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**The Role of Information Systems in achieving
the Sustainable Development Goals:**

An overview of Established and Emerging
Technologies for Development.

Student: Luís Afonso da Cunha Monteiro Claro de Castro

Dissertation presented as a partial requirement for obtaining
the Master's degree in Statistics and Information
Management.

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The Role of Information Systems in Achieving the Sustainable Development Goals:

An Overview of Established and Emerging Technologies for Development.

by

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Dissertation presented as a partial requirement for obtaining the Master's degree in
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“Wonder is the beginning of wisdom”

Socrates

ABSTRACT

The Sustainable Development Goals initiative is one of the most significant Global Development programs created by the United Nations for the future. It is both the result and the continuation of a successful anti-poverty movement called Millennium Development Goals, implemented in the year 2000. At a time of transition marked by the post-2015 agenda for Development, new questions and problems have arisen and new challenges have been set in order to keep track of Sustainable Development. Information Systems and technology are among the key elements behind these Global Agenda Programmes, since they are rightly seen as enablers of Sustainable Development. The aim of this study was to understand what the role of technology might be in achieving the Sustainable Development Goals according to literature and field experts, providing a framework that can be used for discussion in a 2015 post-agenda context.

KEYWORDS

Human Sustainable Development, Information Systems, Sustainable Development Goals, ICT4D, Global Leaders, Established and Emerging Technologies, WSIS.

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Outcomes of the present master's dissertation

2 Paper Submissions:

- Paper Submission for the International Journal of Sustainable Development (IJSD) from Inderscience publisher.

- Paper Submission for the Information Technologies and International Development (ITID) journal.

Partnership Opportunity:

NOVA Lisbon has now the opportunity to integrate the Smart Campus Cloud Network (SCCN) initiative from the TERRE Policy Center and UNESCO. SCCN has the goal to provide universities with the tools to foster sustainable development best practices by having close contact with smart grid technologies, their implementation, usage and monitoring of different fields: water and energy consumption, waste and transportation.

LIST OF ABBREVIATIONS AND ACRONYMS

A.I	Artificial Intelligence
BC	Blockchain
BD	Big Data
BT	Biotechnology
CBIS	Computer-Based Information System
DSR	Design Science Research
GDP	Gross Domestic Product
GIS	Global Information Society
GNI	Gross National Income
HD	Human Development
HDI	Human Development Index
IAEG	International Association for Engineering Geology
ICTs	Information and Communication Technologies
IDMC	International Displacement Monitoring Centre
IFAD	International Fund for Agricultural Development
ITU	International Telecommunication Union
IMF	International Monetary Fund
IT	Information Technology
LIC	Low-Income Countries
M&E	Monitoring and Evaluation
MCH	Maternal and Child Health
MDGs	Millennium Development Goals
MIC	Middle-Income Countries
OECD	Organization for Economic Cooperation and Development
RGS	Royal Geographic Society
SDGs	Sustainable Development Goals
SDSN	Sustainable Development Solutions Network
SHD	Sustainable Human Development
STI	Science, Technology and Innovation
UGC	User-generated content
UN	United Nations

US United States
UNDP United Nations Development Programme
UNH United Nations Habitat
WHO World Health Organization
WSIS World Summit on Information Society

1.INTRODUCTION

At the beginning of this millennium 189 governments of the United Nations officially agreed to fight poverty and promote global partnership by signing the United Nations Millennium Declaration (2000), which was adopted during the Millennium Summit – a three-day meeting between many world leaders in September 2000 – and led to the creation of 8 Millennium Development Goals (MDGs). This framework was in place during the following fifteen years; 18 targets were set and, in order to measure the success in achieving them, 60 indicators were developed for more efficient data-gathering, monitoring, evaluation and reporting of results until 2015.

Before the release of the United Nations Millennium Development Goals Report (2015b), a new project was already being undertaken to determine the following steps to be taken by the international community. The Road to Dignity 2030 Synthesis Report of the U.N Secretary-General on the Post-2015 Agenda (2014) provided an overview of the results and drew conclusions. It was essentially a summary of what we had learnt from the MDGs initiative and a reflection on what the future held: “We are at a historic crossroads, and the directions we take will determine whether we will succeed or fail on our promises” (United Nations, 2014, pp.3). Based on the analysis of the results of the MDGs and new human and environmental challenges, 9 new Goals were introduced and a total of 232 indicators were introduced, resulting in the creation of the Sustainable Development Goals (SDGs).

Behind the successful implementation and results of the MDGs, there were many different factors to be considered, with Information Systems (IS) playing a crucial role in guaranteeing the alignment and cohesion of Infrastructure, data, information management, financial/human resources and technology (United Nations, 2012). Without them it would not have been possible to give fast responses to human needs and challenges posed by different countries at the same time.

Information Systems can, according to Alter (1992, cited by Varajão & Amaral, 2000), be defined as a combination of procedures, information, people and information technologies for the achievement of organizational purposes. Santos (2015) believes in the importance and contribution of IS in achieving the SDGs more specifically Technology, which nowadays is a crucial part of any information system, and has been playing and shall continue to play an unquestionable role to foster human progress and should be used to achieve a society where no one is left behind (Seydiogullari, 2013).

The purpose of the Sustainable Development Goals initiative is to set a worldwide mindset of joining forces and tackling the world's largest challenges such as fighting poverty, eliminating inequalities and achieving sustainable, human and economic development. Pilemalm (2002) suggests that technology not only enables Sustainable Development but also works as a facilitator for change and improvement of human life. Moreover, it operates as a connector and contributor to the global well-being by bringing together people from different nations, religions and backgrounds to work and cooperate towards a prosperous and equal society (United Nations, 2012a).

1.1- BACKGROUND

To achieve Sustainable Development, societies will have to transform, in order to keep the pace of human progress, while simultaneously assuring global sustainability. Sachs and Modi (2015) believe that technology will play a particularly impactful role in today's low-income countries, allowing them to close existing gaps and coming closer to the desired outcomes of the SDGs by 2030. For instance, and as a practical example of how this is already taking place, mobile subscriptions in Africa have gone up from almost no subscribers to nearly 900 million in 2015, thus reducing the digital divide and giving people access to information and communication tools according to these authors (Sachs and Modi, 2015).

Technology has the capacity to transform and directly or indirectly improve human life and the environment; Dzionu (2010) believes that only now are we truly unlocking the power of technology to help us solve social, environmental, political and economic problems. This study was therefore an opportunity to give an overview of the main technologies which are and will be contributors to achieve human Sustainable Development in a post-2015 context.

To keep pace with a fast-changing planet and humankind, new technological alternatives are being developed and tested to bring in solutions for the challenges we are facing today and will be facing in the future (Beder, 1994). It is now an opportune time to address the present and emergent options to achieve the SDGs, given the heightened interest and significance of technology for Development purposes (United Nations, 2012).

Technology brings new possibilities, not only for a more inclusive world with less gaps between the developed and developing countries, but also for deep transformation of the economy and societies in general (Sachs & Modi, 2015):

the Internet of Things can help reduce the digital divide, artificial intelligence can lead to the creation of efficient robots, 3-D printing can help improve production, Geolocation services can help water and agriculture management, Cloud Computing can help gather and make relevant data access possible anytime and anywhere. These are some of the technologies addressed in this research that have been proven to be essential not only for human and economic development but also to help achieve the sustainable path of the Road to Dignity 2030. However, there are different variables that need to be aligned, in a global context, in order to successfully deploy technology for Sustainable Development, which will be extensively addressed throughout this research, in particular in the Study section.

1.2- OBJECTIVES

The main objective of this research was to understand what the role of established and emerging technologies might be in achieving the SDGs.

The secondary objectives were:

- To Establish a relationship between Technology and Development;
- To review the existing literature on technologies for development and how they are being used for Sustainable Development purposes;
- To find established and emergent technologies that can help achieve the SDGs;
- To understand what the role of Development Agents and Global Leaders is in leveraging technology for Sustainable Development;
- To link relevant technologies to the SDGs based on their present and possible future contributions in achieving the goals.

The research questions which led to and will serve as guidelines for this master's thesis research are:

- Is Human Sustainable Development dependent or independent of technology?
- What current and emergent technologies contribute towards the achievement of the SDGs?
- How are the researched technologies proving helpful to improve human life and achieve Sustainable Development?
- How can these technologies help solve current Development challenges?
- What is the role of Global Leaders and Development Agents in leveraging technology for Sustainable Development?

2. LITERATURE REVIEW

In order to successfully understand what the role of Information Systems and Technology is and will be in achieving the SDGs, it is necessary to understand the conceptual Human and Sustainable Development foundations driving the UN mission. It will then be possible to address the program's origins, objectives, to properly understand what exactly the results of the Millennium Development Goals (which originated the SDGs) were and their implications, what the present context is and what is missing to achieve better outcomes for the future, from a Sustainable Development point of view.

This research aimed to give a contribution to the academic field of Information Systems, Technology and Development Studies, and a call for multidisciplinary academic research approaches. By understanding the drivers of such a global and ambitious program, it is possible to take a deep dive into the topic and understand what the role of Information Systems and Technology might be in achieving the SDGs and which present and emerging technologies will be key to help humanity step forward and become more inclusive, equal and 'sustainable'.

2.1- HUMAN AND SUSTAINABLE DEVELOPMENT

In order to have a better understanding of the present of the SDGs initiative and how exactly Information Systems and technology are shaping the field of Development as proposed by the United Nations (2014), it is first necessary to define and understand the context in which Human and Sustainable Development is used. The following concepts will be of great importance to have a historic understanding of both the evolution of these concepts and of what exactly humanitarian organizations such as the UN are striving to achieve and how.

Development is a rather hard to define and broad concept, which is used and cited in scientific, academic, professional, personal, religious and many other different fields. The actual history of the concept of Development is, according to Rist (1996), the author of *The History of Development*, intimately connected to the progress of human history, and the influence of the Western World and its philosophies, concepts and scientific discoveries since early ages.

The concept of Development has been used by humankind, mainly the western world, to define and justify different acts, decisions and judgements throughout history, from the Greek philosophers to the modern scientists and theorists (Rist, 1996).

One of the greatest contributors to modern Development theories is the economist Mahbub ul Haq (1995, pp.ix), who claims that “the ultimate purpose of the exercise of development should not be lost in sight: to treat men, women and children – present and future generations – as ends, to improve human condition and to enlarge people’s choices”. Mahbub ul Haq (1995) was one of the major contributors to the modern concepts of Human Development, which was defined by him as the widening of the range of people’s choices, and how it can be measured. This same definition would be adopted and incorporated in the United Nations (2015) vision.

Amartya Sen, who is another well recognized economist in the Development field, describes Human Development as the expansion of peoples’ ability to live better, with more freedom and opportunity (Heyes & Kapur, 2017).

Sen, along with Mahbub ul Haq and other development researchers and economists, contributed to the creation of the United Nations Human Development Index used by the United Nations Development Programme (UNDP, 1994), through his capabilities-based approach; indicators such as the standard of living were emphasized over income per capita for example, moving from utility to capabilities and distinguishing between means and ends – for instance money vs well-being or freedom. (Elizabeth A. Stanton, 2010). In his most influential book, *The Standard of Living (1987)*, Amartya Sen brought up the importance of human well-being and what defines it; this author helped shape the Human Development policies of the United Nations; in particular, the Millennium Development Goals were heavily based on his ideas.

Heyes and Kapur (2017) identify Human Development as an alternative approach to the measurement of the income/wealth approach, which used as indicators the GNI (Gross National Income) or the GDP (Gross Domestic Product). The Human Development approach focuses itself on three primary dimensions according to the UNDP (2015): life expectancy, education and per capita and Gross National Income (GNI), which makes it easier to provide accurate measurement of the standards of living across the globe.

