to network statement work in close co-operation with Eress. This makes it easier from the Eress point of view. Generally, network statements, European regulations and corridors make the work of Eress easier. However, there is a risk that network statements are written or decisions

related to it are made in upper levels of infrastructure managers' organization, where the practices are not known. These decisions can potentially make harm for the system.

In the Netherlands, the process of writing network statement is a bit different due to their different business model. The infrastructure manager Prorail writes the network statement whereas Vivens is given a mandate on energy settlement. Thus, it is believed that as long they are given this mandate, they can propose changes to the network statement related to the energy settlement. So far, the information provided about energy settlement is limited in the network statement. The network statements are supposed to define the basic situation and not describe any specific system. The document should define the basic process of energy settlement that the railway undertaking needs to understand. It is also possible that there would be more than one settlement system in a country if there were multiple infrastructure managers within a country and they would decide so.

4.11 Business models

Depending on the business model of the infrastructure manager, there are different requirements and expectations for the system. In the Netherlands, the organization related to energy settlement is rather different than elsewhere. This major difference is discussed first and other subjects related to business models are discussed afterwards.

The co-operation for united purchase and use of energy of the railway also called as Vivens started in the Netherlands from the railway undertakings' own action. The idea behind the co-operation was that the thought that it is not good for railway undertakings that the infrastructure manager tenders and purchases electricity, as the railway undertakings will pay the bill regardless of the price and conditions. At the same time, government didn't want to give the advantage of large volume for large undertakings. The co-operation was started and ever since Vivens has made the contracts for electricity use and distribution. Moreover, Vivens is managing settlement of energy for the railway undertakings. In all other countries, infrastructure manager is a partner of Eress, but in the Netherlands the partner is Vivens. As Prorail didin't have any role in energy settlement, it didn't make sense that Prorail would join Eress. Thus, Vivens joined with the acceptance of Prorail. Vivens makes no business and all the money for their operations comes from the railway undertakings relative to their consumption.

By purchasing energy, Vivens will meet some roles of grid settlement. However, they do not have access to all confidential data of the railway undertakings and so they do not fully fulfill the role. All the data can't be visible because the railway undertakings are competitors in the same market. Thus, the business model and roles have some complexities. UIC has defined a role model but it does not say whether a specific role holder should be the infrastructure manager or railway undertaking, for example. However, the role model has some effect on the way how functions shall be organized. Currently, the role model is being updated by UIC.

Despite the differences of roles, the business models should not affect settlement systems much. The roles are something that need to be agreed within the country and can have some effect to the operation with the system. However, the different roles should not obstruct the standardization efforts anyhow. The challenges of such untypical business model may relate to the fact that Vivens has no budget or authority and they need to agree decision with Prorail and all railway undertakings. The possible change that might change the business model in the Netherlands would be the implementation of third party access. If choosing the supplier freely would be possible, a more neutral party would be needed for managing the settlement. However, ten-year long agreement for energy purchasing has been signed few years ago and thus the situation may not change in years. However, the parties should be prepared for the possible change in business models.

The current role model of the UIC causes some challenges. Currently the leaseholder of traction units is given the access to data at exchange. However, the leaseholder can be a bank or some other organization, which is not responsible for the operation of the rolling stock. The other issue is that data manager should have access to meter data and set validation rules for traction units. The challenges arise when the data is allocated to a new country and data owner is not known, or the traction unit is leased and the data ownership is not in relation to the lease agreement. This stiffness causes challenges in some of the business models for example when leasing of rolling stock is used. In many of the countries, energy data is owned by the infrastructure manager but in some countries energy infrastructure manager is owning the data. In order to achieve standard data management, the thoughts about ownership should be the same.

Business model may set some expectations for quality. In such countries, where the national railway undertaking and infrastructure manager belong to the same organization, the other railway undertakings can be more suspicious towards settlement results. They can have concerns about equity and competitiveness. Specially the small undertakings can feel threatened and complain. Especially the cargo operators are cost conscious because they operate in competitive market. This can lead to questioning the settlement results. The interesting question here is that who should have the right to accept a metering result and what should be the means for proving a result?

4.12 Partners

With partners, the difficult discussion is to agree what is within the scope and part of common model and which functionalities should be country specific. When new requests for the system appear, discussion is always needed. It has been experienced that there can be a lot of coming requests. The requests can also have a tight schedule. What is most important, not all the requests are important at all. For infrastructure managers, it can be difficult to know what the railway undertakings need and or they themselves need from the system. Thus, sharing the experiences with the system should be done well. When having a common model, partners can be sure that when they give their input for the

development of the system, the improvements will also be implemented in their system and not only somewhere else.

When new requests for functionalities are coming, it requires analysis of the needs of the current and future partners. However, not all ideas can be implemented. Otherwise, the system will continue expanding. Thus, there needs to be focus in keeping the system compact. This means trade-off between flexibility and size or expansion of the system. Taking care of these aspects is nowadays a responsibility of change advisory board. In change advisory board, the voice of partners is also heard.

For partners, it can be somewhat challenging to understand what a common model requires. The shared vision is to have a common model, but at the same time each country requests few additional functionalities. This means that all partners need to invest in creating a more standard way of working and be flexible in their processes and requirements towards the system to gain the benefits of the common model. Understanding what requirements are special requires in-depth understanding of the processes of other countries but also understanding of the already implemented functionalities. This knowledge is helpful also when new requests appear. Presenting and discussing the requirements is much easier, when the operating environments and systems are known. It has been said that willingness to be standard is the best feature of partners.

Communication during standardization of the system is needed to be done with different parties in different levels. Both existing and potential partners are informed about the process and its steps. However, communication is not enough and working together is needed. It is noteworthy that there is no bilateral discussion between Eress administration and the partners. The objective is to encourage open information and let all partners join the discussion. The challenge is that some partners are more active than the others. The voice of the silent ones can't be heard.

Active communication is needed because Eress administration, developers and partners may see different challenges and even same challenges differently. There shouldn't be too wide gap in the understanding of the parties. For example, if Eress administration does not understand the real problems of the developers of systems, the decision makers can make wrong decisions. In turn, the developers can't tell their opinion if they don't know what sort of discussions decision makers are going through. A good practice is to have a representative developer when plans for new partners or new plans for current partners are discussed. Without a fully standardized solution, there needs to be continuous discussion between the parties.

4.12.1 New partners

Development of the common model is a strategic investment and should be done with long perspective in mind. The decisions should not be restricted into existing partners and

their needs only. Should some potential partners be involved in the discussions? The developed core should allow flexibility so that new partners can enter. Great problems may occur if a potential partner has requirements that are far away from the others. Similarly, if the common model does not meet any needs of the potential partner, this solution can be rejected.

When new partners enter the partnership, they should be provided a well guided explanation and documentation about the common model. Then the new country does not have to make any suppositions. For new partners, it is difficult to understand what is possible and what are the right choices to be made if there is no help available. A catalog that explains all the possible functions would help the new partner. Clear understanding of available functionalities reduces overlapping requests and creation of suppositions and new practices. The process which explains the actions when a new partner enters the partnership shall include workshops how other countries have implemented the solution and what are the possible inputs and outputs. The process should contain also standardization, how the country could possibly modify their practices to meet the requirements of the common model. When a standard way of working is defined, it would be prioritized over a single mode of action.

The cogency of a common model relates to the critical amount of partners. A critical mass of partners creates a reason for a new country to change into the common way of working. It is more difficult to provide a product before a critical mass of partners. Selling can change into buying of services and functionalities when certain number of partners stand behind the solution. New partners will accept the solution easier when it is used in other countries as well. Usually proven work is good work.

Tempting for new partners is that the existing solution fulfills European regulations and there are a lot of know-how within the organization. The objectives of Erex solution is to keep it up to date in accordance to regulations and technology. For new partners, it may be easier and cheaper to join a standard model. Naturally that depends on how much they need to change. Old systems in the countries are usually only based on estimates, which means that there should not be too many things to be changed. However, there might be some practical things or reporting activities that might require modification. For this reason, the existing common solution should be described well so that the potential partners can reflect what will suit them well and what they might have to compromise.

The reasons why new countries might not join such partnership are usually existing solutions and money. If there is an existing solution, the infrastructure manager may want to continue with that solution even though it may not be working too well. The solution is kept because some money can have been spent on developing it. Besides that, it is always easy to continue with something that is already in use. The IT department or energy management team may consider a partnership as competitor too. Besides that, the European economies have been uncertain in recent years and they may want to wait that

they are pushed to find a solution. The countries may consider whether they should join the partnership or develop their own solution. To make this decision, they need to consider which one is more affordable economically. The countries may consider developing themselves a simpler system. However, it may be more expensive to keep the own system and its validation processes updated.

It will be interesting to see how many countries are going to seek a solution when the standards are finished and counting towards the deadline starts. This may be the first wake up call for some countries or railway undertakings and they start to consider what should be done to meet the requirements of the directives. They may not have considered the metering of their old rolling stock or what happens if they are leasing the rolling stock and who is responsible in installing the meters in those cases. In cases when there is only old rolling stock, installing meters is not compulsory. However, it might be compelling due to economy of meter data compared to estimates. Other countries can be requesting meter data for this rolling stock too. Nonetheless, in all cases the changes can be slow and not all countries may implement any solutions before the given deadlines. This can be seen from the experiences with other regulations.

Earlier the awareness of settlement systems has been low and the need and the benefits have not been understood well. However, the situation is improving. The positive aspect is that same regulations are followed and neither any competing international standards exist. Within European countries, it has been recognized that large countries may not be interested to join a partnership. Large nations are focused to manage their trains nationally. Thus, it is easier to seek partners from middle sized countries. If a large country would join, their opinions might have a greater weight due to their volume. This might be poor for smaller countries. The partners are not limited to European countries but the partners must approve to follow European regulations and the way how services are procured. The farther away Eress goes, the different practices may occur.

The potential partners may consider their ability to create train run data. The question is, should the older solution based on the settlement of traction units be provided for possible new partners too? If there are no mature traffic management system or required data available, it could be possible. However, the railway market is moving towards competition where operators and traction units come from different organizations. In this scenario settlement based on train runs is preferable.

4.13 Financing of the development

The funding of the development of the common model is an interesting topic. It has been recognized that creating a modular system is a big work that needs largish investment. Thus, the partnership is not well suited for partners that are optimizing their position in a short term as the development requires community effort. Development of such an advanced common model requires restructuring the system. At the same time, new

partners may join the partnership and they need their systems to be implemented. The re-work can't be done if the budget remains the same. The investment would create better services for all partners and would enable cost savings in the future.

When a new partner enters the partnership, their requirements are evaluated. If the benefit is only for the single country, they need to pay the investment. If others can benefit, then the costs may be shared between the partners. What should be done if one or some of the countries have requirements that are farm from others and the common model? On the other hand, if the common model is too large and complicated for a country, can they continue using their existing system?

It has been recognized that development cost will be accepted easier, if the reason for development comes from somewhere from the outside of the partnership. For example, if UIC tells that something needs to be renewed, it is easily accepted. If the idea of improving the application and standardizing it comes from the inside the arguments are not as easily accepted in countries. When having a solution up and running, budget changes are more difficult to argument compared to the beginning when the start-up cost for the system is approved. Moreover, in a partnership decision making is mutual. If a country itself would like to invest in some development, it may not be possible as the development resources are limited.

4.14 Organizations and politics

When developing a common model, many of the challenges relate to organizations and politics. Some of the challenges can be solved by working together and some can be influenced by discussing with stakeholders. Sometimes influencing can be difficult. The situations and challenges are presented next.

Eress is a very hands-on organization even though it cooperates with many political actors. In many cases, Erex has already been implementing functionalities before the laws are finalized. They can do that because Eress has a good overview of the market, they know the practices and are involved in CENELEC working groups. Sometimes law makers may ask an opinion from Eress about some subjects under preparation.

Eress is a public-public co-operation by its nature. This means that the partners don't have to procure the services of Eress. Public-public co-operation has been defined by European Court of Justice case-law. The contracts of public-public co-operation can be only concluded between public sector parties. This co-operation requires that the partners need to be involved in the development activities and workshops. Earlier, it was emphasized that it needs to be possible for everyone to influence the development, but since then, the EU rules have developed and they require participation. This will help standardization of the system as the partners need to work and seek for solutions together. Eress needs to procure services that they use. Procurement of development is a risk but on the other

hand, independence is also important for Eress. Public-public co-operation means that Eress can't sell its services for non-partners. For example, railway undertakings can't buy anything from Eress if they are not public organizations.