Human Development was, according to ul Haq (1995), an emerging alternative to the classical economic growth school of the late 20th century, where the main focus of development was on the economy, namely on the wealth a nation would be able to generate. The Human Development approach, on the other hand, emphasizes the importance of enlarging people's choices in all fields, - mainly society, culture and politics - , not focusing exclusively on the economy.

The concept of Human Development is flexible in its different dimensions and capabilities according to Sen (as cited in: Alkire, 2010). Its relevancy will differ according to cultural and national contexts. Alkire (2010, pp.10), however, "criticizes the broad modern definition of Human Development, mentioning the importance of "procedural principles" on human development to avoid inequality or the infringement of the human rights of a group to expand the freedoms of another.

Despite the great contributions of the aforementioned authors, the concept and measurement of human development is however only one of the three major Development Theories, the others being Sustainable Development and Human Sustainable Development. According to (Neumayer, 2012), Human Development should be intimately connected to Sustainable Development. The foundations of the Human Development concept given by the United Nations on Human Development Report (1994) and by Sen on the Income Component of the HDI (2000) both entail the principle of universalism and, although the concern for both present and future generations has often been associated with the enlargement of people's freedoms and choices, that principle does not directly cite the compromise with it in regards to the future (Neumayer, 2012). The most commonly used definition of Sustainable Development was given by the World Commission on Environmental Protection and Sustainable Development Report: Our Common Future (1987, pp.6); it was defined as the capacity for development to meet the needs of the present without compromising the ability of future generations to meet their own needs. Despite the fact that humans have long shown interest in sustainability and its practices - see the irrigation technology of the ancient Egyptians or the ecological engineering used by the Mayans to conserve water and food - , the modern concern with environmental and human issues increased mostly in the second half of the 20th Century (Higgins, 2015).

The Club of Rome's well-known report *The Limits of Growth* (1972) featured the first use of the term in modern times; the book authors, Meadows, Randers and Behrens (1972), as well as other researchers and scientists, from both the academic and the business world, developed their own model, which helped them reach conclusions such as:

1. If the current growth rate of world population, industrialization, pollution, food production and resource depletion continue, the limits of our planet's growth will be reached somewhere within the next one hundred years.
2. It is possible to revert these growth trends and to establish a state of ecological and economic stability that is sustainable far into the future. A global equilibrium could be designed to satisfy the basic needs of each person by assuring equal opportunities and realizing individual human potential.
3. The sooner humanity begins working towards attaining the outcome mentioned above, the greater the chance of success.

This approach to the question of Sustainable Development would underline a period of increased Global awareness on the subject, where these authors encouraged the scientific community to give continuity to the study and to help them prepare for a period where global equilibrium and sustainability will matter more than economic growth.

The variables that are implicit in Sustainable Development are usually presented in the form of a triangulation that, according to Soubbotina (2004) and Higgins (2015), should respect the 3 main pillars of Sustainable Development:

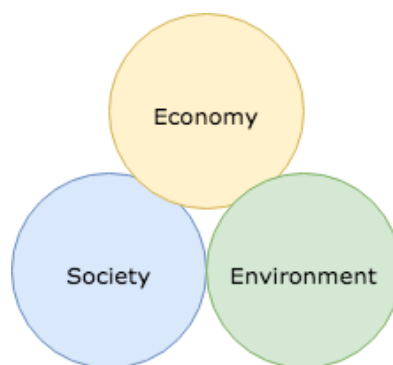


Figure 1 - Triangulation of Sustainable Development - Adapted from: Beyond Economic Growth (Soubbotina, 2004)

More recently within the Sustainable Development field, a new definition of the term has emerged, with Holden, Linnerud and Banister (2017) defining Sustainable Development as a normative value system.

This system entails an interconnectedness of Human Rights, Democracy and Freedom. According to the authors, these are the elements of the Sustainable Development concept which are described as “moral imperatives” - Holden et al. (2017, pp:213). Sustainable Development relies on three moral imperatives: satisfying human needs, ensuring social equity and respecting environmental limits.

The model proposed by the authors on the *Imperatives of Sustainable Development* (2017), differs from the classical model of representing Sustainable Development (see Figure 1), where the variables should be balanced between them, but each has its own space.

Sustainable Development can be defined as three constraints on human behaviour; these constraints will create and define the Sustainable Development space to be shared by all implicit variables as shown in figure 2 and according Holden et al. (2017):

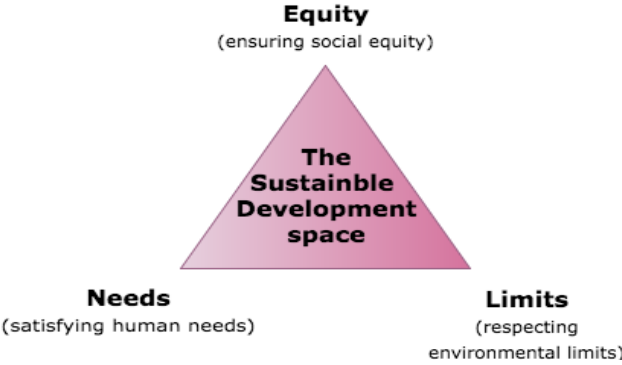


Figure 2- Model for Sustainable Development, retrieved from *The Imperatives of Sustainable Development* (Holden et al., 2017)

Despite the different contexts and concepts of Human and Sustainable Development, they should both be taken into account, according to Neumayer (2012), when measuring successful human progress. For instance, when considering and approaching both concepts and metrics applied to Development Rankings from the United Nations, such as in the SDG Index (2016), it can be inferred that despite the high Human Development (HD) ranking of some countries they are not being able to meet the Sustainable Development standards, resulting in differences of more than 20 places when doing a comparison of the rankings. It is also true that economic growth and development are focused on reducing poverty and contributing towards solving other social issues. History shows us that growth was actually attained at the cost of greater inequality and natural resources overconsumption between the so called developed and developing countries (Soubbotina, 2004).

Human Development is an enabler of economic growth, by providing resourceful, knowledgeable and well-prepared workers through education for the challenges of technology usage and innovation. This leads to a better job market, with more inclusion, opportunities and, above all, more freedom of choice (Soubbotina, 2004). Neumayer (2012); Biggeri and Ferrannini (2014) along with Peeters, Dirix and Sterckx (2013) defend that Human and Sustainable Development should be seen as Human Sustainable Development, thus considered as only one all-encompassing concept.

Neumayer (2012) argues that many countries achieve high levels of HD at the expense of sustainability; in his article on *Human Development and Sustainability* he proposes a model for linking the measurement of both Human and Sustainable Development.

According to Peeters et al. (2013), the care for the ecological system of the planet is a necessity to avoid its deterioration and to keep the biophysical conditions for human development. However, human activities should not go beyond the limits of the environment. Environmental Sustainability, should, according to the UNDP (2011), be at the core of Sustainable Human Development.

The Human Development goal of enhancing people's capabilities and well-being should always take into consideration the biophysical limits and constraints of the ecosphere (Sen, 1987). Nevertheless, and as agreed by Biggeri and Ferrannini (2014), SHD should always start at the Local level. Local Development is thus, according these authors, at the core of the true Human, Environmental and Economic Development.

Information Systems and Technology have always played a key role in putting the above presented concepts into practice, by improving everyday life, measuring and analysing our impact on planet Earth and supporting decision-making and theory building through research based on scientific evidence and computational statistics (Saariluoma, Cañas & Leikas 2016). For example, the book *Limits of Growth* (1972) presented the readers with conclusions about the future thanks to advanced prediction models already being used by the authors in their research.

As time went by and technology kept evolving, it proved to deserve the necessary attention by the International Community as a tool that can greatly contribute towards Human and Sustainable Development and the different initiatives focusing on it, such as the MDGs pre-2015, and now the SDGs until 2030.

2.1.1- Current Main Challenges of the 21st Century

The concern for Human and Sustainable Development has long been part of both rational and survival human instinct since early times and across civilizations; according to Cribb (2017) fighting for survival and looking towards the future to assure subsistence is an inherent human characteristic.

Fire, technology, buildings, vaccines, armies, healthcare, agriculture, clean water, climate science are some representations of our wisdom applied to the challenges of subsistence through history.

The United Nations World Economic and Social Survey (2013) reported that there still were more than 1 billion people living in extreme poverty as a result of extreme income inequality and also that high rates of both production and consumption are resulting in the environmental degradation of the planet. In this research one of the key questions taken into consideration is: Can technology effectively help tackle the challenges we face in the 21st Century?

Currently, and according to the triangle of Sustainable Development (See figure 1), which entails Economic, Social and Environmental sustainability, many challenges will have to be faced to reach a balance between these three different yet connected development fields. There is a need for Development Strategies to be inclusive, ambitious, action-oriented and collaborative, according to the United Nations Millennium Development Goals Report (2013). It is important to change consumption and production rates, reduce inequalities, strengthen economic governance and minimize negative externalities such as pollution, while at the same time enhancing worldwide technology adoption to help reduce food and water waste, and increase energy efficiency.

Technological advancements have changed human life throughout history as technical inventions not only gave humans the possibility of seeing far into the future but also of understanding and measuring how our impact on the planet is changing it (Saariluoma et al., 2005). However, this is not enough to provide solutions to the issues we are facing today. Ackerman and Stanton (2014) believe that some existing technologies could certainly be used as a way of reducing or even completely eliminating the greenhouse effect and solving other environmental and social issues; however, they also believe that the biggest obstacles to this path of action are primarily economic and political, rather than technological.

Despite the existent literature on Sustainable Development related topics such as climate change, environmental damage and protection or water pollution, there is yet a relatively small number of publications focusing on the most prominent and critical challenges faced by humankind in the 21st century as far as Sustainable Development is concerned.

There are conferences and gatherings among global leaders and UN organizations that attempt to cover all the issues that directly or indirectly affect us and require our effort to tackle them. Most of the United Nations initiatives for Development, such as the MDGs programme, resulted from Global Conferences, which determine the steps and directions to follow on areas such as the Environment, Society and the Economy. One of the earliest initiatives with the focus on addressing the 21st century challenges we are facing was an initiative of the Royal Geographic Society in 2015.

The programme, named 21st Century Challenges, was held between 2015 and 2017, and entailed a series of discussions run by the institution. The initiative focused on the biggest social, environmental and economic challenges in the coming decades. Although the discussion sessions took place in the UK, the addressed challenges were all of a global nature (Royal Geographic Society, retrieved from: <https://21stcenturychallenges.org/> in November 2017). Below is a list and discussion of those challenges:

1. Adapting to Climate Change and finding low-carbon alternatives

The first challenge addressed is the need to control Carbon Dioxide emissions and to start using more alternative sources of energy. Carbon Dioxide (CO₂) is a greenhouse gas that traps heat in the atmosphere, resulting in global rises of the temperature. Therefore, high levels of emission greatly increase the probability of extreme weather events such as storms, droughts, heat waves and floods, which will negatively impact human health, agriculture and infrastructure.

2. Ecosystem Protection

The ecosystem is in danger due to overfishing, deforestation and plastic pollution in the oceans. The United Nations (2015b) estimated that 87% of world fish stocks are fully exploited or overfished, which requires changes in their management. When it comes to deforestation, the main challenges are conserving the planet's rainforests and minimizing the destruction caused by the palm oil industry, timber trade and biofuels. Finally, plastic pollution is threatening marine life and it will therefore be a challenge to find practical solutions to clean and reuse all the plastic being thrown away to the ocean.

3. Economy

In 2007, there was a Global Financial Crisis, could this have shaped capitalism as we know it today?

Many different factors contributed to the economic transformations of the past decades. These changes have consequences for manufacturing, production, jobs, skills, innovation, the economy and sustainability. How can Economic Growth be assured in a sustainable way?

Current and emerging technologies are bringing in new alternatives to follow the sustainability path; this will be further addressed in the second stage of this literature review.

4. Education

Education has always been one of the main concerns and challenges for the United Nations; according to the 2015 report *Education for All*, many objectives from the Millennium Development Goals (MDGs) were achieved. However, there are still challenges, mostly lying in the improvement of the targets for the MDGs 2015 post-agenda.

Several of the proposed post-agenda education targets lack specificity and clarity in the concepts employed and outcomes expected (UNESCO, 2015). According to the 21st Century Challenges programme, the main challenges on education will be to prepare young people to fulfil their potential and to assure gender equality in education across the globe.

5. Globalization and Geopolitics

Information, people and resources can move around the world thanks to globalization. What are the opportunities and challenges for the future?

According to the programme, one of the main challenges will be to understand the role of Africa, each of their countries and how they can be supported, as 7 of the 10 fastest growing economies in the world are from this continent according to the International Monetary Fund (2015).

6. Human Health

In this area, the main challenges and concerns are:

- Air Pollution, which, according to the World Health Organization (2015), is the number one environmental health-related risk. How can deaths from air pollution be prevented across the world?

- Reducing the impact of viral outbreaks and pandemics such as HIV, Malaria, Dengue, Ebola or Cholera, while at the same time trying to find ways to eradicate these diseases.

7. Natural Hazards and Risks

According to the International Displacement Monitoring Centre (2014), during 2013 natural disasters displaced more people than war. The challenge is to find ways to improve response and protection of communities.

Over the past years, both organizations such as NASA (Reibeek, 2005 see: https://earthobservatory.nasa.gov/Features/RisingCost/rising_cost5.php, retrieved in November 2017) and academic researchers on the Environment such as Hallegatte (2014) have been focusing on the influence of climate change on natural hazards.

The question posed is: Can a reduction in CO₂ emissions and effective political and environmental measures to combat Climate Change help reduce natural hazards?

8. Natural Resources: Food, Water and Energy

With the rise of the world's population and consequent increase in resource consumption - such as water, food, land and energy supply -, how can a sustainable path of development be assured to find the balance between human needs and environmental resource consumption?

Water, energy and food are linked, this is called the water-energy-food nexus. Water is needed to extract energy and generate power: energy is needed to treat and transport water and both take part in the process of food production. According to the Organization for Economic Cooperation and Development (2017, retrieved from: <http://www.oecd.org/agriculture/water-use-in-agriculture.htm>, November, 2017), farming uses 70% of the world's water, and according SciDev (Zareen Pervez Bharucha, 2013, retrieved from <https://www.scidev.net/global/food-security/feature/sustainable-food-production-facts-and-figures.html>, November, 2017) food production will increase by 70% by 2050.

These estimations and the current reality are putting pressure on Governments and NGOs and will require them to answer an important question: How can we better manage our valuable resources?

9. Communication and Technology

Communication and technology provide many opportunities, but also many challenges.

There had never been a time where humans generated and consumed such enormous amounts of data as they do now, thus it is necessary to truly unlock the potential of data and make it useful for society (IDC, 2014).

Maintaining the pace of technological development is a serious challenge but also an opportunity. However, the real challenge will be not to forget all the people who are not digitally literate, in other words to combat the digital divide.

According to the World Bank's (2016) research on the Digital Dividends, only 3.2 billion people, which is not even half the world, have access to the Internet.

10. Population, Demographics and Migration

According to the Brookings Institute (2014), by 2030 two billion people will have joined the middle class from emerging economies. What impact will that have on those people's lives and on the planet?

There are other challenges addressed by the RGS: one is the ageing of the population , which according to the United Nations (2015) will require governments to design innovative and specific policies targeted to the needs of older people. The other challenge lies in including and planning migration at the national and local level, at a time where human mobility has never been higher (International Organization for Migration, 2015).

11. Urbanisation, housing and infrastructure

Within less than 40 years, it is expected that 70% of the world's population will be living in cities, according to the United Nations Human Settlements Programme (UN-Habitat, 2013). This leads to the last challenge presented by the RGS in the 21st Century Challenges: how can cities be designed and planned to accommodate people while making sure infrastructure both ensures people's well-being and protects the environment?

The RGS's programme was an attempt to address and bring into discussion the main concerns and challenges we are facing nowadays. The United Nations has been working on the development of initiatives that focus on researching, creating and implementing solutions for the above presented Global issues. The Millennium Development Goals were themselves an initiative which made world leaders agree to work together to tackle some of the aforementioned challenges.

2.1.2- The Achievements of the MDGs

The Millennium Development Goals (MDGs) resulted from an agreement during the Millennium Summit and were based on the Millennium Declaration of the United Nations (2000), where 189 governments of the United Nations officially decided to fight and tackle extreme poverty. The result of this gathering was the creation of eight MDGs:



Figure 3– Millennium Development Goals (Retrieved from: UN.org/millenniumgoals, last accessed, October 2017)

To measure the results of the initiative, 18 targets were set by the international community, and to measure their outcomes 60 indicators were developed for more efficient data-gathering, monitoring, evaluation and reporting of results until the year 2015 (Andrews & Khalema, 2015). Two years after the first official Report on the Millennium Development Goals, the attention has turned to the post-2015 agenda and the SDGs (Nelson, 2015).

The effectiveness of the MDGs has been extensively debated since the release of the programme back in 2000, however supporters argue that the initiative has awakened an unprecedented international movement against extreme poverty, reducing it by more than 50% globally (Woolbridge, 2015). According to the United Nations (2015) Official Millennium Development Goals Report there have been visible improvements and progress before and after the implementation of the programme as presented below:

MDGs	Main Achievements Overview	
1- Eradicate Extreme Poverty And Hungar	Extreme Poverty Rate in Developing Countries dropped from 47% in 1990 to 14% in 2015.	The Global Number of Extreme Poor decreased nearly by half from 1,926 to 836 million people between 1990 and 2015.
2- Achieve Universal Primary Education	Global out of school children of primary age dropped by almost half between 2000 and 2015, from 100 to 57 million.	Primary School net enrolment rate in sub-Saharan Africa increased from 52% to 80% between 1990 and 2015.
3- Promote Gender Equality and Empower Women	90% of countries have more women in parliament since 1995.	In Southern Asia, only 74 girls were enrolled in primary school for every 100 boys in 1990. In 2015, there are 103 enrolled girls for every 100 boys.
4- Reduce Child Mortality	The Global number of deaths of children under five was 12,7 million in 1990. In 2015 it decreased by half.	In 2000 the Global measles vaccine coverage was 73%. In 2013 it reached 84%.
5- Improve Maternal Health	Global Maternal Mortality (number if deaths per 100000 births) ratio was 380 in 1990. In 2013 it decreased to 210.	Global births attended by skilled health personnel was 59% in 1990. In 2014 it increased to 71%.
6- Combat HIV/AIDS, Malaria and Other Diseses	Global antiretroviral therapy treatment covered only 0,8 million people in 2003. In 2014 the number of treatments increased more than 10x (13,6 million).	More than 900 million insecticide-treated mosquito nets were delivered to malaria-endemic countries in sub-Saharan Africa between 2004 and 2014.
7- Ensure Environmental Sustainability	1,9 million people have gained access to pipe drinking water between 1990 and 2015.	98% of ozone-depleting substances have been eliminated since 1990.
8- Global Partnership for Development	In 2000 the Official development assistance was 81\$ billion. In 2014 it increased to 135\$ billion.	In 2015, 95% of the world's population is covered by a mobile-cellular signal.

Table 1- Some of the main achievements of the MDG (source: UN, Millennium Development Goals Report, 2015)

The above figure shows some of the MDGs' target achievements. Many different consultancy agencies, NGOs and other independent entities have participated not only in the collection of data and its analysis but also through the implementation of the MDGs in countries at the social and economic levels; according to Lomazzi, Borisch and Laaser (2014), most MDG initiatives worldwide targeted MDGs 4, 5 and 6, which focus on maternal and child health (MCH), while on the other hand fewer initiatives focused on MDGs 1,2,3 and 7. Lomazzi et al. (2014) also mention that some studies underline regional differences; for instance, MDGs 4 and 5 have been considered more important in the African region, while MDGs 7 and 8 had higher importance in the Western Pacific Region.

When looking at general country level progress McArthur and Rasmussen (2017) noticed that faster progress occurred in low-income countries (LICs) and in sub-Saharan Africa, while middle-income countries (MICs) and the rest of the world typically registered larger gains in a more gradual way. During the years after the MDGs' implementation, according to McArthur and Rasmussen (2017) the following occurred:

- Primary school completion rates markedly rose in most of the developing world;
- On undernourishment, countries saw an average acceleration in progress, except for highly populated countries;
- Water and sanitation followed the general trends;
- There were considerable strides in many countries as far as gender equality in education is concerned;
- Environmental indicators, however, saw limited gains and in much of the planet retrogression.

The answer to the question “Did the Millennium Development Goals make any difference?” is perhaps one of the most important questions regarding the UN initiative. For instance, McArthur and Rasmussen (2017) believe that the MDGs’ achievements are connected to the improvements of global policy cooperation in recent years, however it remains difficult to give a conclusive answer to this question; most of the discussion surrounding it is more theoretical than based on empirical facts, whose availability is limited. As it will be further addressed, it is difficult to assess data in a way that the local, national and international levels are aligned (Fehling, Nelson & Venkatapuram, 2013). Moreover, and according to (Higgins, 2013) each country has its own priorities and concerns; for instance, an Arab country can set different targets to a specific goal than a Latin American country, based on its different social, economic, political, religious, environmental and security contexts and limitations.

Kenny and Sumner (2011) from the Center for Global Development also agree that it is difficult to assess with certainty the impact of the MDGs; these authors also mention the importance of the initiative in increasing the “aid flows” during this Century. The MDGs were seen as an opportunity to provide a framework for action according to Kenny and Sumner (2011), where despite the outcomes above presented a sense of compromise among country leaders to achieve the proposed Goals by the UN became official.

Despite the considerable achievements resulting from the MDGs, there are less discussed angles on the initiative, which bring into question its success and highlight some of its failures and missing elements (Easterly, 2009).

2.1.2- What is missing?

Despite the previously addressed achievements and arguments in favour of the MDGs initiative and its results, there are, however, according to both experts and sceptics from different fields several, limitations, criticisms and missing factors that should be taken into account during the SDGs program (Sen & Mukherjee, 2014).

According to The World Bank Global Monitoring Report (2015) and despite the positive results discussed above, many countries have missed one or more of the MDGs targets for 2015 as presented below (UN, 2015):

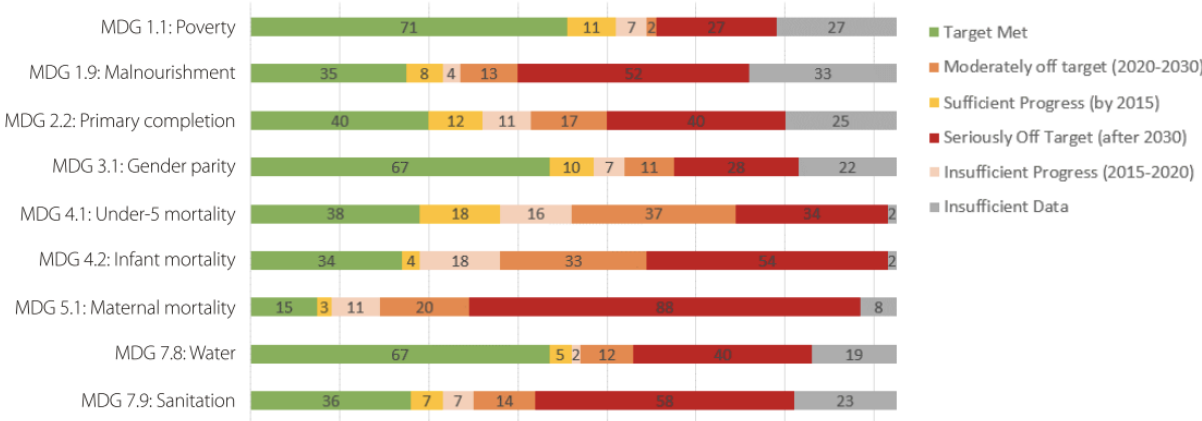


Figure 4- MDGs Progress by Number of Countries (Source: UNDP Report, transitioning from the MDGs to the SDGs, 2015, retrieved in November 2017)

The viability of the MDGs is questioned by Andrews and Khalema (2015), who claim they are either incongruous with the realities of life or a faulty yardstick to determine whether country or region-specific performances are on track, especially in the developing countries.