When infrastructure managers have joined the partnership, they have had different maturity levels with regards to energy settlement. The ones with higher maturity level are setting the requirements for the system and organization, which help other partners to improve too with regards to practices and quality. Moreover, the partners that work more with the system themselves, can give more input for the development of the system. Having fresh eyes outside from the administration is positive as it helps in seeing improvements and deficiencies.

Sometimes it is easier to change the system than ask for infrastructure manager or railway undertakings to adjust their systems or practices. However, during standardization it might be useful to ask the parties to look at some practices if they could be modified to meet the common way of doing things. The ability to make such adjustments depends on the country. In some of the countries decision-making power is within the infrastructure manager. In some other countries, there may be more politics and other stakeholders involved. That means more compromising. Even though the decision power was within the infrastructure manager, the people involved with Eress may need to convince other persons within their organization.

4.14.1 Railway undertakings as stakeholders

Railway undertakings are one of the most important stakeholders of Eress. In their businesses, pricing their transport especially internationally is a challenge. Energy is said to take up 20-30% of their expenses. That expense is difficult to know without meters. Railway undertakings would warmly welcome shared practices and rules across countries. If their cost is only an estimate, they may not know when the price changes, how and why.

Large railway undertakings can affect the development Erex. In many of the countries there is one large railway undertaking, which influences the requirements of the country. Moreover, the large railway undertakings have stable in-house systems where changes can be difficult to get through and changes are slow. The systems are originally build for other purposes. Practices of large railway undertakings are challenging to influence. For smaller railway undertakings, it is easier to make proposals as change is easier for them. In the Netherlands, Vivens is not a law-making organization and can't propose changes directly. They need to compromise and agree with all railway undertakings before making decisions.

4.14.2 Politics

In regulatory level, the co-work of has been successful and collaboration of Erex with DG MOVE is close. They recognize Eress as a forerunner and sometimes Eress can advise DG MOVE on how to move forward. Some challenges related to politics appear on national levels. Governments consider public transport as subject that they can control. The degree of politics varies across the countries. It is dependent on the status of infrastructure manager and openness of market. Moreover, political guidance and decisions can slow down the decision making of potential partners. One of decisions where politics appear is the implementation of third party access. If politicians make too detailed or non-pragmatic decisions, harm can be done for implementing the solution. For example, having too many organizations responsible for the activity can make the process unnecessary complex.

The political environment of a country has effect on the national railways. There have been movement against market opening in some of the countries. They may be afraid of change and that may result being protectionist. In passenger market, there are ticket co-operations but cargo operators have no co-operation so far. Many countries consider railways as their national asset and security is still important for them. Therefore, not all countries like the idea of running their systems outside the country. There is also a risk of more countries leaving European Union, which could mean that regulations and standards would not apply anymore.

4.15 Summary of the empirical results

As a summary of the empirical results it can be said that there are lot of multiple constraints that prevent a fully standard software system. However, the barriers are not large. Most of them can be configured and parametrized into the system. On the other hand, countries may not want to be pushed to use the same system. Partners are willing to have more flexibility than what configuring offers. Thus, the desired system might be built from compatible modules.

Directives on European level and international standards are bringing the countries closer to each other. But then again, railway domains and specially energy domains in relation to railways are still rather different within Europe. Differences exists but no single law, regulation or requirement have been discussed as a great barrier when experts were interviewed. The differences are requirements that rise from countries' practices and wishes with regards to the settlement of their railway energy. The energy markets and invoicing practices cause different requirements for the settlement but this distinction of requirements is at the end of the whole settlement process. As Erex operates with public transport and governmental infrastructure managers, there are always political risks. They can be realized if unfavorable decisions are made.

What needs to be done when a structured product family is being built, is to discuss what is the desired common model like. How large the core is and how does architecture of the system support flexibility is something to be decided too. In accordance with these decisions each challenge needs to be solved one by one. Being flexible towards the requirements would make solving of these challenges easier. That requires discussion within infrastructure managers' organizations and with large railway undertakings. Having a common model and a product family still needs lot of work even though standardizing efforts have been started. The development of the common model needs to take into account all current partners. Still, the model should not be limited to existing users or models. However, for new partners, proven work is usually good work. Fulfillment of European regulations is tempting for potential partners too.

There are not many prominent single requirements causing challenges for the common model. Instead, there are large number of smaller issues that need to be taken into account. This means that all the challenges can be solved. The question is, what are the strategic decisions towards the common model. These decisions towards the size of the core and allowed flexibility guide how the single challenges should be solved.

This chapter discussed empirical results. The challenges found in the empirical part are various. In the next chapter, relevant literature is studied. Moreover, challenges related to product families and their variability are discovered too.

5. PRODUCT FAMILIES AND THEIR VARIABILITY

The key challenge considered in the empirical research is the process of merging many different implementations into a same managed product family. To achieve a common model that allows the use of such product family, communicating the differences of requirements and existing implementations is needed. In addition to communication within the Eress administration and developers, communication is needed with partners and potential partners. The building of product family starts with understanding the existing and desired variability of the partners. According to the research strategy chosen, topics of challenges found in the empirical part, will be examined in the literature in this chapter. However, the topics are limited to product families and IT perspective as defined in chapter 1.

5.1 Variability in software

Variability is the ability of system to be expanded, changed, customized, or configured efficiently for use in particular context (Svahnberg et al. 2006). Galster et al. (2011) argues that variability is usually understood as the ability of a software to be changed to meet the needs of different contexts, environments and purposes. Software variants usually origin from the need of adapting software to a specific context by copying (Koschke et al. 2009). Clone-and-own is a manual approach for software reuse, in which software variants are created by using parts from variants that are already existing (Dubinsky et al. 2013). The clone-and-own approach is simple and intuitive and requires very little upfront investment compared to other methods (Fischer et al. 2014).

However, when the number of those variants increases, the method affects maintainability of the variants, which becomes more challenging and expensive (Koschke et al. 2009). Fischer et al. (2014) argue that the approach inevitably causes maintenance issues and hinders efficient reuse. One example of challenges is that bug fixes need to be made for each variant individually as they do not have any shared platform. When deriving new products, identifying reusable implementation from the product variants is challenging, even though variability information helps in locating the reusable features and their implementing artifacts. Some partially automate tools are available, but still, usually the process is fully manual. (Fischer et al. 2014)

Even tough literature does not support this "clone-and-own" approach but proposes different approaches for re-engineering cloned products into a software product family, the ad-hoc approach is widely used in practice (Dubinsky et al. 2013). To understand the reasons behind, Dubinsky et al. (2013) have conducted a research in industrial organizations. They have found out that this approach is used mainly for its efficiency: it

seems to save time and money and the use of the approach is easy. In fact, many are satisfied with the practice. However, others would like to change into a better managed approach. The challenges with ad-hoc approach relate mainly to maintenance and lead to overhead in maintenance issues. The management of changes to all individuals is difficult, integration of individual applications is challenging. Moreover, some tasks need to be done multiple times and last, it is not clear which one of the applications is a master. Short-term thinking and lack of governance are the main reasons why this approach is still used. There are lack of planning and resources to build a software product family but at the same time, people involved can be unaware of other approaches. In many cases, organizational structures do not support required governance. There is lack of reuse tracking and shortage of such roles and processes that would support reuse. Lastly, measurement of work and throughput is lacking. To overcome these challenges, literature offers various techniques for re-engineering of products into product families. The approaches exist on both technical (application engineering) and functional (domain engineering) levels. (Dubinsky et al. 2013)

5.2 Software product families

In contrast to ad-hoc copying style of reuse, software product families provide a more organized way of reuse, which take advantage of similarities in different product variants (Koschke et al. 2009). Northrop et al. (2012, p. 7) state that two main issues differ software product families from ad-hoc method. First, reuse assets in software product families are designed for reuse. Second, the product family is treated as wholeness and not as multiple products that are managed and maintained separately. Each of the applications is a tailored entirety from the common assets, which form the core for each product. To allow flexibility, the individual products may have a small collection of unique additional artifacts. (Northrop et al. 2012, p. 7)

Clements & Northrop (2001) have studied software product families and say that they can be seen as a set of software systems sharing common and managed set of features. They intend to satisfy specific needs of a certain market segment or mission. Moreover, product families are developed from a set of core assets in a specified way (Clements & Northrop 2001). On the other hand, Bosch (2000) says that the heart of software product families is a product family architecture and a set of reusable components. The components are designed in a way that is connectable into the product family architecture. As a result, the product family consists of software products that are developed using the defined reusable assets. (Bosch 2000)

Asikainen et al. (2007) have compared these two definitions and say that the definitions have remarkable similarities but also differences. The common part is that both definitions mention the notion of a set of reusable or existing core assets and are used for developing a set of software products. However, the definitions have also remarkable differences. The definition of Clements and Northrop can be considered as market driven

as they discuss meeting the needs of a certain market segment as one of the defining characteristics of a software product family. Whilst Bosch's definition highlights concerted software architecture as the biggest common factor of a software product family. Thus, this definition is technology-driven. (Asikainen et al. 2007) Clements and Northrop do not define any constraints for the structure how software product family is build and organized but particularize that the products in software product family share common features. Once again Bosch describes that the product family is built from a set of reusable components. However, sometimes the term product line is used when products are implemented in different technologies. To avoid confusion, term software product family is used in this thesis.

To meet the needs of very different requirements, modular system structure can be used. A modular structure allows high diversity whereas complexity is less increased, when specific features are built into additional modules and common parts are included in base module. (Pohl et al. 2005, p. 176) However, component-based development does not mean a product family as default. Northrop et al. (2012, p. 218) say that software product families certainly rely on component-based development. Typically, component-based development refers to selection of components from a library or marketplace in order to build systems. However, product families offer a more systematic and strategic way to use the components. In product families, the components are specified in the product family architecture and they will be connected in prescribed way, where the guidance comes from both the architecture and documented processes. (Northrop et al. 2012, p. 218)

In order to have control of software variants, they may be organized as software product families. To take most advantage out of these product families, variation points of cloned variants need to be identified. The variation points describe commonalities and variabilities between the variants. (Koschke et al. 2009) Analysis of architectures and commonalities and variabilities of the systems is also way to evaluate whether creation of product family from existing products would be feasible (Stoermer & O'Brien 2001).

The reason why software product families are not usually designed upfront is that it is difficult to foresee the coming needs in advance. Thus, software product families usually evolve from experiences from markets that have similar but not identical needs. (Koschke et al. 2009) According to Stoermer & O'Brien (2001), the software product families often evolve from separately existing products in a specific market segment. Typically, several products are derived before there is a systematic migration and shift into organized product families (Stoermer & O'Brien 2001). Similarly, Berger et al. (2013) say that in more than 50% of industrial cases software product family is formally implemented after bringing out several similar product variants that are implemented with ad-hoc reuse techniques. The method of implementing product family based on existing software variants is known as bottom-up approach. (Berger et al. 2013)

Variability does not itself create quality. However, it enables flexibility and productivity that are quality attributes of software product families. It has also been said that variability in product families helps in achieving the wished benefits of product families. (Galster et al. 2011) The objective of creating variability in a software product family is not only to make the variants as similar as possible. As Asikainen et al. (2007) describe, software that allows variability can meet the needs of different user categories, allow different pricing strategies and be used on different operating systems and hardware. Moreover, different sets of features can be provided for different customer needs. The software can also cover different market areas with localization including languages, legislation and market structure. Implementing all these elements without organized variability would be a difficult thing to do (Asikainen et al. 2007). Thus, this means that different product family have many similarities but can fulfill demands for differences and flexibility.

5.3   Business case of a software product family

In the empirical part, the interviewees have discussed cost sharing and the need for strategic investment. Similarly, according to Alves et al. (2010), setting up a software product family is an important business decision. Marketing plays an important role when transitioning form single-system development to product families is considered. From the marketing perspective, factors like reuse ratio and return on investment (ROI) need to be reviewed. (Alves et al. 2010) The business case, which includes the estimated financial ratios, will be presented to management, which will make the decision whether the product family will be launched or not. However, the business case is not only about numbers. Business case should address the needs of the decision makers. Moreover, the business case should consider the decision makers' values in terms of time to market and other financial aspects. There can also be set of alternative business cases presented so that a specific approach can be chosen by the management. (Northrop et al. 2012, p. 149)

Launching a product family requires initial investment. The start-up cost for moving to product family approach includes development of core assets and cost of adopting processes for product families, which include training, tool development and procurement. These costs will occur even before the launch of the first project. (Northrop et al. 2012, pp. 143-144) Other likely costs shall be estimated too. Product development costs happen when core assets are used to derive new products. Incremental costs occur when new functionalities are developed as core assets or the existing assets are improved. Also, the scope of the product family can be extended. Third, annual costs refer to upgrades and annual maintenance costs in case of any defects. (Northrop et al. 2012, p. 146)

When calculating the return on investment, all the costs are added together and compared with the estimated incomes. The cumulative cost for developing the product family increases over time. The business case and ROI calculations tell whether the product family is a good investment or not and point out the break-even point. (Northrop et al.

2012, pp. 143-144) The business case and the financial factors should be considered through the product family life cycle, but specially in the requirements engineering phase (Alves et al. 2010).

5.4   Variability management

Variability and its management are key elements of the development of software product families (Chen & Ali Babar 2011). According to Svahnberg et al. (2006) "variability is the ability of a system to be efficiently extended, changed, customized or configured for use in a particular context". Variability can come from customer requirements or either from constraints that can derive from business or technological issues (Pohl et al. 2005). Variability helps in understanding and managing the commonalities and differences between the systems. Moreover, variability provides a managed way to develop new and different software variants that can have different features compared to other software in the family. The development of new variants is done in an organized way as variability is planned for reuse of software artifacts in product family. (Galster et al. 2011)

In fact, when software product family engineering is compared with other approaches of software development, the biggest difference is variability and its management (Bosch et al. 2001). The objectives of variability management are to bring out variability and represent variability explicitly in software artifacts through their life cycle. Other targets include establishing and managing dependencies between different variabilities but also support the exploitation of the variabilities for building and evolving a software product family. (Chen & Ali Babar 2011; Schmid & John 2004) This means that the variability in various artifacts needs to be defined, represented, exploited and implemented but also evolved throughout the software product family life cycle. All these tasks belong to variability management in software product family engineering. (Asikainen et al. 2007)

Software product family engineering as a term in turn refers to the engineering and management techniques that are used in creating, evolving and sustaining a software product family (Chen & Ali Babar 2011). Alves et al. (2010) say that software product family engineering makes use of the shared properties of different software systems in order to have as high reuse level as reasonable. On the other hand, Chen & Ali Babar (2011) say that software product family engineering aims at developing software systems by using platforms and mass customization. The objective of software product family engineering is supporting systematic development of a family of software systems. The methods include identifying and managing similarities and variations in the systems. (Alves et al. 2010)

According to Anastasopoulos & Balogh (2007), software product family engineering provides means to develop set of software systems faster, better, and cheaper. However, the whole software engineering process is affected by the software product family engineering approach and phases from requirements collecting to maintenance and

evolution need to adapt new methods. This means that successful adoption of software product family engineering requires a profound mind sift in the organizations. (Alves et al. 2010)

5.5 Variability and software architecture

In the empirical research, it has been discussed that software architecture needs restructuring so that a product family is possible. Moreover, a product family needs a clever architecture. This means that shared artifacts are in the center of the architecture and modified parts are as far from the core as possible. To study this topic more closely, variability and software architecture are discussed in this section.

Variability of a software product family primarily influences and is facilitated through software architecture. More generally, software architecture is at the heart of software systems and development activities throughout the software life cycle shall refer to the architecture. The activities include implementation, testing and maintenance. (Galster et al. 2011) Thus, Galster et al. (2011) state that the importance of software architecture in variability should be clear and it should be treated as a top priority. If variability is not taken into account during design of software architecture, it causes a quality risk for the system and also increases later rework. (Galster et al. 2011).

Bass et al. (2012) define software architecture as following: "The software architecture of a program or computing system is the structure or structures of the system, which comprise software components, the externally visible properties of those components, and the   relations among them." Informally, software architecture is often used as synonym to the structure of a system on a high level of abstraction (Asikainen et al. 2007). The documentation of software architecture is organized into different architecture views. The architects need to be able to model variability of the system throughout different architecture models and views. (Galster et al. 2011)

5.5.1 Variability and architecture description

Software architecture defines the structure of a system. The structure is also documented in an architecture description. This description includes the key stakeholders of the system but also top concerns of the stakeholders. (Galster et al. 2011) Architecture description is needed to be able to assess the overall quality of each software product and the product family as whole. The objective of architecture description is to describe in same document the architectures of each product and the architecture of the whole software product family, which combines the single product architectures with the means of highlighting the commonalities and variabilities of the products. The documented architectures help to consolidate and maintain the software products. (Koschke et al. 2009)

Users of variability description are asking for new and better approaches to assess software architecture of product families. However, in industrial organizations the start of the use of new methods and tools is challenging too. (Galster et al. 2011) Thus, it can be said that architecture description practices are lacking good practices. This causes problems as the architectures and models can't be refactored, which means improving the structure of existing application without changing the functionality. Neither can synchronization between different architecture models be done. (Galster et al. 2011)

5.5.2 Expressing variability in architecture

Architectures are increasingly understood as a platform that can support presenting commonalities and variabilities among the product family. Moreover, architecture can be considered as a platform, where trade-offs are communicated. Architecture provides a mean to communicate stakeholders their conflicting requirements and goals. However, practice is lacking suitable documentation of existing systems, which means that architectures can't be used entirely. In these cases, architectural reconstruction would be needed. (Stoermer & O'Brien 2001)

Challenges in describing variability through architectures exists. According to Galster et al. (2011), some practitioners claim that it may be too complex to model all commonalities and variabilities in architecture. This can be considered as a major problem as in these cases the work can be omitted. This causes that it is even more challenging to understand the entirety of the product family. Moreover, the software architectures that are designed outside the product family domain, may not include explicit descriptions of variability. This leads to situations where variability information exists only as tacit knowledge in the minds of architects. (Galster et al. 2011) However, the software architecture community has acknowledged that variability is a concern of different stakeholders. This means that variability in architecture and variability as part of all architectural aspects should be addressed well enough. However, it is currently not well enough understood. (Galster et al. 2011)

5.6 Variation points as decision points

Variation points define variability from the perspective of features. A variation point is a decision point where architects or other stakeholders select a variant. The choice of single variant is also a choice of associated variation points and variants. (Galster et al. 2011) In variation points, a choice needs to be done between zero or more variants. Moreover, variation points help traceability, evaluation and development of traceability. Thus, it can be said that variation points are a key factor of the variability management and not some by-products of designing and implementation of variability. (Deelstra et al. 2009)

According to Galster et al. (2011), the variation points should be analyzed towards scenarios and risks of the system. Scenarios and risks include goals of the system, most

common use cases of the system, architectural alternatives, quality risks and other potential risks. Often variability is described also through simple layered or modularized component and connector models to helps visualization of variability. These models usually contain commonality elements and describe the parts of the system that may include variable elements and therefore change the system. (Galster et al. 2011) Understanding of variability and variation points is needed for successful adoption of a product family. Modeling of this variability information helps in planning, developing and communicating the product family. Thus, modeling variability and those modeling practices are presented in the following subsections.

5.6.1 Modeling variability

There are a large number of methods for modeling variability in software product families. According to Asikainen et al. (2007), the modeling methods can be categorized into three categories. The categories are feature-based methods, methods based on modeling variability through software architectures and methods that do not bind to any particular concepts. (Asikainen et al. 2007)

In software product families, a feature is defined as a distinctive characteristic, quality or user-visible aspect of a software system (Kang et al. 1990). A feature-based method typically is based on feature models and feature configurations (Asikainen et al. 2007). Feature models are often used in describing and hierarchically structuring commonalities and variable features of software product family members (Berg et al. 2005). A feature model is a description of a software product family whereas a feature configuration is a description of an individual application (Asikainen et al. 2007). Features represent product capabilities and characteristics from the user feature point of view. They indicate variability corresponding to a variation point. (Berg et al. 2005) In feature model, individual applications are distinguished from each other through the features that each application includes (Asikainen et al. 2007). In literature, feature modeling is commonly suggested for the management of variability in software product families (Berg et al. 2005).

The methods that are based on software architecture focus on the overall structure of software systems. The software product family architectures usually describe different components and their connection points, but also the compositional structure of the components and connections between interfaces. (Asikainen et al. 2007) In turn, Galster et al. (2011) describe three ways describing variability in software architecture. The methods are annotations with means of UML, dedicated variability description that including variability models and views to variability or their definition. The third category concludes informal methods. In these models, variability is not necessarily described as part of architecture. Examples include documents of API's, user manuals or variability descriptions in header files. Sometimes the method is combination of all three categories.

The choice is dependent on the degree of variability, type of variability and organizational factors. (Galster et al. 2011)

When product family is being built bottom-up, which means that a set of software is already existing, a throughout analysis of existing software artifacts is needed. Bottom-up software product family adoption approaches have focused on three main subjects, which are feature identification and analysis, feature location and re-engineering. During feature identification, a set of artifact variants are analyzed to identify features. The features represent optional functionalities in software artifacts. Some of the feature analysis approaches also allow discovering constraints and relationships between the features. The result of this analysis is a feature model. In the next phase, when the features are identified, feature location aims to locate them to their concrete implementation in the artifact variants. Third, re-engineering aims at refactoring the artifact variants and therefore conform them to a software product family approach. Thus, this phase focuses on transformation. This phase includes selection of reusable assets and their mapping to a feature model. (Martinez et al. 2015)

5.6.2 Modeling in practice

Before the actual development of product family, understanding the commonalities and variabilities is most important. Before this knowledge about expected features, no architectural decisions can be made. Thus, in this section, the practices for feature modeling are presented shortly.

In software product families, different user needs can be approached through variation points and variants that are choices in variation points (Galster et al. 2014). Consequently, many of the modeling techniques are based on describing variation points and their variants. To identify variation points, Galster et al. (2011) suggest three steps. The first step focuses on identification of important decisions, which need to be made to be able to build the applications in product family. The identified decisions are candidates of variation points and their alternatives. The second step evaluates the candidate decisions whether they are in line with the proposed product. Third step is to decide whether the decisions and alternatives are such alternatives that will be included in the variation point. (Galster et al. 2011) In turn, Halmans & Pohl (2003) suggest to make the variation points and variants prominent with use case diagrams. Moreover, they advise to make the decision points visible by providing a UML presentation of each variation point and its possible variants. The extension of describing variation points and variants helps to document the variation points explicitly, they are easy to comprehend and easily visible as they are not hidden in textual documents. Other benefits include that variation points also easily tell when the customer has to make a selection. (Halmans & Pohl 2003)

5.7   Requirements engineering

There are two very different types of products that are derived from the software product families. The first category is standard products that aim for mass market such as consumer electronics like mobile phones. The second, and here studied category are individual products that are derived for individual customers. The derivation processes for these two categories differ significantly. For standard products, derivation is based on market analysis, market prognoses and potential typical customer profiles. Whereas when talking about individual products, customer specific requirements need to be elicited, considered and agreed. These requirements for individual customer products are found out in a requirements engineering process. (Halmans & Pohl 2003) This situation is very different from the mass products, as here the requirements of individual customers need to be respected and at the same time, the benefit of the whole product family needs to be taken into account. According to Halmans & Pohl (2003), the main difference is that the requirements of the product family need to be considered during the requirements engineering process so that as many as possible of the customer requirements could be satisfied with the reusable product family assets.

According to Clements & Northrop (2001), requirements engineering provides tools to manage the commonality and variability of products in software product family. Requirements engineering relates to the actual real-world objectives, functions and constraints of software systems (Zave & Pamela 1997). In practice requirements engineering refers to the management of requests and requirements coming from users. As one of the challenging tasks of Erex is to deal with the requirements coming from the partners, literature about requirements engineering and its challenges is studied here shortly.

When new software is developed or existing software is improved, the needs of the users and other relevant stakeholders are being asked. Managing requirements of a software product family is non-trivial as the stakeholders have diverse perspectives and thus the requirements are different. Moreover, the requirements do also have complex configuration dependencies, are represented in many ways (e.g., textual, goals) and represent different levels like features or qualities. (Alves et al. 2010) The communication of the requirements may be challenging due to the stakeholders' various backgrounds but still, this is the context where decisions regarding requirements engineering need to be done (Thurimella & Bruegge 2012).

Compared to single custom-built software, requirements engineering for a family of software products has a focus on a more systematic reuse of software. According to the nature of requirements engineering, the focus is not only on technical issues, but reuse is also pursued by organizational, marketing and process perspectives. (Bosch 2000) There are some aspects that should specifically be considered during requirements engineering phase. Firstly, identification and management of the common and variable requirements

is needed for the success of the product family. Secondly, the people involved like domain engineers have the responsibility to design, build and evolve a reusable set of core assets that can be effectively reused in deriving individual products. Third, stakeholders do not include only the stakeholders of a single application like customers, users, developers, testers and maintainers but also the ones that are involved in the development and management of the software product family. Fourthly, techniques and specially modeling techniques differ from the ones that are used in single-system requirements engineering. Requirements in single-system cases are often modeled from the use perspective, whereas requirements of a software product family shall reflect the commonality and variability information that is utilized in the reuse of the artefacts. (Alves et al. 2010)

During requirements engineering phase, many important decisions are made when developing a software product family. The common shared requirements also called as the core of the system are defined during requirements engineering process. Besides, the unique requirements of each product are decided too. (Alves et al. 2010) Thus requirements engineering plays a significant role when developing a product family. Besides that, managing requirements is one of the key activities also after adoption of the product family.