The MDGs, as previously addressed, are underpinned by three main pillars of development (see figure 1): economic, social and environmental development. According to Mansouri (Anderson, 2011, see: www.smh.com.au/national/education/what-is-missing-in-the-un-millennium-development-goals-20110613-1g02z.html, last accessed on November, 2017), there is, however, a key component missing: culture. The professor from Deakin University argued in an interview to The Sydney Morning Herald that in order to solve advanced economic, environmental and social issues, humanity will first have to address cultural issues, which the professor believes are the root of many development problems. The UN (2012), in its Review of the contributions of the MDG Agenda towards development, identified a series of limitations and criticisms made to the programme, among which the absence of targets such as decent work conditions, human rights, governance, security and peace.

Despite the fact that these issues were addressed in the Millennium Declaration of the United Nations (2000), they were not set as goals or targets within the MDGs framework. According to Sen and Mukherjee (2014), the Millennium Development Goals are somehow reductionist, simplistic and do not do justice to the declaration that originated them; for instance, the authors mention that some goals such as poverty alleviation or women's empowerment were given priority over inequality or sustainability.

These authors defend that the goal of gender equality can remain: the aim is to promote gender equality and empower women, while at the same time looking to support groups of women who have been marginalized.

Regarding Governance, and according to a study on maternal health made by Transparency International (2013), 30% of all Development assistance did not reach its intended targets due to corruption; this suggests a lack of specific governance and security measures which, according to Denney (2012), can help identify risks and measure citizen security.

Among sceptics, one of the most common criticisms made is that the MDGs are nothing more than a bureaucratic accounting exercise with very little tangible impact. Fehling et al., (2013) and Andrews and Khalema (2015) defend that the achievements of the MDGs were relatively limited progress due to the global recession and the fact that the Goals were not sufficiently addressed in terms of policy priorities at the national level (McArthur & Rasmussen, 2017).

The MDGs have demonstrated a limited conceptual basis to address development change according to Kenny and Sumner (2011), while being both reductionist and incomplete in identifying the structural causes behind each goal and in the creation and implementation of effective strategies and policy actions .

For example, the MDGs only cover some of the multiple dimensions poverty entails according to the International Aid's definition of the term, which is based on the work of Amartya Sen (1987), according to whom poverty entails the deprivation of economic, human, socio-cultural, political and protective capabilities (Loewe, 2012).

Despite the MDGs' achievements and overall progress, many developing countries, in particular from Africa, remained behind the proposed MDG targets, as addressed by Andrews and Khalema (2015); the definition of progress or its absence, in quantitative or qualitative terms, is highly controversial, which is one of the main obstacles regarding the comparison criteria and its conceptualization, design and adoption.

The same authors developed an alternative measurement method, which could possibly show Africa in a positive light in terms of their MDG-related progress, as opposed to the very negative picture painted if one simply takes the numbers at face value (Andrews & Khalema 2015).

According to Vandemoortele (as cited in Higgins, 2013), there is a tendency to misinterpret the MDGs as “one-size-fits-all” goals and targets at the country level; this interpretation makes the achievement of the MDGs less likely in countries with low starting points, namely Sub-Saharan Africa.

As a consequence, when looking at the country level progress of the MDGs there is a need to measure progress not only in relative terms (where a certain goal is to be met within a specific number of years in order to meet the MDG target), but also in absolute terms, where the total amount of change will be taken into account (Higgins, 2013). Easterly (2009) uses the example of primary enrolment rates in Africa vs Other Developing Countries to address the question of relative vs absolute progress; despite the slightly higher Gross Primary Enrolment Rate in the non-African developing countries in 2005, the overall growth of developing African countries between 1960 and 2005 was two times higher in this aspect.

This issue will lead to one of the most commonly mentioned limitations and criticisms regarding the MDGs’ data framework, which is the lack of real-time data, as described by the United Nations (2015). The MDGs were perceived as a top-down exercise, where the selection of indicators resulted solely from the limited consultation of international agencies.

The United Nations Report on the Lessons Learned from MDG Monitoring of the IAEG-MDG (2013a) also accounts for the inconsistencies between some goals, its targets and indicators.

The aforementioned question of absolute vs relative progress also resulted in discrepancies between the global and national monitoring process. This all raises the question: How should national and global targets be aligned?

According to the Sustainable Development Solutions Network (2015) and the United Nations (2013), in order to solve some of the issues discussed above:

- Targets should be consistent and aligned with Goals;
- Establishing clear levels of disaggregation for relevant SDGs indicators to make data monitoring and evaluation more flexible is crucial;

- The exercise of defining targets needs to find a balance between a bottom-up and a top-down approach;
- National statistical capabilities, data quality and availability should be part of the development framework to facilitate monitoring.

Finally, as reported by the United Nations System Task Team on the post-2015 agenda (2012), greater flexibility should be given to tailor targets to specific regional and national realities, at a time where it was learnt from the outcomes of the MDGs that regional development is critical for an effective and coordinated response to the increasing number of development challenges in the Road to Dignity 2030.

Different criticisms, limitations and missing goals, targets and indicators of the MDGs were previously addressed with the purpose of assessing how technology is being used to help solve these issues and what emerging alternatives will be there to further help in the future.

In the next section, the focus will be on the transition from the MDGs to the SDGs, what it entailed, what improvements have been made and what the premises of this new direction announced by the UN Synthesis Report (2014) toward the Road to Dignity 2030 were.

2.1.3- From MDGs to SDGs

In December 2014, the United Nations former Secretary-General Ban Ki-moon released his *Synthesis Report of the Secretary-General on the Post-2015 Agenda*. This document marked on the one hand the end of the MDGs programme and on the other hand the rise of a new United Nations Development programme called the Sustainable Development Goals (SDGs). “We are at a historic crossroads, and the directions we take will determine whether we will succeed or fail on our promises, with our globalized economic and sophisticated technology, we can decide to end the age-old ills of extreme poverty and hunger..... and achieve Sustainable Development for all” (United Nations, 2014 pp:3). This report was intended to guide future negotiations for the new Sustainable Development Agenda.

Over the past 20 years, there have been two main trends dominating the International Development Debate: the focus on reducing extreme poverty in its various dimensions around the globe, which was represented in the MDGs programme, and the concept of Sustainability, which gained popularity at the Rio +20 Summit in 2012 and would give birth to the SDGs (Loewe, 2012).

During the MDGs initiative, a lot of global progress was recorded; according to the World Health Organization (WHO, 2015) the programme has contributed to the way people think and talk about the world, shaping not only the international discourse but also the debate on Development.

The 2030 Sustainable Development Agenda goes well beyond the MDGs, comprising not only poverty eradication, health, education and food security, which remain priorities, but also including economic, social and environmental objectives as well as a focus on making societies more inclusive, peaceful, cooperative and secure (Denney, 2012).

During the 70th session of the United Nations General Assembly on September 25th of 2015 a new declaration was adopted, its name being “Transforming Our World – The 2030 Agenda for Sustainable Development” (Woolbridge, 2015). The result of the Assembly was the creation of the SDGs:



Figure 5 - Sustainable Development Goals adopted by the United Nations in 2015 (Source: <http://www.un.org/sustainabledevelopment/sustainable-development-goals/>, Retrieved in November, 2017)

Although the priorities have remained similar, the SDGs Agenda is much broader than that of the MDGs, as argued by Fukuda-Parr (2016). With 17 goals, 169 targets and 304 proposed indicators the SDGs are, according Uitto (2015), a universal and inclusive approach to Sustainable Development with a global vision of progress which entails the three pillars of Sustainable Development: Economy, Society and the Environment (Soubbotina, 2004 & Higgins, 2015).

The SDGs are intended to be Universal but at the same time specific to the constraints and opportunities of each national situation (Uitto, 2015). Countries can now incorporate global goals into their national targets to facilitate and promote the accountability of the SDGs, whose framework is designed to be more transparent and participatory than their predecessors, according to the United Nations Division for Sustainable Development (2016).

The SDGs resulted from a United Nations Open Working Group established in 2013, made up of 70 countries, especially created to develop the SDGs as we know them today, by giving developing countries the possibility to provide their contribution to the initiative along with other stakeholders, such as governments, civil society and the private sector (Woolbridge, 2015). For these reasons, Fukuda-Parr and Yamin (2013) believe that the SDGs do not simply differ from the MDGs in the number of goals and targets, but also in their purpose, conception and creation process:

- The MDGs were a North-South aid agenda, with the emphasis on reducing extreme poverty in the developing world.
- The SDGs, however, are a universal agreement on what the Development direction of humankind should be, and everyone should take part in it, not only the developing countries.
- Finally, the SDGs and their targets are focused on complex and even abstract concepts such as sustainability and inclusion rather than tangible and measurable outcomes, which were the focus of the MDGs.

On the topic of data monitoring, evaluation and accountability, the World Bank (2016) is focusing on the increase of the availability and quality of data, by making it more timely, reliable and disaggregated by relevant metrics, such as income, gender, location or ethnicity.

In general, and according to Bapna (n.d.) in a panel called “The UN Sustainable Development Goals: 17 or One?” hosted by the Wilson Center (See: <https://www.wilsoncenter.org/event/the-un-sustainable-development-goals-17-goals-or-one>, accessed in November, 2017) it is expected that the SDGs will have a broader reach; this programme aims to eliminate poverty by attacking its root causes - such as environmental quality and lack of economic and social Sustainable Development - , promoting partnerships and cooperation between nations to that end. The SDGs also seek open communication and to make their 17 goals more integrated, instead of individual goals being addressed in isolation.

Despite the fact that most of the previously addressed key goals missing from the MDGs have now been taken into consideration by the SDGs agenda for 2030, there will be, according to Woolbridge (2015) and Fukuda-Parr (2016), other key challenges to be taken into consideration for the future:

- 1. Missing out on integration potential:** The possibility of national governments deciding to focus solely on the goals that are aligned with their own development agenda and therefore neglecting the most transformative goals can pose a major challenge for the programme;
- 2. Data and Monitoring:** The concern that, as in the MDGs, many countries might be unable to access the means to collect, analyse and disseminate the necessary data for measuring and reporting their progress;
- 3. Financing & the North-South divide:** To implement and monitor the SDGs, it is estimated by current projections that 17 trillion dollars may be needed. This poses a challenge for both the Developing and Developed countries: on the one hand, developing countries need to mobilize their domestic resources, and on the other hand developed countries should provide the necessary funding.

In this section, different aspects of the transition from the MDGs to the SDGs were addressed, primarily the improvements and changes made regarding data collection and monitoring, the definition of goals and the International vs National agenda alignment. The SDGs are now seen as universal and inclusive above all, with every country playing a relevant role to the programme (United Nations, 2014b).

2.1.4- What is being done to achieve the SDGs by 2030?

Before shifting gears from Development to an Information Systems perspective of the research and matching concepts, goals and challenges with technologies and their contributions to the SDGs, it is first necessary to address what is currently being done to achieve them by 2030.

There are already many different ongoing initiatives and projects related to the SDGs.

Before working on the implementation of the SDGs, stakeholders must figure out the best way to approach each one of the Goals at the national level according to the Sustainable Development Solutions Network (SDSN, 2015); as previously addressed by Uitto (2015), the SDGs programme now gives countries the opportunity to address their main issues regarding the Sustainable Development Agenda and adapt them to their national and local reality.

Countries are now developing their strategies and plans to achieve the SDGs based on their previously achieved goals and targets, and their priorities for the present and future of the country.

This planning stage is of great importance due to the complexity of the goals, and the challenge of developing an integrated plan that connects each goal and the national circumstances and priorities (SDSN, 2015). As previously addressed, and according to Andrews and Khalema, (2015), there was a need to adapt each MDG to the national and local level, which has now been taken into consideration in the SDGs; previously, the MDGs were considered a top-down exercise from the Developed to the Developing countries. To help in this long-term planning task countries are using *backcasting*, which is considered by SDSN (2015) as a best practice for long-term planning; *backcasting* generates a desirable future and then works backwards in order to figure out how that future could be achieved. The core of this strategy is developing a long-term plan that takes into consideration the SDGs targets and milestones and what steps will be taking stakeholders to the desired endpoint at a specific date (SDSN, 2015). This strategy will help develop the policies, technical reforms, investments and partnerships needed to achieve the SDGs by 2030.

In order to allow an integrated approach of the SDGs and connect the International, National and Local levels, and due to the identified difficulty in collecting MDGs-related data, Ban Ki-moon created in 2014 an Independent Expert Advisory Group (IEAG) to give answer to the necessity to implement, monitor, evaluate and report 17 Goals, 169 defined targets and 232 indicators, which are now entirely interrelated (CSIS, 2017).

The MDGs experience also demonstrated the importance of developing partnerships both at the national and international levels: bilateral partnerships between states, public, private and multilateral actors are crucial to deliver effective results on a Global scale (SDSN, 2015).

Currently, there is an increasing number of initiatives being held on the online platform for SDG partnerships.

(see: <https://sustainabledevelopment.un.org/partnerships/>, last accessed in November, 2017); The goal of this platform is to provide global engagement for multi stakeholder partnerships, and voluntary commitments from everyone devoted to support the implementation of each SDG. This platform seeks to inform all stakeholders on the initiatives carried out to allow them to follow and keep track of the progress of those initiatives, according to the United Nations Division for Sustainable Development (2016).

To ensure the awareness, engagement and participation on the SDGs, according to Devex, (2015, source:<https://www.devex.com/news/7-steps-toward-sustainable-development-by-2030-86861>, last accessed in November 2017) , last accessed in November 2017), it is necessary to make people feel closer to the cause of Sustainable Development through understanding and commitment.

Education is therefore one of key elements that will play a decisive role in the success of the 2030 Agenda since it can lead to the inclusion of not only the International and National communities but also minorities, making it a more inclusive and universal initiative. The International Commission on Education highlights the importance of education in supporting Human Development (Yoshida & Zusman, 2015); education is both the tool which will lead to awareness and global conscience for Sustainable Development and the primary means to tackle most of the SDGs until 2030.

Over the past twenty years, the agendas for Human Development and Sustainable Development have run parallel to each other (Yoshida & Zusman, 2015); the SDGs seek to reconcile the global community and integrate both agendas through education initiatives and actions. Education represents one of the most important investments towards Sustainable Development, therefore the Global Education First Initiative is an attempt to accelerate the progress towards the Education for All goals, through political and financial support for education (Unesco, 2014). The United Nations intends to make Sustainable Development a lifelong learning process (Filho, Mifsud, & Pace, 2018) , by conducting ongoing research and field projects with the intention of accelerating the educating process towards the achievement of the 2030 SDGs.

There are currently many different ongoing partnerships and initiatives regarding each SDG (see: <https://sustainabledevelopment.un.org/partnerships/>, last accessed in November, 2017), however, and according to the Sustainable Development Knowledge Platform, (see: <https://sustainabledevelopment.un.org/topics/technology> , last accessed in November, 2017), to eradicate poverty and reorient trajectories from unsustainable Development to The Road

for Dignity 2030, affordable technological solutions have to be developed and disseminated. It has long been recognized that science, technology and innovation are the pillars not only for socioeconomic development but also to achieve Sustainable Development, as defended by the Elsevier Research Intelligence (2015). The field of Sustainability Science provides critical insights into the global landscape underpinning the SDGs; this discipline encompasses research output, citation impact, collaboration and interdisciplinary research, aiming to lead to a more informed dialogue between academics, civil society and policymakers to help them step forward (Elsevier Research Intelligence, 2015). Sustainability Science was launched in 2006, at a time where research was needed to support discussion around how to achieve the MDGs at the time.

Now, with all eyes on the Road to Dignity 2030, this scientific field has already had a huge impact on the research agenda, and aims to inform practical improvements by addressing global challenges and building bridges between disciplines (Becker, 2014). Information Systems and Technology have played a crucial role in achieving Human and Sustainable Development in the last decades. The United Nations Conference on Sustainable Development (2012) identified the importance of creating a technology facilitation mechanism which would later result in the creation of the United Nations Addis Ababa Action Agenda during the third International Conference on Financing for Development (AAAA, 2015a), alongside many other guidelines on science, technology, innovation and capacity building were addressed, such as:

- The creation, development and diffusion of new innovations and technologies are powerful drivers of economic growth and Sustainable Development;
- The crafting of policies that promote the creation of new technologies, incentivize research and support innovation in developing countries;
- The encouragement of knowledge-sharing and the promotion of cooperation and partnerships between stakeholders, including Governments, firms, academia and civil society;
- The Adoption of science, technology and innovation strategies as integral elements of national Sustainable Development strategies to strengthen knowledge-sharing and collaboration;
- Encouraging the development, dissemination, diffusion and transfer of environmentally sound technologies in developing countries.

- The establishment of a Technology Facilitation Mechanism based on a multi-stakeholder collaboration between member states, civil society, the private sector, the scientific community and UN entities, which resulted in the creation of a forum on science and an online platform for the SDGs (see: <http://www.un.org/sustainabledevelopment/> last accessed in November, 2017).

The UN is already making an effective use of different technological tools to engage the community and raise awareness on the SDGs. For instance, the SDGs action application (see: <https://sdgsinaction.com/>, last accessed in January 2018) allows different stakeholders and civil society to address local challenges regarding each goal and what do in an interactive and cooperative way.

The SDGs action campaign, which is one among many other SDG initiatives, is currently using Virtual and Augmented Reality to showcase the present global issues, hoping to engage people to participate and embrace the cause.

In this first part of the literature review, different approaches to development were introduced, along with an overview of the MDGs and the SDGs; it was an attempt to analyze the past, present and future of these Development programmes, their achievements, failures, gaps and the next steps to take.

In the next section of the Literature Review, The Development Field will meet the Information Systems and Technology fields in order to try and understand what the role of these scientific areas is and will be in achieving the Sustainable Development Goals for 2030 and successfully move towards the Road for dignity.

2.2- INFORMATION SYSTEMS

The XXI century is marked not only by the social, political, economic and environmental challenges previously addressed but also by being the era of information, which, according to Nelson and Cox, (2010), is one of the most valuable resources for institutions, from Businesses to Governments and NGOs. According to Campbell-Kelly, Aspray, Ensmenger and Yost (2013) the concept and field of Information Systems as we know it today resulted primarily from the development of analog technologies during the 1930s for scientific use, which would then be improved at the cost of millions for military purposes to make those machines become faster, more independent and fit war purposes, such as decoding enemy messages.

To achieve the 2030 SDGs the United Nations and the International Telecommunication Union (2017) have recognized the importance of IS and associated opportunities and risks. The importance of Information Systems to give answer to the challenges posed by the information age we are living in and the way technology is shaping human lives around the world will continue to increase (UN, 2011). There was, according to Willard and Halder (2003), a gap in the literature of the IS and Development fields; the authors claim that in order for SD to be effective and efficient, it must harness the information society, institutions and technological tools to tackle current and future global issues.

In this section, different concepts regarding Information Systems are explored first, followed by an overview of the most impactful present and future technologies and how they might contribute to the achievement of the SDGs.

This research was made based on business, governmental and non-governmental reports, as well as field work, relevant books, journals and websites on IS and Information and Communication Technologies (ICTs). Finally, the research questions to be taken into consideration and which will drive this sub-chapter are:

- What are Information Systems and what are their different components?
- What is the role of technology for development?
- What technology tools are currently being used to tackle the Sustainable Development Goals and which ones will be used in the future?

2.2.1- Concepts

Information Systems are at the core of every organization nowadays; according to Wallace (2015), the information society and economy we are living in require a new operational model in order to keep pace with the increasingly fast flow of information and technology dissemination, therefore information systems play a crucial role in gathering, storing, analyzing and making use of all this information.

According to Nelson and Cox (2018) an IS is a set of interrelated components that collect, process, store and disseminate data and information; it also provides a feedback mechanism to monitor and control its operation to make sure goals are accomplished.

The goals are usually related to business profits, the improvement of industrial processes or customer service; however, in this research the focus was on Development issues and on finding out which IS and Technologies are helping the most in achieving the SDGs and what might the contribution of emerging technologies be.

IS control many of the products we use on our daily lives; with IS it is possible for individuals to communicate instantaneously with one another, make online purchases using mobile devices, manage and participate in large scale projects with members globally dispersed or even move large amounts of money around the world among many other functionalities (Nelson & Cox, 2018). IS are changing and will continue to change the way we live and interact with each other, as noticed by Mustaquim and Nyström (2014): multinational firms, small businesses, nonprofit organizations, governments, self-employed people, volunteer organizations and universities all rely on information systems to interconnect them and help them achieve their goals. For instance, such complex initiatives like the SDGs and previously the MDGs would not be possible without the use of IS and related technologies.

Nelson & Cox (2018), agree that, thanks to IS it is possible for organizations to achieve their goals and use data more efficiently and effectively, which is one of the key concepts regarding this subject. For instance, the UN's (2015) MDGs Initiative and resulting report was only possible thanks to the help of advanced Computer-Based Information Systems, which helped the process of collecting, storing and analyzing data to extract relevant information about the MDGs initiative until 2015. Information is an essential resource in our society, but what exactly makes it valuable?

According to Wallace (2015) the following 3 characteristics contribute to the value of information:

- 1- **Timeliness:** Having recent data available is crucial to guarantee the most up-to-date information on a certain subject. Emerging concepts and practices such as Real-Time Data resulted from the importance of having this quick source of data stream at any given moment. For instance, and as mentioned by the UN (2015), one of the biggest challenges faced by the MDGs programme was the timeliness of its data sources, which ended up being out of date, not corresponding to the present at the time of the report's release due to the time gap between the collection of the data, the processing of it into relevant information and the final reporting.

- 2- **Accuracy:** Another feature of valuable information is accuracy. The larger and more complex a project or study on a certain topic is, the more difficult it will be to obtain highly accurate information due to the large number of participants and sources of data. It is the case of most UN initiatives, whose accuracy due to the large amount of data sources they work with, is often pointed as a limitation within their reports (Jacob, 2017).
- 3- **Completeness:** The more complete a piece of information is, the smaller the margin of error. According to the Sustainable Development Solution Network, (2015) the level of data completeness is also a challenge faced by the UN while conducting surveys, which might not be filled completely. In addition, some ethnical minorities might sometimes not be covered in a certain region for research purposes, which will also affect data completeness.