5.8   Communication to customers

The objective of software product family development is pro-active and constructive reuse. The whole idea of software product family is to develop software products that share a remarkable number of features and are having a shared platform. From the software product family provider viewpoint, the success is dependent on the development costs of the product family and sales that reflect the customer acceptance. The development costs are usually relative to the degree of reuse. When a relatively big number of customer specific requirements can be tackled by using existing variability and functionalities, then return on investment (ROI) of building the family shall be high. If many of the requirements require tailoring or other customer and software specific solutions, then the effort for building product family applications increases and hence will ROI decrease. (Halmans & Pohl 2003)

Variability enables the derivation of new product family applications by re-utilizing the realized product family assets. It is a mean to enable the use of software in different customer needs. To be successful in this, variability shall be well organized in a software product family. If customer requirements vary significantly from the previous needs, the degree of reuse is low. Thus, it is important that the existing variability is adequately taken into account when bringing out and addressing requirements of the new customer. (Halmans & Pohl 2003) Similarly, in the empirical part it has been found out that it is important to communicate the existing variability and functionalities to the new partners. The objective then is to minimize new requests and encourage the use of existing functionality.

When a single application of a product family is being defined, the provider is facing the challenge of communicating the variability to the customer. Similarly, should functional and quality features of the product family be communicated. This part is very important and the customer should be assisted in making trade-off decisions when the customer and the provider are agreeing about requirements. Moreover, estimates of realization costs should be given for the alternatives that are considered. (Halmans & Pohl 2003) Transparent information would probably affect customer's decisions but this information can be lacking as it can be difficult to calculate or due to lacking such practices. Halmans & Pohl (2003) state that the requirements engineer has to be able to quickly estimate potential costs for developing special requirements, especially if there is an alternative under consideration that can be selected using existing product family variability, whereas the other alternative means that new functionality shall be developed and current product family assets shall be adjusted. In practical terms, customer often needs to decide whether new features shall be implemented to fully satisfy the original customer requirements or if a much cheaper solution that covers 80% of the requirements can be achieved by reusing existing assets (Halmans & Pohl 2003).

According to Clements & Northrop (2001), product family variability shall be considered in the early product definition phase when new products are developed. Only in cases where customer is aware of the capabilities of the product family, its variability and offered variants, the customer can make the decision whether the product family can fulfill their requirements or not. Customers are typically not interested in technical details but how the product family can meet the customer requirements, the customer should only be informed about relevant aspects of the variability and variants rather than explaining all details. In any case, variability in product family is typically rather complex to understand. Therefore, unimportant technical realization details should not be revealed to customer at least in the first phases. Therefore, attention should be paid to present complexity in a way that customer can understand from his perspective what the variability enables. (Halmans & Pohl 2003)

5.8.1 Essential and technical variability

Customers are not typically interested how the actual realization of variability is done. For this reason, Halmans & Pohl (2003) propose differentiation between essential variability, which defines variability from the functional, or customer viewpoint and then technical variability, which represents the realization aspects of the variability. Customer shall be most interested about essential variability, whereas product family developer is concerning mostly technical variability such as how variation points are realized, how their variants are build and what are their interdependencies. (Halmans & Pohl 2003)

The role of requirements engineer is to communicate with both customer and product family engineer, who is responsible for the development of the products. Thus, requirements engineer shall understand and be interested about both types of variability

and act as an interpreter between the two interests. Requirements engineer should balance between the customer's wishes or needs and on the other hand with the technical capabilities that the product family provides. The second role of a requirements engineer is to transfer the customer requirements for the product family engineers. The requirements need to be documented in a way that supports the product engineers. Their work is to derive the customer specific application from the product family assets. Thus, the documentation should reflect which of the requirements can be exploited by reusing the product family assets and which ones require new development but also what is the relation of these new requirements to existing assets. Suggested methods are use cases and scenarios. (Halmans & Pohl 2003)

As stated, variability can be divided into essential and technical variability. Essential variability represents functional and customer viewpoint. Technical variability on the other hand represents realization aspects like IT-infrastructure, binding time and implementation. However, the focus here is on essential variability, which is more important from the customer perspective but also firstly designed when product family is being built. Technical variability shall be considered when it is known what kind of functional variability and product family is wanted. As the focus on this study is on factors that are part of essential variability, the Figure 4 below describes essential variability and its subcategories.
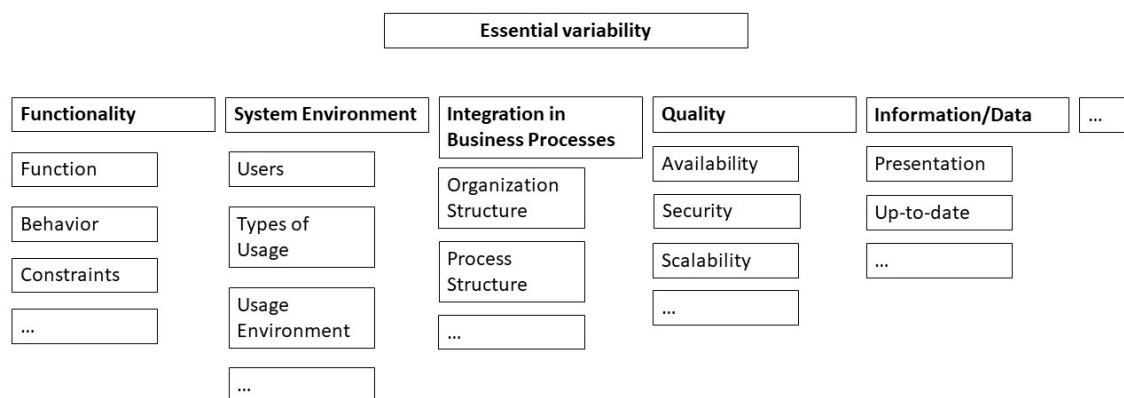
Figure 4. Essential variability, adopted from Halmans & Pohl (2003)

The five categories of essential variability are functionality, system environment, integration in business processes, quality and integration and data issues. One empty box is drawn to present categories that may exist. Such representation appears also within each category. (Halmans & Pohl 2003)

The category functionality subsumes all functionalities that appear within the product family, which means that this category consists of the variability of the product family. The subcategories describe more specifically which kind of separation is used inside the category. The subcategory functionality includes all the variability aspects within a product family that are used in derivation process of each product family applications.

The two following subcategories describe functionality of a single function. Behavior describes the functional differences within a specific function. For example, the execution order of sub-functions within a function can be different in different applications. The third subcategory constraints represent preconditions that are checked before a function is executed. (Halmans & Pohl 2003) Even though this category functionality is represented in the picture as significant as other categories, it could be presented also in a different way as the demanded functionality is to be defined first when deriving a new application. The chosen functionality also sets requirements for other types of variability to be used.

The category system environment describes different aspects of variability related to the way of use and place of use of the application. In other words, this category includes all the aspects that allow the embedding of the application in different usage environments. The subcategories include users, type of usage and usage environment. The third category integration in business processes describes the variations in integration the software to business processes. Roles and their responsibilities need to be modified to meet the needs of the customer organization. Second, the process structure defines the variability needed to reflect business processes of an organization. (Halmans & Pohl 2003)

The fourth category quality includes non-functional and quality aspects such as availability, security and scalability of the system and its use. The fifth and last one of the presented categories is information and data. They define how data and information are presented in the system. There can also be different requirements how often data or information shall be updated. All variability aspects that support the derivation of applications with different needs to represent or actualize data belong in this category. (Halmans & Pohl 2003)

5.8.2 Domain and application engineering

Software product family engineering consist mainly of two different activities: domain engineering and application engineering (van der Linden 2002). Terms development and deployment have been used to describe the same phenomena (Bosch 2000). During domain engineering activity, the commonality and the variability of the product family are defined (Halmans & Pohl 2003). According to Asikainen et al. (2007), the software product family architecture and components implementing the common part are implemented during the development process.

During application engineering activity, the individual customer specific applications are practically developed. Application engineering utilizes shared assets that result from the domain engineering by selecting and configuring them. (Halmans & Pohl 2003) The individual applications are derived based on a set of requirements coming from a specific market or customer. The architecture and components formed during development process constitute the basis for the deployment process. The architecture and the common

artefacts are adapted to match the given requirements for the individual application that is deployed. Often, customized functionalities need to be developed to fulfill such product-specific requirements that are not covered by the available artefacts. (Asikainen et al. 2007)

Besides the terms domain and application engineering together with development and deployment there are more similar terms defined. Czarnecki & Eisenecker (2000) have introduced terms problem space and solution space. The terms represent the development phases of software product family engineering. The term problem space refers to domain analysis and requirements engineering phases, in which the systems' specifications are established. (Berg et al. 2005) Domain analysis recognizes what constraints apply to systems in domain. The constraints may include standards, legal restrictions, business constraints and specific hardware platforms. (Northrop et al. 2012, p. 80) Solution space in turn refers to architecture, design and implementation phases, in which the concrete applications are created. The outcomes from these both stages form the product family infrastructure. (Berg et al. 2005) Thus it can be seen that there are different terms and definitions about the subject and they all have a little bit different meaning or they emphasize different parts of the same phenomena.

In traditional software development, there needs to be done a decision whether a single characteristic is included in a product or not. This decision is done in the problem space of the development and the software will be designed accordingly. (Berg et al. 2005) However, van Gurp et al. (2001) state that when developing a software product family, these decisions of whether a characteristic will be included in the product or not, need to be delayed. The reason is that it needs to be reviewed how the specific characteristic could be realized in the system and how it affects the product family and its variability. In other words, variability should not only be reviewed in the problem space, but also in the solution space. As a consequence, variability shall be considered and managed at each phase of development from the first requirements to the final implementation. (Myllymäki 2002)

5.9   Continuous review of variability

As found out in previous section, variability should not only be considered in some specific situation or phase of development. The variability and its consistency and traceability should rather be made sure from requirements to architecture and to implementation. (Galster et al. 2011) Similarly, the variability needs to undergo continuous and timely change. Otherwise the product family may be unsuccessful in making use of the similarities of product family members. (Deelstra et al. 2009)

The product family architecture and its artifacts enable that it is possible to make some small changes in and between different products and their versions. However, not all future changes can be forecasted or included in the family and its components. Thereby,

at some point of the life cycle of the product family, evolution brings out needs for new functionality to be implemented. When the product family was developed, these functionalities can be discarded or unforeseen. (Deelstra et al. 2009) Clements & Northrop (2001) recommend to assess artefacts periodically to identify, which assets should be reusable for all applications. This helps the product family to keep up with the evolution.

Like individual software systems, clone-and-own software tends to be managed separately. However, product variants of the family should not be maintained individually. Products in product families share an integrated platform, which manages common assets. Maintenance should be taken care through that shared platform. (Linsbauer et al. 2016) However, the problem domains and variants shall be mature and stable so that maintenance and development of the shared platform is possible at all. If the product family is managed successfully, the studied benefits of software product families such as improved quality, easier maintenance and reduced long-term costs can be achieved. (Pohl et al. 2005)

5.10 Challenges related to product families

In the empirical research, the focus was on finding challenges that make creation of product family difficult in case Erex. Earlier, in this theoretical part, the focus has been on product families and features of their development. At the same time, some challenges have been found. The objective of this study to see whether literature finds similar challenges than what has been found in the empirical part in relation to product families. For this purpose, in this section challenges related to product families and their creation are studied.

Several authors have reported challenges that relate to the setting up of a product family. The main categories of found challenges are lack of strategic mindset, methods and approaches used, scope of the product family, knowledge and information issues and decision making. The challenges of each category are presented in the following subsections.

5.10.1 Lack of strategical mindset

The shift from clone-and-own practices or single products into product families is a throughout change in organizational mindset. However, there are few issues that are often lacking.

- Business factors dot not support product family: Product families rely not only on software development practices but they are also dependent on several key business factors. The organization should understand the business ideology and processes of product families. Moreover, the set of business factors must be in

line with software product family engineering process. Therefore, business and engineering aspects of the software product family must be in strong coordination. (Ahmed & Capretz 2007) This means, for example, accepting the investment on core assets of the family.