Information System components have been constantly changing for a long time, from the use of non-technological tools such as paper to develop diagrams, processes and other related IS tasks such as calculations to the modern concept of Computer-based Information Systems (see figure 7), which according to Wallace (2015), Nelson & Cox, (2018) and Bourgeois (2014) is composed by:

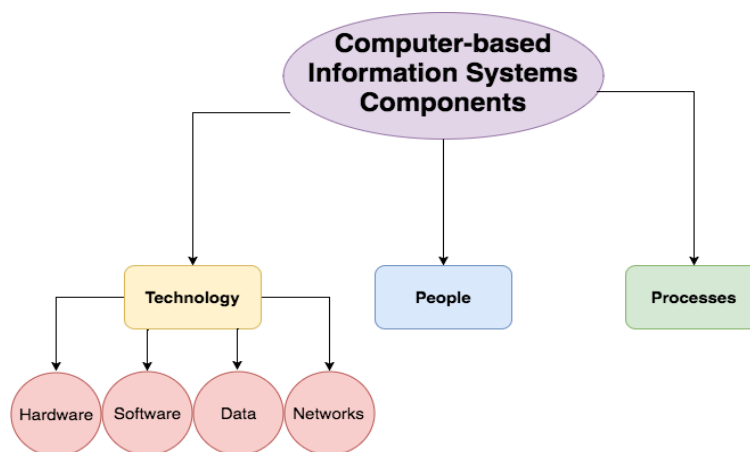


Figure 6 - Computer-based Information System components (Adapted based on the work of: Wallace, 2015, Nelson & Cox, 2018 and Bourgeois, 2014)

A CBIS is a combination of three main components, which allow an effective collection, processing, management, analysis and distribution of information (Wallace, 2015).

People are responsible for assuring the alignment of all the CBIS' components; according to Nelson and Cox (2018) the success of an organization relies on people managing, running, programming and maintaining the respective IS.

For instance, many present systems rely heavily on people's contribution for its development, says Wallace (2015), such as Wikipedia, Ebay, Youtube or Facebook, which are platforms based on User-Generated Content (UGC), which is itself a crucial ingredient of the Web 2.0 (Bourgeois, 2014).

The WEB 2.0 or any other CBIS would not be possible without Technology, which is used in a variety of contexts and is generally understood as the application of scientific knowledge for human related purposes (Nelson & Cox, 2018). According to Vergragt (2006) technology encompasses three essential 'dimensions': (1) it is a tool to enhance human ability to shape nature and solve problems (see agriculture enhancing tools such as a rake), (2) knowledge of how to create things or how to solve problems (for instance, of how to improve crop development tracking) and (3) culture (understanding our world and the human value systems). Technology has four important components, which are part of the CBIS. They are:

- **Hardware:** The physical components, such as computers, mobile phones or tablets.
- **Software:** Non-physical. It is a 'set of instructions' that conduct hardware activities. Examples of software include operating systems such as Linux for computers or Android and iOS for mobile devices.
- **Data:** In the XXI century data is at the core of every IS; this data, which usually describes the characteristics of an object or event, has many different shapes and forms (Baltazan, 2018). Data can include temperatures, colors, pollution levels, crop productivity index, vocal frequencies, only to name a few examples.
- **Networks:** The previously addressed technology components have long been considered the core of IS; however, in today's world, very few devices are not connected to another technology tool or network. Therefore, networks are increasingly gaining importance within the Information Systems field. The Internet is the most famous example of a network.

Within the Technological field, the terms Information Technology (IT) and Information and Communications Technology (ICT) are often used interchangeably; however, they both describe the hardware and software used to make an IS according to Wallace (2015). The only differences between the two is the communication/network aspect of ICTs, such as mobile phones, televisions or radios, and the storage of electronic data in the Cloud (UN, 2008).

Finally, the processes of a CBIS define the steps to be taken in order to reach a specific end goal. Processes are part of the main concerns of organizations, and require people's decisions on some steps in order to be successful; with the contribution of technology it is possible to get things done faster, cheaper, make better use of the resources and make it easier to adapt to change (Nelson & Cox, 2018). CBIS play a crucial role in setting up and following many processes, including operations, maintenance and the security of a system; Nelson & Cox (2018) mention the fact that processes can help people make an online payment, help distribution and logistics or even tell people what to do during natural disasters.

The Information Systems field has been focusing its studies on how people, technology, processes and data work together; this relatively new research field draws practitioners from business, computer sciences, sociology, anthropology and administration to name a few. Wallace (2015) mentions its growing interest and importance within universities, the private sector and governments, which makes this rapidly growing and changing research field an interdisciplinary combination of knowledge, methodologies and research subjects at the service of humankind.

2.2.2- Technology for Development

According to Hilty, Seifert and Wetzel (2005) there has not yet been enough discussion and cooperation between the global information society and the Development field. Fortunately, over the past few years an increasing number of studies connecting IS and Technology with Development have been undertaken in the multidisciplinary field of Information and Communication Technologies for Development (ICT4D), which used to have its research focus mainly on the IS field and related issues, but rapidly became widespread to other fields by promoting the interaction between researchers, practitioners and policy-makers (Walsham, 2017).

According to Vergragt (2006) Technology has reached a global scale of dissemination and adoption; it has an impact on most if not all of the previously discussed 21st century global challenges. Governments and the private sector have also recognized the importance of Science, Technology and Innovation (STI), which, according to the European Commission's publication on the role of STI to foster the SDGs (2015), are considered key drivers behind increases in economic growth and prosperity.

Some of the policies and actions previously mentioned in the UN's Addis Ababa Action Agenda Report (2015) also mention the STI as a way to support the SDGs.

According to the literature, there is a near consensus in the academic community that Technology has been shaping human life over the past decades, namely with the use of the Internet, mobile phones or cloud computing, and currently emerging technologies such as Artificial Intelligence, Big Data, Cloud Computing or Blockchain. For instance, there is an increased association between ICTs and human development according to the United Nations (2008, pp:4): ICTs have the potential to become “the motor of equitable redistribution of knowledge and skills in the areas of education and public health, or encourage production and trade within nations and between them”.

More recently the Secretary-General of the United Nations, António Guterres, on his foreword of the collaborative report of the International Telecommunications Union and United Nations: Fast-Forward Progress (ITU, 2017), addressed the impact of the current digital revolution and the importance of ICTs to create new opportunities and improve the service delivery of the United Nations for all its key activities: - from helping local communities with technology adoption and implementation and usage to data collection, analysis and reporting.

The World Bank Report on the Digital Dividends (2016) highlights the importance of Technology to bring people a wider range of options and foster inclusion, efficiency and access to innovation (World Bank, 2016). More than 40 percent of the world's population has access to the Internet, and in the bottom 20% poorest households nearly 7 out of 10 people have a mobile phone according to Hess et al., (2016). However, there are at least 1 billion people worldwide lacking the skills necessary to fully enjoy the benefits and potential of ICTs (ITU, 2017). According to Sachs and Modi (2015), if the SDGs are to be achieved, they must leverage emerging technologies, such as the Internet of Things (IoT), robotics, Artificial Intelligence (A.I), 3D Printing, Cloud Computing and Big Data, to name some of the most prominent technological tools of our time. ICTs in general are enabling the transformation of the most expensive public services such as education and health care, and also helping the economy of low income countries grow exponentially by boosting agriculture, trade/commerce, transportation and environmental monitoring and protection (Sachs & Modi, 2015).

According to the Report ICTs & SDGs (2015) written by The Earth Institute, which is located at Columbia University, and Ericsson there are 5 major ways in which ICTs can dramatically speed up the uptake of the SDG-supporting services:

1. ICTs themselves are spreading with remarkable speed and at a global scale. The uptake of mobile phones, computers, the Internet and social media have been the fastest adoptions of technology in human history.
2. ICTs can markedly reduce the cost of deploying new services in healthcare; for example, ICTs make it possible to give an extended role to low-cost Community Health workers. Students can access quality online teaching even when no teachers are locally available, and digital finance allows individuals to obtain banking services even when there are no physical banks.
3. ICTs make information readily available, anytime and anywhere through the Internet, social media, mobile devices and other e-channels. Information travels instantly around the globe.
4. National and Global Information networks can support the rapid upgrading of new applications and speed up technological development, reducing technology costs, making it more resilient, easier to use and with increased applicability.
5. By providing low-cost online platforms for training workers in the use of new technologies, such as MOOCs for example, it is possible to have access to high-quality courses and training materials on how to design and use technology.

The ICT Revolution is not based on one technology, it represents the interaction of many crucial technologies, including computer design, photonics and fiber optics, digital wireless, digital signalling, encryption, packet switching, satellite communications, robotics, machine learning, A.I, remote sensing, Geographic Information Systems and many others, which are, along with data storage, data processing, computing, nano-assembly and other techniques, creating what Ericsson (2015, pp:11) has termed the “Network Society”.

During the first years of the MDGs initiative, the importance of the ICTs for developing countries was still questioned in terms of their applicability as they were still considered a luxury by many people (UNDP, 2008). However as time goes by and technology becomes increasingly accessible and affordable, that perception has changed; it is now that within a few years the impact of Technology on Development will further increase, with it becoming a major driver in the quest to achieve the SDGs (Sachs & Modi, 2015).

The international community now officially recognizes the potential of technology for development and has encouraged the debate and discussion to create strategies and define its role as an integral part of international and national development plans to achieve the SDGs (United Nations, 2016).

National Governments will play a key role in achieving the SDGs. According to the Report from Columbia University's Earth Institute and Ericsson (2015) they should:

- Establish timelines for universal broadband connectivity of public facilities and services no later than 2020 in order to achieve the targets by 2030.
- Public services should incorporate ICTs so that businesses and citizens can interact with the public administration online for the purposes of payments, transfers, tax administration, registrations and others. This e-government system will lower the cost of public services and make corruption far less likely, creating a flow of Big Data which can be used for evidence-driven policymaking.
- Governments should partner with universities to scale up ICT training programs.
- Governments should create national online and open databases that incorporate Big Data from public services, satellites, remote sensors and other devices in the IoT. This real-time online data will be crucial to achieve the SDGs and to promote investments and partnerships by the public and private sectors.

In the past decades, there has been a particular interest in new technologies that may have the potential to enable environmentally sustainable economic and social development, according to Souter, Mclean, Akoh and Creech (2010). The potential of these technologies suggests that it may be time to add a fourth circle representing the role of ICTs to the Sustainable Development triangulation diagram previously addressed (see figure 1).

2.2.3- Established and Emerging Technologies at the service of the SDGs

There are currently many existing technologies which have been shown to have direct or indirect impact on global development and the improvement of human life. These technologies are the ones that ought to make the difference in order to successfully achieve the SDGs. In this section, different technologies will be addressed, focusing on how they are being used now and how they might be used in the future according to different literature sources: open-data from the UN, business reports and relevant books, websites and academic journal publications.

Science, technology and innovation have long been recognized as the basis of socioeconomic development. They are also core contributors to Sustainable Development and crucial to meet the SDGs (Elsevier Research Intelligence, 2015).

Established Technologies at the service of the SDGs

The mobile industry has moved from being a luxury service provider in an analogue economy to providing the foundations of every interaction in the digital world according to the Group Spéciale Mobile Association (GSMA, 2016); by taking into account their report on the Impact of Mobile Industry in the SDGs it can be inferred that the mobile industry contributes to each one of the SDGs to varying degrees, the most affected goals being ([see the report here](#)):

- SDG 9: The Mobile Industry contributes to this goal by upgrading and extending its infrastructure, connecting remote communities, stimulating economic participation and supporting innovations related to the IoT.
- SDG 1: By providing affordable connectivity, voice and data services, the mobile industry acts as a provider of financial services and a powerful platform of mobile remittances to developing economies.
- SDG 4: The Mobile Industry impacts this goal by providing connectivity to schools and students, allowing them to access digital resources. Education platforms and their content are also provided, along with facilities to purchase school-related services in poorer economies using mobile payment systems.
- SDG 13: By providing emergency communications systems, connectivity and other services - such as early warning systems based on data analytics and sensors -, the mobile industry can contribute to improve the resilience of communities to the effects of climate change, natural disasters and other calamities.

Over the past decades, the capabilities and reach of ICTs have increased dramatically, and the Internet has become a crucial enabler not only for social and economic transformation but also for allowing development challenges to be addressed in new ways (Heeks, 2008).

The Internet has been playing a major role in society since the 90s, being central to the emergence of the Information Society and digital economy, affecting both developed and developing countries.