- Lack of understanding product family as a strategic asset: There is a cost of setting up a software product family, which payoff point is in the future. The organizational strategy does not always support this approach. There should be a comprehensive strategic plan that shall be aligned with initiating, launching and maintaining a software product family. The strategic plan should support the identification and exploitation of long-range business opportunities of the product family. (Ahmed & Capretz 2007) If the strategy will change often or it is not followed and trusted, this will probably affect the success of the product family.

- Inadequate marketing strategy: Marketing strategy is one of key concerns of businesses overall. It has been found out that so are the success of product family and marketing strategy associated. The marketing strategy should answer the questions about the market in overall, but describe competitors and customers too. (Ahmed & Capretz 2007) If marketing strategy is not sufficient, it will probably affect the future and feeling of safety of the product family. The market strategy and market research should also be updated frequently so that the product family strategy can reflect the needs of the market in time (Ahmed & Capretz 2007).

5.10.2 Methods and approaches

In previous sections it has become clear that product families require more structured processes and methods to be use. The reason is that product families are larger entities than individual systems. Next, few practical challenges related to methods and approached used are presented.

- Variability assessment is lacking structures: Architects are often assessing variability without any methodological guidance. Thus, they often apply informal process based on their own experience and common sense. However, these informal processes are very unpredictable with regard to the required results and efforts in terms of the outcome and required effort. (Deelstra et al. 2009)
- How to know whether, how and when variability should evolve: This challenge has many aspects. The answers might be financial or technological but do mainly relate to requirements of the customers. Deelstra et al. (2009) recommend to concentrate on existing variability and demanded variability. Demanded variability is the difference in provided functionality and their quality that differ from the situation today. Demanded variability can be measured though scenarios. The mismatches are potential required modifications in variability. (Deelstra et al. 2009)
- Reactive way of working: The variability assessment is done only when immediate problems or needs appear. As a result, these assessments are lacking resources: there is time pressure or lack of experts. (Deelstra et al. 2009) Variability management processes may be lacking resources or appreciation. This may lead to inefficient use of resources and short-term planning.
- Generalized instead of optimal decisions: sometimes decisions are generalized to cover over many features (Deelstra et al. 2009). Presumably the goal is efficient but sometimes this may lead to wrong decisions. According to Deelstra et al.

(2005), there have been some heavy examples of generalization found in industry. In some extreme cases, similar functionality is re-implemented for each single application. In an opposite case, all updates and changes would be updated into the reusable product family artifacts. In the first case, the reuse potential of product family has not been fully exploited, and in the second case, the complexity of the product family is unnecessarily increased. (Deelstra et al. 2005)

- Addressing only one abstraction layer: many evaluation techniques focus only on a one layer of description at a time. However, variability is a cross-cutting concern of all layers of abstraction. Therefore, understanding of changes is needed in many levels such as architecture and implementation. A technique that would take all necessary levels into account, would be needed. (Deelstra et al. 2009) Berg et al. (2005) do also point out that variability shall be managed in an appropriate and consistent manner during all the software development phases. This helps to achieve the full benefit of software product families.

5.10.3 Requirements for a software product

Customers typically have wide range of requirements for their software product. Communication of these requirements coming from multiple stakeholders is often challenging. Requirements engineering faces lot of other challenges too. There are compromises that need to be made and decisions whether this approved requirement is part of the core or product specific. The challenge is to let the customers see the benefits of the product family rather than only loss of flexibility. The challenges related to requirements are presented next.

- Poor communication of requirements: Large number and diversity of stakeholders may have different needs and expectations for the system. The group includes all stakeholders that are involved in or affected by the development of the system. All the requirements coming from different parties should be communicated successfully. Different parties have different responsibilities and knowledge. Executives represent the organization's business goals and constraints, end users have the knowledge of how the products will be used, marketers know the needs of the market, technical managers are familiar with available resources and developers know the available and reasonable tools and technology. Moreover, depending on the case, legal assistance or governmental agencies may be included. To be able to collect and choose the right requirements for the system, all the right stakeholders should be included. The diverse stakeholders presumably have conflicting requirements which causes the need for trade-offs to be made. Making the right compromises requires mechanisms for capturing and analyzing the different requirements. Thus, they need to be communicated and understood. The analysis must handle the conflicting requirements and decisions. The made decisions must be communicated too. (Northrop et al. 2012, p. 58)
- Requirements analysis not successful to achieve economies: The requirements analysis aims at finding commonalities and variabilities of the requirements. The analysis shall also involve mechanism to communicate stakeholders where compromises of requirements should be made to achieve a more economical solution. If the compromising fails and all possible requirements are accepted, requirements analysis fails. Moreover, the requirements analysis should end up

into a proposal, where reuse within the product family is a central concept. Some of the popular techniques include feature-oriented domain analysis (FODA) (Kang et al. 1990) and use cases. (Northrop et al. 2012, p. 59)

- Confuse between product family wide and product-specific requirements: There should be clear understanding which requirements shall be family-wide and which requirements are special for single products. (Northrop et al. 2012, p. 62) Adding unnecessary features to core does harm as the core gets complex without a good reason. Adding additional functionalities to core may lead to situations where some customers might want to leave out some functionalities from the core assets.

- Variants are too large or too different from existing assets: newly developed assets or components shall be integrated to the core assets in the product family architecture. New components that are too large or different may cause integration challenges. They might require structuring the product in new ways. For that reason, variations and adaptations within components are usually easier for the system integration. (Northrop et al. 2012, pp. 67-68)

- Customers see the loss of flexibility rather than recognizing the benefits: Some of customers may be unwilling to give up the control of development of their product. They would like to keep the systems build to reflect their full desired functionality despite of the cost, schedule or the other benefits that the product family would provide. If the customer is very strict in this opinion, there should be a serious discussion whether a long-term business relationship is viable. (Northrop et al. 2012, p. 156) Better approach would be of course to convince the customer of the benefits, which may require some additional approaches and time.

5.10.4 Knowledge and information issues

Managing variability and building a product family are complex entities. Sharing this understanding is difficult and thus are knowledge and information issues one of the key challenges when building and managing a product family. Information sharing is challenging because architectures are complex, knowledge exists in different levels and in the heads of people. The challenges related to knowledge and information issues are presented next.

- Domain information is localized: There are cases where the relevant domain information is inadequately documented and shared. This leads to a situation where the understanding is as tacit knowledge in the heads of few key people. This creates a risk of knowledge leaving the project or the organization. Due to poor documentation, there is also a bigger risk of misunderstandings and time wasted finding out what is already known. Thus, knowledge of the key people should be documented at an adequate level. At minimum, the assumptions and decisions about what is common, what is variable and what is left out from the product family, shall be well documented. There should also be documented explanation why those choices have been made and how has the business case assisted in these decisions. Documenting and sharing of knowledge can mitigate this risk of localized information. (Northrop et al. 2012, pp. 83-84)

- Variability information is scattered: often variability information is scattered and there is no model, where variability information from different levels would be combined. Often there are no resources to building such an explicit model.

(Deelstra et al. 2009) However, not using any model is a bad choice too as without any structured method it is difficult to keep an overview of all variation points and their relations (Deelstra et al. 2005).

- Lack of information and knowledge: while new products are derived, unexpected incompatibilities may be identified due to lack of information and knowledge (Deelstra et al. 2009). Deelstra et al. (2005) say that these unexpected incompatibilities have a significant impact on how a product within a product family can be developed and time required for it.

- The scope for architecture may not be well defined and stable: The scope of the architecture should be well defined and stable so that architectural decisions can be reliably made. This means that the requirements for products must be expressed clearly and completely enough so that architectural decisions can reliably be done based on the requirements. The architectural decisions also require shared knowledge about forthcoming technology and relevant domains. In any of the situations where the architect has to make guesses, the architecture will pose a risk. (Northrop et al. 2012, p. 36) This is mainly a knowledge and information but also a communication risk which may lead to unsuitable architecture.

- Poor communication of architecture: When the architecture is built, it needs to be delivered for its consumers. This means that it shall be documented and communicated in such ways that developers can understand it. Outdated architecture is as useful as an undocumented architecture. Moreover, an architecture that is done for architects and developers may not be understandable for other stakeholders as they may not understand complex UML diagrams. (Northrop et al. 2012, p. 36) Therefore often some other, simpler ways are needed to communicate the architecture and its core elements like variability.

5.10.5 Decision making

There are continuously decisions to be made with regards to the product family. There are decisions to be made on different levels. However, the decisions have dependencies. Continuous decisions include whether a requested functionality should be implemented for a single product or to the shared core or whether the functionality should be implemented at all. Challenges related to decision making are presented next.

- Product specific or shared artifact: New applications often raise a need for new features to be implemented. The challenging part seems to be to make the decision, whether an accepted feature will be delivered for all systems in a product family as a shared artifact or it should be product specific. (Deelstra et al. 2005)

- Which features should be implemented: sometimes it can be difficult to assess whether a single feature should be implemented. Practical arguments like time to market and short-term cost may lead to inefficient decisions. Such arguments can lead to non-optimal decisions for the product itself but mainly for the product family. Moreover, this can be harmful from the engineering perspective too. (Deelstra et al. 2005)

- Decisions on different levels: Decisions are made in many different functions. There are top-level decisions and architectural decisions. Architectural decisions can be made on full-fledged product architecture, "normal" architecture or on a temporary and occasional architecture. Moreover, there are decisions regarding

the actual variant. (Galster et al. 2011) This requires understanding from many different perspectives and communication between different roles because different roles make decisions in different levels.

- Dependence of decisions: in many decisions, there is a temporal aspect. Often some decisions need to, or is beneficial to make before deciding something else. There is also a time perspective when individual decisions need to be made. Decisions are rarely independent and therefore other decisions and issues need to be paid attention when making these decisions. Decisions are highly dependent from other decisions. Often there are trade-offs to be made between different aspects. For example, decision of defining variation point can be reviewed from different perspectives as user, server load, complexity of implementation and time-to-market. (Galster et al. 2011)

- Some customers dominate user group forums: There may be situations where specific customers with their own agendas dominate the user groups. In such situations others are not heard (Northrop et al. 2012, p. 156) This can be expanded to cover other stakeholders also and even within the product family organization. In such cases, the result might be product family requirements that reflect the needs of the dominant customer. This would mean that needs of other customers would be neglected. (Northrop et al. 2012, p. 156)

5.11 Summary of theoretical findings

The main objective of product families is to achieve as much shared features as possible. The shared requirements form the basis for each application in the software family. The more there is commonality, the less effort is needed in the design and development of flexibility. (Pohl et al. 2005, p. 202) It has been found out that successful product family organizations have different characteristics. Their products, markets and missions, business goals, organizational structures, cultures and policies, software process disciplines but also the maturity and extent of their shared assets are very different. (Northrop et al. 2012, p. 3) Despite any background factors, the main issue is that the product families need to balance between commonality and variability so that the flexibility allows building individual software systems so that they satisfy the goals and needs of demanded customers (Pohl et al. 2005, p. 202).

Individual software systems within a product family differ from each other through the features they deliver (Asikainen et al. 2007). However, Galster et al. (2011) do state that variability does not automatically increase perceived quality. On the contrary, variability enables flexibility and productivity, which are quality attributes of product families. This means that variability in product families helps in achieving the benefits of a product family. (Galster et al. 2011) The proven benefits include significantly reduced development and maintenance effort (Galster et al. 2014).

Software systems today must deal with versatile environments, different user groups, and varying usage scenarios and deployment settings. Technology progresses fast and stakeholder requirements are more difficult to predict than earlier. Thus, usage scenarios

are often not set at early design and are implemented as late as possible, because they can also change during the system's lifetime. (Galster et al. 2014).

This chapter has discussed literature from the chosen perspective. The topics that appeared in the empirical part were paid special attention to see if the challenges found are similar in both parts. In the next chapter, the results of the study are presented. This means that the challenges found in the empirical and theoretical parts are compared and categorized relevantly. Additionally, a synthesis of the paired challenges is presented.

6. RESULTS OF THE STUDY

In this chapter, the results of the study are presented. The challenges identified in empiric and theoretical part were collected and combined. First set of challenges were found both in the empirical and theoretical part and thus they were combined with their corresponding pair. The second set consists of challenges identified only in the literature. In fact, most of the challenges in this set seem potential challenges in this context as well, but they were not identified in the interviews. Last set of challenges were found only in the empirical research. Most of the challenges are highly related to the domain and not actually to building a product family, which was studied in the theoretical part. In the following sections, these three mentioned categories of challenges are represented.

6.1 Challenges existing both in empirical and theoretical study

First, the challenges that were found in both empirical and theoretical part, are presented. They are presented in Table 1 below. In the first column, the challenge from empirical research is presented. On the second column, is the corresponding challenge found from the theoretical part. The challenges are not in order of importance.

Table 1.   *Corresponding challenges from empirical and theoretical parts*

	Empirical challenge	Theoretical challenge
1	Some partners are more active than others	Some customers dominate user group forums
2	Maintenance is challenging	Ad-hoc method leads to maintenance problems
3	Making improvements when same code exists in multiple instances	Management of changes to all instances difficult with ad-hoc method
4	Partners need to be flexible to gain benefits	Customers see the loss of flexibility rather than recognizing the benefits
5	There should be a well guided explanation and documentation about the common model so that the new partners do not have to make any suppositions	Domain information is localized
6	Definition of standardized or common model	The scope for architecture may not be well defined and stable
7	Definition of the business objectives and KPIs of the common model	Defining business case, reuse ratio and ROI
8	Communication between partners and administration; standardization as a part of process when new	Communicating the variability to customers for trade-off decisions; poor communication of requirements

	partner enters - the country could possibly modify their practices to meet the requirements of the common model	
9	Communication between administration and developers	Poor communication of architecture
10	Size of the core	Generalized instead of optimal decisions
11	Finding shared format for train run data; settlement is very different as far there is no standardized energy market; different legal and system frameworks (both in railways and energy)	Application domain and interfaces should be stable and well understood as possible
12	Overlapping and parallel projects, understanding the overview difficult	Variability information is scattered
13	Flexibility vs. standardization, size and cost of the system; developed core should allow flexibility so that new partners can enter	Building products and balancing between communality and variability so that flexibility allows building individual applications, which satisfy the goals and needs of eligible customers
14	When new functionalities are developed in standards and implemented in systems, wrong decisions can be made	Difficult to foresee coming needs in advance - experience needed to create a family

This table is a result of combining the challenges found in the empirical and theoretical parts. They are not definitely describing the exactly same challenges, but it was found out that the phenomena are corresponding. Next, the pairs of challenges are explained shortly. There will be a short explanation what the challenges mean and why they were considered as corresponding.

On the first row, challenges relate to active and less active customers or partners. The challenges found are the same. The loud are heard better than the silent. Thus, the requirements expressed by the loud ones can be prioritized, which may not be good for the development of the family. The second and third row talk about maintenance challenges. They were found in both parts of the study and are obvious as changes need to be done to all instances and can have different consequences in different implementations. The fourth row talks again about partners and customers. This is a result of a dilemma of hoping to receive benefits of the product family but not liking to stretch one's own requirements. The fifth row discusses documentation of the solution and domain information. Literature says that the key information is often in the heads of key people. Thus, the documentation should describe decisions of what is common and what is variable.

The sixth row says that the standardized or common model should be defined. The literature in turn says that the requirements should be expressed clearly and completely to be able to make architectural decisions based on the requirements. Similarly, the requirements of the common model should be described clearly because before that no other decisions or architectural descriptions can be made. Seventh row discusses defining business objectives similarly in both columns. Business objectives are the basis for other decisions to be made. The eight row discusses communication between the organization providing the solution and the customer. The requirements should be communicated clearly and new customers assisted in making trade-off decisions between the offered variability and their requirements. On the ninth row, communication between administration and developers and in the second column communication of architecture are listed here. The first column may include other issues as well, but architecture is definitely one of the most important topics that should be clearly discussed between those parties. On the tenth row defining the size of the core is listed as a challenge. According to the literature, there should be a balance of implementing functionalities to core of the system or either to instances separately. None of the options is always the best.

On the eleventh row, a challenge found from the literature says that the domain, where system is applied, should be stable and well understood. The similar challenge relates to the interfaces of the system that are the borderlines between the system and the domain. Three different challenges found in the empirical part where combined here as they reflect the same challenge that literature proposed. Firstly, finding shared format for train run input and the differences in settlement end outputs are describing variability of interfaces. Moreover, different legal and system frameworks both in railways and energy market reflect the challenge of understanding the domain. In addition, the energy market is developing and new interfaces are being developed such as reporting to energy market. On the twelfth row, empiric research claims that overlapping and parallel projects make understanding the overview difficult. On the other hand, literature says that variability information is often scattered. It means that one layer of abstraction is considered at a time, which makes forming the overview challenging. Thus, the challenges describe similar phenomena. The thirteenth row describes challenges related to finding balance between flexibility and standardization. In the empirical part, there were two different challenges identified. First one discusses flexibility, degree of standardization, size and cost of the system and the second challenge discusses flexibility from the point of view of a new partner of the system. Literature has identified that building products and balancing between commonality and variability is a challenge. The fourteenth and last row discusses experience and its effect on building the family. Empirical research has identified that when creating new standards, many wrong assumptions can be made. It has been a challenge when developing the standards but also when building the system. Literature says that experience is needed to create a product family.

6.2   Challenges found only in the theoretical study

The following table presents challenges found only in the literature and no corresponding pair was found in the empirical study. The relation of each challenge into the case is described shortly after the table. In the end, there is a short conclusion of the challenges presented and their relation to the empirical study. The challenges are not in order of importance. The Table 2 including the challenges is presented next.

Table 2.   *Challenges found in the theoretical study*

	Theoretical challenge
1	Which of the requested features should be implemented
2	Requirement analysis not successful to achieve economics
3	Variations are too large or too different from existing assets
4	Addressing only one layer of abstraction
5	Inadequate marketing strategy
6	Lack of understanding product family as a strategic asset
7	Variability assessment is lacking structures
8	Business factors do not support product family
9	Reusable assets need to be identified periodically to enable continuous evolution
10	Difficult to describe all commonalities and variabilities in architecture, which is described outside product family domain and thus variability is in the heads of architects
11	Dependence on decisions (decision making order)
12	Reactive way of working
13	Lack of knowledge and information
14	How to know whether, how and when variability should evolve
15	Decisions on different levels
16	Confuse the requirements between product family wide and product specific requirements

The first row describes a challenge of deciding which features should be implemented. It is a rather obvious challenge in any product family. The second challenge says that requirement analysis is not successful to achieve economics. It means that if too many

requirements are accepted, which is not economical. This might have earlier been a problem in the case but change advisory board (CAB) has been implemented. Its task is to review coming requests whether they should be accepted or not. There is not yet too much experience with CAB but anyway this challenge is clearly something that should always be remembered when dealing with product families. The third challenge says that variations are too large or too different from existing assets. This might be a relevant challenge if the two different models (train run based and traction unit based settlement) are being combined. The fourth challenge is called as addressing only one layer of abstraction. It means that variability is addressed only from one point of view at a time. However, understanding variability is needed in many layers such as architecture and implementation. This is a relevant challenge in many of the product families as assessment techniques often focus on only one layer. The fifth challenge is an inadequate marketing strategy. The marketing strategy should define who are the competitors and customers of the product family and what is the market like. This might be a potential challenge in the case.

The sixth row describes a challenge of lacking in understanding the product family as a strategic asset. In this empirical case studied, it is discussed. However, another matter is whether the actions reflect the understanding. Or do all persons share this understanding? Thus, is should be considered as a potential challenge. The seventh challenge says that variability assessment is lacking structures. Literature says that often informal processes are applied. This might be a potential challenge in the empirical case too as the techniques of variability assessment were not discussed. The eighth row says that business factors do not support product family. One practical example might be that business factors support short term success whereas it takes a lot of resources to develop a product family. This could be a potential challenge in the case too even though the business factors were not discussed. The ninth challenge is that reusable assets need to be identified periodically to enable continuous evolution. This is a potential challenge in any product family as far as the periodical evaluation of the assets is not part of some defined periodical process. The tenth row says that is difficult to describe all commonalities and variabilities in architecture, which is surely a challenge in any product family because commonalities and variabilities form a complex structure themselves.

The eleventh challenge says that there is dependence on decisions and thus there is a dependence on decision making order. This is a potential challenge in the empirical case too as there are many decisions to be made in many levels. The twelfth challenge is the reactive way of working. Time and other pressure might lead to solving single problems at a time and thus this is considered as a potential challenge. Thirteenth challenge is lack of information and knowledge. Lack of information and knowledge leads to surprises when developing a new derived instance. As the product family in this case includes a lot of separate systems and stakeholders, this is a potential challenge. Fourteenth challenge is to know whether, how and when variability should evolve. It is an obvious challenging

topic in any product family. The fifteenth challenge are decisions on different levels. There are for example strategic and architectural decisions but also many detailed decisions that relate to the development of the product family. This is a potential challenge as many of these decisions relate to each other but are done by different people in different positions. The sixteenth and last challenge is the confuse of the requirements between product family wide and product specific requirements. Potentially, there could be partners that do not want to use part of the core solutions. That would be a challenge.

As a conclusion, it was recognized that all these challenges found only in the theoretical part are potential to be happened in the case too. This means that they could be presented as challenges for the system. The challenges can even be recognized already but they were not expressed clearly in the interviews. It is possible too that they are not recognized as challenges even though there might be a risk of them to come true. A greater conclusion is presented in chapter 7 discussion.

6.3   Empirical challenges

Next, the challenges identified only in the empirical research are presented. For these challenges, no corresponding pairs were found from the literature. The challenges were categorized to closer understand the relation to the theoretical study. The challenges are not in order of importance. The challenges together with their category are presented next in Table 3.

Table 3.   *Challenges found only in the empirical study*

	Empirical challenge	Category
1	Practical challenges (GPS, roles and ownership of trains, business models and expectations of quality)	Domain
2	Agreements for changing international data	Domain
3	Different meters and their measuring cycles and interfaces	Domain
4	Automation and its cost for quality	Domain
5	Old technical and architectural decisions and technical depth	Solution
6	Testing is challenging, each functionality needs to be tested individually and in each instance	Solution
7	Low quality train run data; requesting changes is difficult	Domain
8	SLA requirements in the energy market, timing and quality of data	Domain
9	Reporting to energy market: changing moving consumption to fixed consumption	Domain

10	Fulfillment of roles defined in energy code	Domain
11	Contradicting regulations in railways and energy market	Standards and regulations
12	Third energy package will be implemented differently in different countries - how will railways relate to the regulation	Standards and regulations
13	Difficult for railway undertakings to fulfill all requirements	Standards and regulations
14	Railways change slowly and are very nationally focused	Domain
15	Risk of competing standards if lobbying fails; The need of affecting and lobbying regulation making bodies	Politics
16	Risk of many countries leaving EU and regulations would not apply anymore	Politics
17	Political parties can have their own agendas	Politics
18	Railways are a specific energy user	Domain
19	Two domains are more closely bound together than before	Domain
20	Understanding of what's special at partners' requirements	Solution
21	Regulations are not detailed and countries adapt them differently	Standards and regulations
22	Dependence on standard making bodies	Standards and regulations
23	Risk of governing something without a practical solution	Politics, standards and regulations
24	Decisions in countries' upper levels can potentially make harm to the system	Politics
25	Standards get outdated and are after some time being updated a lot, whereas system and its architecture is tied to old standard	Standards and regulations
26	Standards do not describe future but current situation	Standards and regulations
27	The need to recognize practical challenges so that they can be configured	Domain

The categories identified were domain related challenges, solution, standards and regulations and lastly politics. Challenges in category domain are such general domain related challenges that are typical for this domain only and can't be solved straightforwardly with the help of literature. The challenges relate here to two domains, railways and energy market and to this specific situation where they are meeting each other and are bound together more closely than ever. The challenges and their influences can best be eliminated by recognizing them and using domain knowledge available.

Standards and regulations are related to the domain also but are a specific group. However, some of the challenges are rather general and could be applied to other domains as well. Thus, they form their own category. Political challenges are the third group of challenges. They are a similar group than standards and regulations and could be applied elsewhere too. Standards, regulations and politics are such categories that reflect stakeholders of the product family. The challenges usually can't be eliminated by the own actions of the product family building organization. They are rather facts that need to be paid attention when building the product family. The objective is to manage those challenges and be prepared for them. These categories were not studied in the theoretical part, which explains why they appear only in the empirical part.