According to the Internet Society (2015), ICTs have made important contributions to the MDGs, by enabling access to information and educational resources, improving food production, distribution and health services and allowing data-driven decision-making in many fields, namely when it concerns natural disasters and other calamities.

However, the Internet Society (2015) is concerned with the fact that technology has not yet been sufficiently recognized, and although one of the targets of the SDG 9 (access to the Internet in the least developed countries by 2020) is focused on addressing this issue, other ICTs related opportunities which are dependent upon the Internet might be missed. According to the Internet Society's (2017) *Report: Paths to Our Digital Future*, there are 3 key elements regarding Internet governance which directly and indirectly impact both the contribution of other ICTs to the SDGs and the chance of achieving them by 2030:

- **Connectivity:** There is still limited Internet access in the Least Developed Countries (LDC) compared to developed countries. This might make it difficult to connect and use other ICTs to efficiently collect and access data regarding the SDGs.
- **Affordability:** If Development stakeholders and citizens are to use the Internet effectively to achieve the SDGs, Internet access and broadband should be cheaper in developing countries.
- **Reliability/Resilience:** It is crucial for governmental and business service delivery, and for anyone to participate in the digital economy.

For instance, Web 2.0 and Social Media, which are highly important and impactful ICT4D, are dependent upon Internet access. These ICTs have transformed the way people communicate and interact with each other. For example, farmers are promoting their products on Facebook, extension services are using social media to reach their clients and NGOs are using it to create awareness on Development causes to influence policy makers (CTA, 2015). According to the Technical Centre for Agriculture and Rural Cooperation (2015), Web 2.0 and social media allow Development actors to easily connect with peers and other stakeholders, strengthen networks, access valuable information, produce, publish and redistribute relevant content.

Web 2.0 and social media are often mentioned by the literature as highly significant ICT4D to the extent that they promote participation and dissemination of information across the globe.

The WWW creator, Tim Berners-Lee, claims that the the key feature of Web 2.0 is that it enables anyone to become a creator, not just a consumer; nowadays the WWW is seen as a key Development enabler, helping reduce transaction costs, improve efficiency and democratize service access (Ramalingam, Hernandez, Martin, & Faith, 2016).

Currently, there is a dedicated web service for development purposes, namely the improvement of information-sharing, collaborative production of content and its distribution and integration: it is called Web2forDev and according to Ashley, Corbett, Jones, Garcide and Rambaldi (2009) it can help:

- Interconnect networks of bloggers, who can now share common interests and spread ideas on Development topics;
- Connect remote and disperse communities to online social networks;
- Social bookmarking, which helps disseminate interesting and relevant content:
- RSS feeds which allow content to be automatically distributed between websites, platforms and devices, namely computers and mobile phones.

The increased development and use of new technologies is leading to an exponential increase in the volume and types of data available, which is part of the cause of the Data Revolution we are currently going through according to the Report “A World that Counts” developed by an Independent Expert Advisory Group of the United Nations (2014).

This revolution relies on existing and new sources of data to fully integrate statistics into decision making, promoting open access and use of data to ensure increased support for statistical systems; for instance, the emerging concepts of open data and big data are the foundation of the Data Revolution (CSIS, 2017). The World Bank (2015, pp:2) defined Open Data as “data freely available online for anyone to use and republish for any purpose”, Open Data can support the international development agenda, and contribute to the achievement of the SDGs (World Bank, 2015) by:

- Fostering economic growth and job creation;
- Improving efficiency, effectiveness and coverage of public services;
- Increasing transparency, accountability and citizen participation;
- Facilitating better information-sharing within governments.

However, and as mentioned previously, the quality and availability of data is crucial for its transformation into valuable information; according to the UN (2014), there was no consecutive five-year period during the MDGs where the availability of data was more than

70% of the required, and despite the notable improvement of the national statistical systems' ability to provide data directly in recent years, there are still improvements to be made regarding data collection, analysis and reporting until 2030.

While before the advent of the Internet data centres were the only option available to keep all the generated data and information stored, in recent years the development of cloud computing – with all the advantages it brings - has been increasingly sparking the interest of IT developers and Internet users (Maaref, 2012). With cloud computing, organizations, institutions and companies can use a network of remote servers hosted on the Internet to store, manage and process data, according to Nethope, Intel, CRS, Microsoft, CDW and TechChange (2015). It also:

- Facilitates data sharing, providing access to information anywhere and anytime;
- Allows the sharing of organizational infrastructure, thereby reducing costs;
- Facilitates the experimentation and adoption of new systems by reducing capital investment and infrastructure;
- Enables improved cost models to improve the affordability of ICTs.

As an example, Fujitsu is already using its cloud computing platform to collaborate with the Japanese agricultural sector, by helping find new solutions to challenges such as global food issues. Fujitsu (2016) uses sensors to capture soil/crop conditions and collect information on farm operations - such as the weather and GPS location - and make this integrated data available on their Agricultural Knowledge Management System. Despite the above presented contributions of the Cloud, as well as the energy savings it might lead to, there is an ongoing business and academic discussion regarding the carbon footprint of organizations which, according to Greenpeace (2010), might contribute to aggravate the problem of the carbon emissions and global warming (Kumar & Buyya, 2012). Simply improving the efficiency of the equipment doesn't make Cloud Computing a green technology; according to Biswas (2015), it is also important to make its usage more carbon efficient, by reducing the electricity demand of the cloud and using renewable energy sources instead of focusing solely on cost minimization.

The Economic, Social and Environmental processes can hardly be completely understood without taking into account their spatial dimensions, according to Campagna (2005); this can be explained by the fact that the environment is best described by the topological relationships among physical objects, with human activities producing an impact on the

environment spatially. As an example, and underlying the importance of spatial variables, Akinyemi (2008) refers in his study to the use of poverty maps made within a Geographic Information System (GIS) to better understand who the poor are, where they are found and for how long they have been in that situation.

Consequently, decision makers can better identify and understand from maps the socio-economic and development variations among regions for planning purposes (Akinyemi, 2008).

The Environmental Systems Search Institute (ESRI, 2008) defines GIS as the technological tool for understanding geography and making intelligent decisions- GIS software allows users across the globe to share ideas on how to meet their resource needs, plan efficient land use and protect the environment. We have today some paradigmatic examples of its effectiveness: for instance, the International Fund for Agricultural Development (IFAD) uses GIS for Earth observation in order to get a clearer picture of land use and environmental degradation according to the International Telecommunication Union (ITU, 2017); in Yemen the IFAD is investing in forest problem tree analysis and climate change vulnerability mapping by using GIS modelling combined with satellite observations and social vulnerability assessments. According to Campagna (2005) the GIScience has been proven to offer theories, methods and applications to effectively support the following categories of tasks, which are connected to the fulfilment of the Sustainable Development principles:

- Producing and maintaining geographic information;
- Supporting distributed access to environmental and spatial data information;
- Solving spatial problems;
- Supporting collaborative decision-making on spatial issues;
- Supporting public participation.

GIS have proved to be able to solve complex problems faced by practitioners in planning and implementing Sustainable Development policies; according to Campagna (2005) GIS will be crucial for the improvement of horizontal and vertical collaboration in decision-making among the actors involved in the SD processes at all institutional levels: national, regional and local.

Over the past years, among the emerging academic and scientific fields, biotechnology has emerged to become very instrumental in the development and economic boom of the developed world according to Godwill (2013), who also defines biotechnology as a set of

tools that uses living organisms or their parts to make or modify a product, improve plants and animals or specifically develop microorganisms to improve human well-being.

Following the discovery of genetic engineering and modern biotechnology, this technology can contribute to the protection of the environment, agriculture, health and socioeconomic and industrial development (Godwill, 2013).

Within the vast field of biotechnology, and according to O’Toole and Paoli (2017), Microbial Technology (which is a biotechnology) is critical to achieve a majority of the SDGs, due to the central role of microbes in the regulation of ecosystem services:

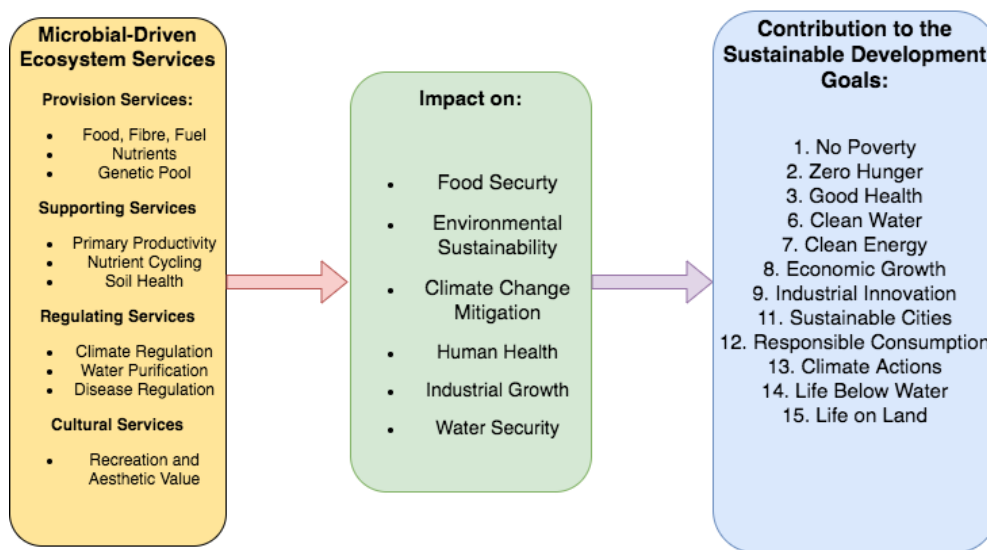


Figure 7- Contributions of Microbial Technology to the SDGs (Adapted from: The contribution of microbial biotechnology to Sustainable Development goals: microbiome therapies, O’Toole & Paoli, 2017)

The above figure represents how Microbial Technology is contributing to the SDGs; this technology plays a crucial role in disease regulation, directly impacting human, animal and plant health, which will affect farm productivity and food security. Microbes are crucial for climate regulation by consuming greenhouse gas; they can also be used for the purification of water for consumption (O’Toole & Paoli, 2017). Despite the contribution of biotechnology on SD issues (Adenle and Ammann (2015)) there have been some controversies surrounding the possible risks of genetically modified organisms; social-political and scientific disputes between the United States and Europe have influenced the regulation and decision-making on GMO issues in many developing countries, O’Toole and Paoli (2017) address the importance of innovation assessment from policymakers in order to align the GMOs issues with the SDGs.

Emerging Technologies at the service of the SDGs

STI are recognized as major drivers of change and it is expected they might be the key to bringing humanity towards the path for Sustainable Development, as illustrated by the Kondratieff cycles theory, where each economic fluctuation (cycle) begins with technological innovation, which then becomes the cornerstone of an economic upturn in the following years (Allianz, 2010):

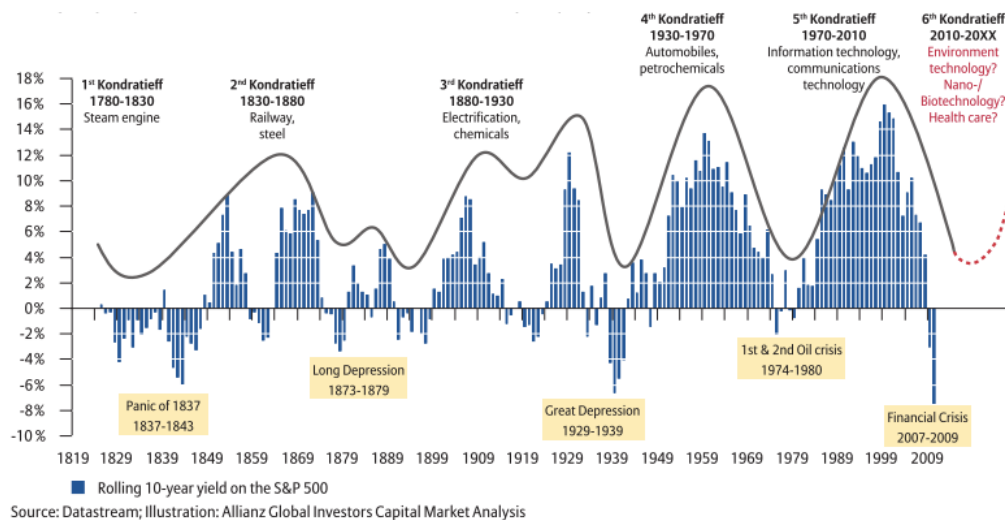


Figure 8- Kondratieff Cycles (Retrieved from: Analysis & Trends The sixth Kondratieff - long waves of prosperity, Allianz, 2010)

The above graphic helps us answer a key question regarding the economic challenges of the 21st century:

- Has the 2007 Global Financial Crisis shaped capitalism as we know it today?