The challenges placed in category solution are the ones that might have been recognized in the theoretical part when product families where studied. They relate to the actual solutions or products and have a technical perspective. There were three challenges in this category. The first challenge is to understand what's special at customers' requirements. Even though requirements engineering and communication with customers were discussed in literature, this special challenge was not considered. Literature says that is should be considered, whether a solution that covers 80% of the requirements, could be accepted by the customer. Solution would not fulfill all their requirements but would be a more economical solution if the solution meets the other products in the family much better. However, in the empirical part it was found out that sometimes it is challenging to recognize what is different in the customers' requirements from the others. Different customers may have different terms for similar meanings and at first their requirements may sound very special. Communicating the requirements can be difficult too. However, when the requirements are studied more closely, it can be found out that the solution covers about 80% of the requirements or even more. Thus, there is a difference in the challenges presented in empirical and theoretical part.

The second challenge in category solution was that testing is challenging when ad-hoc or in other words clown and own method is used. In these cases, all functionalities need to be tested individually and then tested again in all instances as there can be unexpected consequences. In comparison, the challenges found from the literature say that maintenance is difficult with ad-hoc method. However, testing was not brought up specially as it was in the empirical part. The third challenge in the category names solution was old technical and architectural decisions and technical depth. When building product family, this is a significant challenge on the development side. However, it was not discussed in the literature studied.

In this chapter, the results of the study were collected, combined and presented. Also, the arguments for pairing the challenges were presented. In the following chapter, the results are analyzed and discussed profoundly. Additionally, the study will be assessed and suggestions for future research are presented.

7. DISCUSSION AND IMPLICATIONS

In this chapter, the research results are analyzed. The results and their meanings are discussed profoundly. Then, the study will be assessed and suggestions for future research will be presented.

The challenges found in this study were divided into three categories. The first category consists of challenges that were found both in the empirical and theoretical parts. The challenges were combined with a matching challenge from the other part. As a result, there were fourteen pairs of challenges of this type. The second category consists of challenges that were found only in the theoretical part. The number of the challenges is similar to the first category as there are sixteen challenges in the second category. An interesting finding was that all the challenges in the second category are substantially potential to be relevant for the empirical case also. According to literature studied, these challenges are typical for product families and their development. These challenges were not expressed directly in the interviews or addressed at all, but nevertheless, they are considered likely to pose challenges or risks of challenges at least. The thought about this likeliness raises from the experience of the researcher. Thus, these challenges should be paid attention in the case organization if not addressed already.

The third category comprehends challenges that were found only in the empirical study. There was a rather big amount of such challenges (27). Almost all these challenges are specifically tied to this specific domain closely. Many of such challenges relate to railway and energy domains meeting each other or to laws and standards of this specific environment. Such case specific challenges were not found from literature directly as the focus of the literature study was on product families. Moreover, literature may not recognize such case specific challenges at all. Thus, experts of this domain have an important role when managing these challenges.

Challenges found only in the empirical study were further categorized to ease their analysis. It was found out that majority of the challenges can be categorized with terms such as domain or standards and regulations, which are highly case specific challenges. Some challenges were given the category political challenge, but still far from product families. Lastly, three challenges were categorized to belong under category solution. It refers to the products and their development. This means that such topics could have potentially been discussed in the theoretical part. Their subject matter was similar than subjects studied from the literature but no such challenges were expressed in the studied literature. However, the amount of these challenges is relatively small when comparing to all challenges found in both parts.

In this case, managing case specific challenges means that they need to be understood and managed as well as possible. For example, laws, standards and other requirements must be understood and taken into account when building the family. The options are trying to live with them or trying to affect them. In practice, the both options are utilized. The other example of typical case specific challenges are practical differences in the operation environments. For this type of challenges, the important part is to recognize them so that they can be managed, typically configured as an option to the system. In many cases, the possibilities to solve these differences is moderate, which means that often adapting the product is the easiest thing to do, at least in cases where it requires no major effort. However, the possibilities to affect the situations depends highly on the subject, as there are various types of differences. Moreover, the organizational factors of the infrastructure manager responsible do affect how easy it is to request changes to the processes or systems. Making adaptations to the system itself is easiest in the early phase when the product family is being built. Making any adjustments later requires always some rework.

When building a product family bottom-up, the most important thing is to understand what is similar in the existing systems and their use contexts, what is configurable and what is different. Understanding the different variables and variation points is a key to success and required before any further development of the product family. As product families and their development include a wide selection of different aspects in different levels, clear documentation and visualization of communality and variability would help communication and knowledge sharing, which are crucial for the success of the product family.

As result of the analysis and categorization of the challenges, it can be concluded that the challenges found in this study are rather typical for product families that and specially for product families that are built bottom-up. Bottom-up refers to a situation where few implementations exist before structured development of a product family starts. Bottom-up situation is often caused by methods like clone-and-own, which creates the challenge of separate instances. There were many challenges that were found both from the empirical and theoretical study, which means that they may be rather typical. Moreover, there were challenges that were found in the theoretical part only but could possibly affect the empirical case too. Thus, the challenges found in the empirical part support the challenges represented in the literature. Moreover, there are lot of challenges that are highly case specific.

For the case study and people involved in the development of the product family, the important part is to hear that they struggle with generic challenges related to product families. The challenges are found elsewhere too, which makes it easier to manage and solve them as possible solutions can probably be found both from the literature and industry. There are many challenges that can be influenced within the organization. For example, categories like lack of strategical mindset, methodological challenges, scope of the product family, knowledge and information issues and decision making often relate

to persons involved and their actions and decisions. Such employee and organization related issues might be much easier to affect than case specific challenges that often require influencing some stakeholders. Some of the case specific challenges can be managed by specific expertise from the area. However, they might be more difficult to affect in short term. For example, the challenges of two domains meeting each other will take years to solve and many stakeholders need to interact with each other at different levels before that largish challenge is resolved.

7.1   Assessment of the study

Assessment of validity and reliability in a qualitative research is rather challenging because there are no simple measures to evaluate them. Yin (2009) suggest to evaluate construct, internal and external validity and reliability, which altogether comprise evaluation of validity and reliability. Since Yin's assessment categories are used in software engineering research, e.g. in Raatikainen et al. (2005), they are used in this research study too to discuss the results of the study.

Construct validity refers to determining right measures for the concepts studied. To ensure construct validity, multiple respondents from various organizations were interviewed. In addition, two different analysis methods, document and content analysis were used. As much original data (for example transcripts from interviews) was used. In addition, many people involved got to see and comment the study before publication. However, the study did not include observing people in their work and therefore may not have covered all the details and practical challenges raised in their work.

Internal validity reflects causal relationships of the entities that are being studied. However, the objective of this study was to represent challenges in the product families and not define the causal relationships related to the challenges. Thus, internal validity is not considered relevant to this study as the study has concentrated on descriptive method.

External validity refers to determining the correct domain, in which the results can be generalized. In this study, it was found out that the results found in empirical part are rather similar than results found from the theoretical material. This supports the findings of literature. However, no new theoretical generalizations were made. Three challenges found in the empirical part could have been addressed in the literature by their topic. However, no generalization was made on the issue as the hypothesis requires testing and validating the hypothesis with more cases as only one case was used in the study.

Reliable study and its operations can be repeated with similar results. To support reliability, rigorous procedures such as interview questions and content analysis with categorizations were used. However, the weaknesses of reliability are preconceptions of the people involved in the study. The interviewees can have different understanding of the topic and they can talk about issues that are relevant for them right now and forget to

talk about some aspect totally. Moreover, the interviewer's preconceptions guide the interviews too as the interviewer can be prejudiced or the question layout can limit the answers. The interviewer's vision was increasing with the interviews, which can be both a negative and a positive thing. The perception and vision can also have guided the pairing of empirical and theoretical results. However, the procedures for data qualitative data analysis were designed so that they could be followed to conduct similar research again.

7.2 Suggestions for future research

The study resulted in similar type of results from the empirical and theoretical part with regards to the topic of product families. However, more research on a larger sample would be needed to reliably estimate observed similarity. It should be verified whether the challenges found only in the theoretical part would be verified as challenges for the empirical case also. On behalf of case specific challenges found in the empirical part, more research would be needed to see whether such challenges appear elsewhere too and what might be the possible ways to manage those challenges. Another interesting research topic would be to study whether product families always face a bunch of case specific challenges to be solved.

During this study, it was observed that there is very little research done on the construction of product families bottom-up. This refers to creating product families when already few instances exist. As this method is said to be the most typical situation to start a product family, it is interesting how little guidance and research is targeted for this phenomenon. Assunção & Vergilio (2014) say that the interest on this topic has been growing in research, but that the transformation phase still lacks research.

Galster et al. (2011) would find it interesting to study the assessment criteria, which decide whether a new required functionality will become part of the shared core assets or not. This would be an interesting research topic also in the scope of this case. According to Galster et al. (2011), this decision whether the functionality is implemented in the core assets or in the product specific artefacts, is usually done based on intuition.

In this chapter, the results of the study have been discussed profoundly. Moreover, the assessment of the study and suggestions for future research were presented.

8. CONCLUSIONS

In this chapter, the study will be concluded. This includes presenting the choices of what was studied, why but also presenting the results of the study.

According to European Union, all member countries shall settle energy used in their railways through an energy settlement system by 2020. The regulations do also require installation of energy meters to new or upgraded rolling stock. Energy meters allow settlement of the energy from the railway undertakings precisely through their metered consumption. Energy settlement systems are built to receive meter data, validate and allocate it for the right railway undertaking.

Erex is a such settlement system. The settlement module of Erex needs to be adopted to each country to an existing framework of laws and regulations, systems and practices. These factors mean that 100% standard system can't be applied to every country. For this reason, the product must be adapted to meet the needs of different partners. Erex has been developed during the years and improved for new partners. This has caused that instances are not easily manageable as whole. For example, maintenance is challenging because improvements need to be done and tested in each instance. During the recent years, the number of partners has been raising and similarly has the need to improve management of the instances. This would mean shared core functionality for all partners. Having the same principles for the system is means having a common model. This means building a product family, where commonalities and variabilities of different systems are well managed.

Many of the current challenges are rather typical for software that is derived with ad-hoc method, which is also called clone-and-own method. The methods utilize copying and separate instances. Typically, few product variants are derived in this way before more manageable methods are constructed. The more advanced approach are product families, where variants, variability and variation points are managed in a more organized manner.

The objective of this study was to find out what is challenging when product families are developed bottom-up i.e. when individual products are already existing. The subject was investigated in case Erex. Thus, the study also intended to look for factors that obstruct the development of a common model or the use of same product in all countries. In other words, this means finding out the variabilities of the systems. To achieve this goal, experts from five European countries were interviewed. The interviewees are responsible for adaptation, development and operation of the system in their respective countries. In addition, experts from different roles from the organization owning and operating the system were interviewed. Developers of the systems were interviewed too.

When the empirical research was finished, literature was studied to find out what is challenging when product family and its variability are being developed with bottom-up approach. Thus, the focus was on product family literature and on publications that discuss the challenges of the product families. Hence, this study compared empirical and theoretical results. The objective was to see if the results of the empirical research support the results of the theoretical part or if the empirical research suggests new findings to be generalized. The result of this comparison was that empirical results support existing studies very well. There were lot of challenges found in the both parts of the study. Moreover, challenges found only from the literature seemed very potential to be challenges for the empirical case too. Those challenges were not mentioned in the interviews but it seemed possible that these challenges are already existing or could be potential challenges for the case studied as the development of the product family continues. Thus, these challenges can be of great worth for the product family. Recognizing these potential challenges in early phase can help avoiding them.

The third group of challenges found were only discovered in the empirical research. However, these challenges are closely related to this specific case and its domain. This kind of challenges were not studied in the theoretical part and generally, are very hard to find from the literature. For example, railway domain meeting energy market is something that is very rarely discussed in any publication. In this group of challenges, there were only few challenges that could have been addressed in the theoretical part by their subject. However, compared to the whole amount of challenges found, these three challenges had only little role. Mostly, it was found out that the empirical results support current literature very well. This means that challenges found in the case are rather typical for product families that are being built bottom-up.

This study gives some input for further actions for the product family studied and the persons involved in its development. Firstly, there are challenges in the development of the product family that are typical in other product families too. When solving these challenges, experience can be found from the literature and industries. Secondly, there have been identified a group of potential challenges for the case. They should be considered carefully to see whether they could cause challenges for the product family and how they should be managed. Naturally, similar actions shall be put into practice for challenges that have already been recognized. Third, best experience from the domain should be used to solve challenges that are highly case and domain specific. This is the mode of operation already today and thus it needs to be made sure that the experience is available also in the future.

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APPENDIX A: COUNTRY SPECIFIC FACTORS

FINLAND

Electricity market law 588/2013 (FINLEX 2013) defines real estate group's internal electricity grid that is not defined in the directive. Railway grid has been defined as such internal electricity grid of a real estate group, which means that the Finnish Energy Authority has no jurisdiction in it. For this reason, Finnish Transport Safety Agency is the only regulatory body for the railway grid. Finnish Energy Authority is the regulatory body for 110 kw transmission network to the railway grid.

However, the railway grid is not a typical internal network of a real estate group, because it has several accesses to high-voltage transmission system but also to regional transmission systems. Moreover, trains that are the consumption points of the grid are continuously moving, which means that the move from the area of a single access point of the railway grid to other areas while they move. Finnish Energy Authority, railway undertakings eSett (imbalance settlement unit) have agreed that railway grid needs to apply the rules for distribution networks to the extent that the clarification or settlement of electricity to the energy market is required.

Regulation TRAFI/57058/03.04.02.00/2015 (Finlex 2015) has stated the rules for stabling. Stabling refers to authorized work that is done in the railway system to support trains. Stabling means transfer work, where units are changed. In the communications between traffic control of infrastructure manager and railway undertaking, a pre-defined operating language specified by the infrastructure manager must be used. The traffic control must create an ID for the stabling work for the communicating purposes so that the stabling work is identified and does not interfere with any other stabling work. The highest accepted speed during stabling is 50 km/h. (Finlex 2015)

The costs of electricity transfer service for railway undertakings are described next. The basic cost per traction units is based on metering and balance management costs. Transmission fee of high voltage network is based on the cost of the grid and high voltage network. Average transmission fee is used in the whole railway network. Losses for the railway network are calculated as such: net consumption of individual consumption points is reduced from the net consumption of the substations. For fixed installations, the loss is 3,3%. The cost for loss energy is based on the purchasing electricity price of the government. (Finnish Transport Agency n.d, appendix 21.)

Transportation electrical power and preheating of passenger trains are additional services. The Finnish Transport Agency provides the transmission and electricity balance management for the railway undertaking needed for the transportation electricity and preheating. Based on the electricity balance, the railway undertaking can acquire its electricity. Transmission costs are comprised of transmission fee, railway network losses and energy measurement and assessment services. The Finnish Transport Agency will

charge the transmission costs from the railway undertakings in relation to their consumption. The transfer prices are published in advance. (Finnish Transport Agency n.d., p. 56)

SWITZERLAND

Use of electricity through catenary is a basic service provided for railway undertakings. Stabling of train compositions, shunting routes and shunting in marshalling yards are examples of ancillary services. Consumed electricity is invoiced separately. During peak hours, there is 20% increase in the price and 40% decrease during the night. If energy measurement devices are not installed and calibrated correctly, infrastructure managers can make sample measurements for train categories to set their relative consumption values right. (SBB 2017, pp. 84-92)

BELGIUM

The electricity for electric rolling stock is taken from the overhead contact line. Intrabel transforms the voltage and distributes the electricity from its substations to the users. The substations are located between high voltage network and Infrabel's railway grid. This means electricity required by railway undertakings can be collected via pantographs. The compulsory cost for the supply of traction current includes costs of energy and balancing acts, taxes and costs defined by the suppliers, green certificates and cogeneration certificates but also CO_2 emission rights. (Infrabel 2017)

The metered consumption is determined based on the electricity that is delivered through the pantograph. 90% of the generated energy will be reduced from the amount. Generated energy constitutes during regenerative braking. The railway undertaking operating the vehicle must report the composition for the infrastructure manager and the information can be corrected within four days. Electricity has three different price time categories (normal hours, working hours and off-peak). (Infrabel 2016)

On average, cargo trains consume far fewer energy per ton-km traveled because the speed is lower and the trains stop less frequently along their routes. These are seen in the estimation formulas that are used for validating the metered consumption and used if there is no meter in the train. For passenger trains, the formula is as following: $(32 + 0.023 * D1 + 0.033 * D2)$ Wh/ton-km, for high speed $(40 + 0.023 * D1 + 0.033 * D2)$ Wh/ton-km and cargo: 4kWh/km + 12 Wh/ton-km. The variables D1 and D2 refer to the number of degree-days in month. A remarkable part of the consumption of passenger trains is consumed for heating or cooling the rolling stock. Outdoor temperature determines if there are such needs. This need can be estimated based on degree days that reflect the daily average temperature. Each day below average of 16.5 degrees (celcius) near Brussels is counted as one degree-day (D1 in the formula, heating). Each day above 20 degrees is counted as one degree-day (D2 in the formula, cooling). Accordingly, a day with an average equivalent temperature of 25 Celsius counts as 5 degree-days for that month. (Infrabel 2016)

THE NETHERLANDS

Use of the overhead line infrastructure is considered as a basic service. The purchase and supply of electric tractive power is facilitated mainly by VIVENS. CIEBR supplies the electricity for two routes. The electricity can be used also for train preheating at storage sidings from the overhead contact line. Shunting services are provided by specialized companies. The transport costs of the electrical power are charged from the railway undertaking as grid managers charge them from ProRail that delivers them for the railway undertakings. Railway undertakings utilizing this power need to submit a periodic statement of their actual and expected electrical power consumption. The invoices are based on estimates of the consumption per railway undertaking but still railway undertakings need to be charged based on kilowatt hours used yearly. The difference between the estimated consumption and actual consumption is subject to settlement. (Prorail 2017, pp. 44, 76-100, 99-100) For this purpose, the Netherlands is planning to have Erex system up and running by the end of 2018 (Vivens n.d.a).

Before Erex can be used for energy settlement, costs are allocated through an energy allocation model. The model is based on characteristics and type of rolling stock, which refer to trains' scheduled speed and number of stops, energy savings and heating energy. For passenger trains train kilometers and carriage kilometers are used as a basis for estimate. For freight train kilometers and weight are calculated. Difference between realized consumption that is measured at substations and model based consumption is proportionally divided among users. (Vivens 2011)

DENMARK

Consumption data of trains having meter on board is sent to Erex for calculating charges. The charges are calculated according to the valid tariff at that hour on the spot market. There are two different grid areas, which means that location affects the charge. If the train does not have meter on board, the charge is based on the month's average tariff for grid area. The amount is based on the reported kilometers travelled during the period multiplied by an amount of kWh/km. KWh is calculated differently for each sub-entry and is used also as a basis for the charges. (Rail Net Denmark 2017)

In both cases, if there are meter on board or not, electricity-trading tariff is added to the charge. The electricity tariff is supplemented by state's electricity tariffs, public service obligations, leakage, administrative fees and VAT but also difference loss if no meter is used. Charges can be calculated differently on the Øresund Bridge as the supply switches between Swedish and Denmark. Trains can use electricity for pre-heating and other purposes via sockets. Such pre-heating or other standby used that is supplied via pantograph is calculated and charged together with normal transport costs. Use from sockets will be added separately including required tariffs. (Rail Net Denmark 2017)

SWEDEN

The railway undertakings are invoiced in Sweden primarily based on the actual consumption of vehicles through energy meters. In other cases, standard templates are used and in those cases the invoices are based on gross to kilometers completed per vehicle type. At the end of the year, Swedish Transport Administration will declare amount of electricity consumption reported and supply to the grid. The difference is distributed for vehicles without energy meters. (Swedish Transport Administration 2016)

Vehicles can either have a meter from Swedish Transport Administration, their own meter or no meter at all. The meters of Swedish Transport Administration are charged hourly. The charged amount is based on the current electricity price but it also includes network charges of the specific grid area. Railway undertakings that have installed their own meter must report their electricity monthly per vehicle. They are charged according to mean price. They are not charged a price related to specific grid area since there is no information about the time and place of consumption. (Swedish Transport Administration 2016)

Trains can use electricity for other purposes as well than traveling, typically for warming or cooling. This can be done via pantograph of heating points. The charges for this service are based on a fixed cost per days having a connection to the energy or heat source. The trains that have a raised pantograph and energy meter are charged from their stabling consumption along with traction current. (Swedish Transport Administration 2016)

NORWAY

The price consists of the price of electrical power, grid hire as grid enables sending power from Bane NOR's production site to converter stations, conversion and transfer losses but also Bane NOR's administrative costs. The allocation of energy costs is made according to measured energy consumption on the trains with the help of energy meters or either based on reported gross kilometer tonnage travelled and key indicators that help to converse gross kilometer tonnage into energy consumption such as type of traction unit, line section and service pattern. (Bane Nor 2017)

Bane NOR is also offering railway undertakings an access to preheating facilities. Railway undertakings shall pay a fixed annual rent for each preheating facility. Bane NOR does not offer shunting at present. Thus, the railway undertakings shall organize it themselves. (Bane Nor 2017)

APPENDIX B: INTERVIEW QUESTIONS

INTERVIEW QUESTIONS FOR ALL INTERVIEES

Current implementations

- What sort of differences there are at the implementations currently?
- What are reasons to these differences?

Requirements, processes & practices

- What are the country specific obstacles that hinder standardization?
    a. Why are they hindering? How they could be solved?
- How could countries adapt to a standard model?
- Are there some special interests for the system in partner countries?
- How do practical domain matters hinder standardization?
- How is it possible to find a target model, in which all members could engage to join in certain time frame?
    a. What are the restrictions why it is not possible to join such standard model at this moment?
    b. What kind of needs there are for localizations outside such standard model?
- What are such requirements that countries can't be flexible?
- In which matters a compromise could be done?
- Are there different practices in process steps that hinder standardization?
- Which time series types are used for settlement?
- What are the differences in requirements for reporting?
- What is challenging for the other countries?

Laws

- How does EU legislation guide development of Erex and its standardization process?
- How do country specific legislation guide development of Erex and its standardization process?
- What is the relation of Non-EU countries (Norway and Switzerland) to EU regulations?

Agreements and network statements

- How do network statements guide the development of Erex and its standardization work?
- Network statements are done well in forehand before the period of validity. What are pros and cons of this practice?
- How do the network statements hinder standardization?

Roles & partners

- How do business models of the partner countries vary?
    a. How do these differences hinder standardization?
- What are the roles defined in laws?
- What participants/stakeholders affect development of Erex and how?
- Who is responsible on the development of Erex? Who has the deciding power?
    a. Do decides if minor changes are made? Who if processes require change? What if there are largish IT changes expected?
- How can suggestions of such changes be presented to the countries?
- How the different interests of partners are managed and prioritized?
- How is harmonization process seen from the point of view of potential new partners?
- How do you think new partners could adapt to the European model?
- Are there some other stakeholders that have role in harmonizing process?

Nordic model
- Could the model based on settlement of traction units be provided for new countries in the future?
- What is the strategic intent of countries using settlement based on traction units to transfer into settlement of train runs?
    a. How could they adapt to this model based on train runs?

Energy market

- How is the energy market of your country functioning in relation to railways?
- What requirements there are for reporting energy consumption?
- Where do the railway undertakings get their electricity?
    a. Can they or do they have to choose their supplier independently?
- Are there some laws or rules that determine processes related to settlement of energy on railways?

Interfaces

- Should there be in the future a proposal for standard interface between Erex and Traffic Management Systems?
- Should there be in the future a proposal for standard interface between Erex and Invoicing Systems?

General

- What should be asked from other interviewees?
- What is challenging in the harmonization project from your point of view?
- What are the biggest challenges in the big picture for standardization?
- Are there long-term needs that may occur in energy market/politics/infrastructure manager?

SPECIAL QUESTIONS FOR CERTAIN INTERVIEWEES

System Administrator & IT Business Analyst

- What are your roles in Erex harmonization?
- How is standardization seen from the system administration point of view?
- What sorts of visions there are for Erex?
    a. What is seen important?
    b. How needs are prioritized?

Marketing and communications

- What is the marketing potential of a harmonized system?
- What is your view about the possibilities of Erex to broaden to the whole Europe?
    a. Outside Europe?
- What sort of restrictions there are for the countries that do not want to join the partnership but do something else?
- What is the role of communications during harmonization?
- What is attracting new partners? What do they find challenging?
- Are there some agreements with current partners that have an impact on the standardization work?

Analyst

- What are challenges in imbalance management and reporting to energy market?
- How can the solution implemented in Finland be built so that it suits other countries as well?

Developers
- How do you think a standardized model should be developed?
- How do other systems affect standardization possibilities?
    a. Is it possible to affect the development of other systems?
- Who is responsible for the co-operation of Erex and countries' traffic management systems?
    a. Who decides whether traffic management system will be updated to meet better the needs of Erex?
- How are requirements and development activities prioritized?
- Would you please explain generally how would you build the system from scratch now? Explain as general process, not on technical level.
    a. How would this be different from the current situation?
    b. How do the historical decisions affect standardization project?
- Are the needs for semantical standardization?
- How well could the system adapt to different needs with modules, parametrization or configurations?
- Are there such functions that are used by only one country? If yes, how many and which ones?