It can be inferred that the 2007-2009 financial crisis was the turning point not only for capitalism but also for technological innovation thanks to the emergence of new technologies such as A.I, Big Data, the IoT, Nanotechnology, 3D Printing, Virtual and Augmented Reality (VR & AR) and Blockchain. According to Sachs and Modi (2015), Ramalingam, Hernandez, Martin, Faith (2016) and the ITU (2017) these emerging technologies are and will be greatly supporting the SDGs in a variety of ways:

- **The IoT** is defined by the ITU as a global infrastructure, enabling advanced services by interconnecting both physical and virtual things based on existing and evolving interoperable ICTs (Biggs, Garrity, LaSalle, & Polomska, 2016); it is expected that 26 billion connected devices will be part of the network by 2020.

From agriculture to healthcare, water and sanitation, education and environment, the IoT will help detect anomalies, optimize and maintain systems, make predictions, capture and analyse data across a range of different sectors (Biggs et al., 2016). According to Nethope et al., (2015) the IoT allows the UN and its partners to better understand the Sustainable Development variables in their environment by collecting useful data with regularity and precision, which will enrich the data that analytics tools use to generate the insights needed to support development programs and improve their impact.

- **Artificial Intelligence** - which is defined by Martynenko (2017) as intelligence exhibited by machines and their capacity to mimic human reasoning for control of complex systems, through pattern recognition, voice recognition and natural language - will be entering high-tech service providing in legal analysis, medical diagnosis, self-driving vehicles and other areas of complex problem solving. This new technology is a combination of different disciplines, working together to improve the efficiency of machines to deliver value to human beings and organizations; according to the AI Global Summit Report (2017) AI has great potential to help achieve the SDGs.
- **Big Data** will be a crucial technology for Sustainable Development and it is already being used. As addressed earlier in this thesis, data collection, analysis and reporting was often one of the biggest challenges faced during the MDGs programme (UN, 2015). Used Data was often collected through censuses and surveys with lags of years; thanks to Big Data - according to the UN Global Pulse paper on Big Data for Development (2012) - all the relevant data can be collected and accessed in real time, allowing the production of high-quality information and indicators for the SDGs.
- **Nanotechnology** is defined by Salamanca-Buentello et al. (2005, pp.383) as “the study, design, creation, synthesis, manipulation, and application of functional materials, devices, and systems through control of matter at the nanometer scale, that is at the atomic and molecular levels”. It has emerged as a versatile technology alternative that could provide efficient, cost-effective and environmentally acceptable solutions to the sustainability challenges facing society (Diallo, Fromer & Jhon 2014). Nanotechnology can contribute to the global challenges in many different ways: water purification, green technologies, greenhouse gases management, materials supply and green manufacturing (Diallo et al., 2014).

It also plays an important role in stimulating the development of other green technology tools, namely renewable energy materials, 3D printing applications and other networked production systems (Sachs & Modi, 2015).

- **3D Printing**, also known as Additive Manufacturing (AM), is used to create 3D objects from digital models and prototypes of different materials such as plastic, metal, ceramic, graphene, glass, paper, food types and even living cells (Ramalingam et al., 2016). For instance, according to the ITU (2017) 3D printing might be of great assistance to SDG 12 (Responsible Consumption and Production), since it could slash the use of raw materials, reduce waste and produce better products. Its benefits include the reduction of product development costs through rapid prototyping, the possibility of combining non-traditional raw materials with mainstream materials as a means of mitigating raw material shortage and reducing environmental impact and the reduction in the production setup costs, which provides the opportunity to transform the material production, supply chains and make logistics processes more flexible, efficient and locally adapted (Nethope et al., 2015).
- **Virtual Reality** is described by Jamei, Mortimer, Seyedmahmoudian, Horan and Stojcevski (2017) as a computer technology that replicates an environment, real or imagined, stimulating the physical presence and environment in its interactions within the VR. According to Jamei et al. (2017), this technology might be used alongside other technologies such as GIS and Data Management to help plan and develop Smart Cities. Currently the SDGs Action Campaign (see here: unvr.sdgactioncampaign.org/, last accessed in December 2017) is making use of the VR technology to create awareness among global leaders as far as the challenges posed by the SDGs are concerned. In the future, the objective is to make it available on several platforms in order to allow engagement with the UN messages and education programs.
- **Blockchain**, which has not yet been addressed in-depth by the literature in the context of Sustainable Development, is a technology which, according to Swan (2015), is the equivalent of another application running on the existing stack of Internet protocols, adding an entire new layer to the Internet. Blockchain enable economic transactions - both immediate digital currency payments and long-term, more complex financial contracts.

This new technology will have a profound impact on International Development and can contribute to the achievement of the SDGs by (1) improving the security and transparency of institutions, (2) aiding funds management and transactions and (3) giving a digital identity to more than 2 billion people who are not yet part of the Global Economy (such as people living in remote areas and developing countries) or by allowing real-time participation of anyone within the Blockchain network (GSMA, 2017).

The rampant use of technology worldwide, which resulted in the Technological Revolution we are currently going through, also has some potential downsides. Although the purpose of this research goes well beyond discussing the risks and challenges arising with the development and use of (new) technologies, there are nevertheless some concerns that should be mentioned. According to Sachs and Modi (2015), these risks are:

- The possible reshape of the brain and the consequent loss of some essential human skills;
- The loss of real human interaction and communities, as a result of the decline of human interactions, trust and sociality;
- The mass displacement of human work caused by robots;
- The concern over the vulnerability of networks and consequent impact on the digital economy;
- Cyber-warfare;
- The loss of privacy to governments and ICT firms.

In order to successfully implement, track and measure the impact of ICTs on the SDGs the United Nations General Assembly (UNGA) decided to hold a yearly World Summit on the Information Society until 2025; the WSIS forum can serve as a place to adequately discuss the role of ICTs as a means of implementation of the SDGs and its targets (ITU, 2017).

The WSIS initiative's goal is to encourage the development of a global information society; increased attention has been given to the relevance of tracking, monitoring and tackling the Digital Divide, which is considered as a key impediment to Development and the achievement of the SDGs by 2030 (ITU, 2014). The WSIS Matrix (see here: www.itu.int/net4/wsis/sdg/, last accessed in January, 2018) served as a guideline for the development of the study's reference model.

3. METHODOLOGY

Design Science Research (DSR) was used as a research methodology. This study was an attempt to not only address two different yet complementary disciplines but first and foremost to explore how these theoretical notions can be put into practice to provide an actual contribution to the fields of IS and Development.

3.1- DESIGN SCIENCE RESEARCH

DSR is a multidisciplinary methodology that allows the combination of different research techniques (Venable, 2006) and can be used in different fields such as Natural or Social sciences. According to Dresch, Lacerda and Antunes (2015), DSR is a methodological approach concerned with creating artifacts that serve human purposes.

The research paradigms used in Information Systems until recent times focused on a small set of research topics and ideas such as IS acceptance or success, as explained by Allen (2015). Moreover, those formerly dominant research paradigms were used to produce and publish research for most of the widely known journals of IS, focusing on descriptive research approaches, which results in explanatory and not very applicable studies (Peppers et al., 2006). DSR, on the other hand, intends to create, explain and apply a solution to a certain problem.

Design Science provides IS research the possibility to enhance its processes with scientific rigor (Hevner, March, Park, & Ram, 2004), thereby contributing to industry practice and society by helping solve real world problems or improving outcomes (Iivari & Venable, 2009). This was the purpose of this research, where two different disciplines - IS and Development - are brought together to provide an overview of the role of technology in achieving the SDGs.

The following process model created based on the work of Vaishnavi and Kuechler (2007) and Peppers et al. (2006) and illustrates how DSR is used throughout the research: from the identification of a problem to the creation of an artifact, which is represented by a reference model to its validation by the study presented in the next chapter and its respective conclusions.

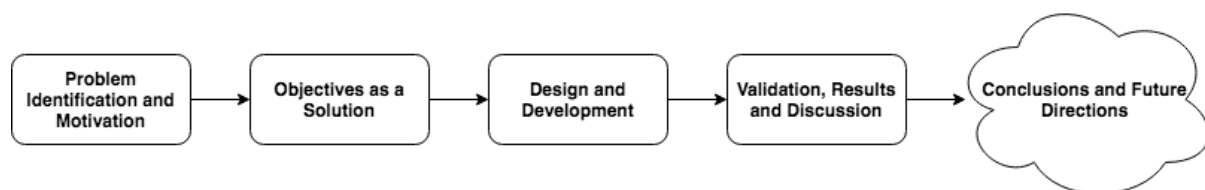


Figure 9 - Adapted DSR process steps from Vaishnavi and Kuechler (2007) and Peppers et al. (2006).

DSR methodology allows the combination of IS and Development to link the addressed technologies to each of the 17 Goals for Sustainable Development. This exercise resulted in the creation of an artifact, which constitutes the applicable knowledge of this research (Hevner et al., 2004). The created Technology-SDGs reference model can be described as a more general contribution, in the form of a nascent design theory, where knowledge is seen as an operational principle according to Gregor and Hevner, 2013 . The present model intends to be a guide and serve as a framework for global leaders and Development agents to understand the present contributions of each of the addressed technologies towards the achievement of the SDGs, while at the same time contributing to the scientific and academic debate around the role of technology in achieving Sustainable Development.

According to Vaishnavi and Kuechler (2007), artifacts must then be analyzed, validated and evaluated in its use and performance in order to make the necessary changes to improve on the behavior of systems, people and organizations.

The below presented Figure 10 shows the adopted DSR approach, where according to Venable (2006) there are 2 spaces interacting with one another:

1. **Problem Understanding Space:** The purpose of this space is to understand each SDG, what past results were obtained during the MDGs and what the desired outcomes for the future are, by consulting Development related journals, reports, open-source data from the United Nations and other relevant academic contributions to the topic of the SDGs.
2. **Solution Space:** Based on gaps, challenges and limitations identified, it can then be understood which technologies are already being used and might be used in the future to achieve the SDGs. Focusing on their contributions, impact and importance, contextual information was retrieved from Technology for Development reviews and sites, open-source United Nations materials and case-studies, IS4D and ICT4D journals.

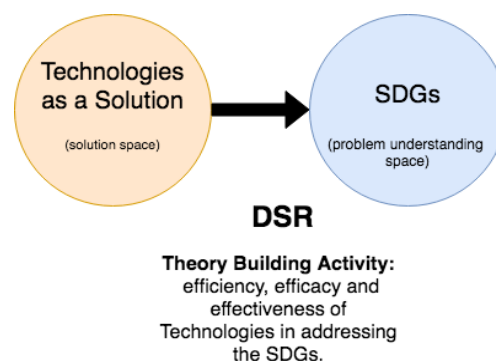


Figure 10- Methodological Approach - DSR Component, adapted from Venable (2006)

3.2- RESEARCH PROCESS

Inspired by the process used by Wieringa (2014) in the book *Design Science Methodology for Information Systems and Software Engineering*, the following workflow was developed and used to guide this research:

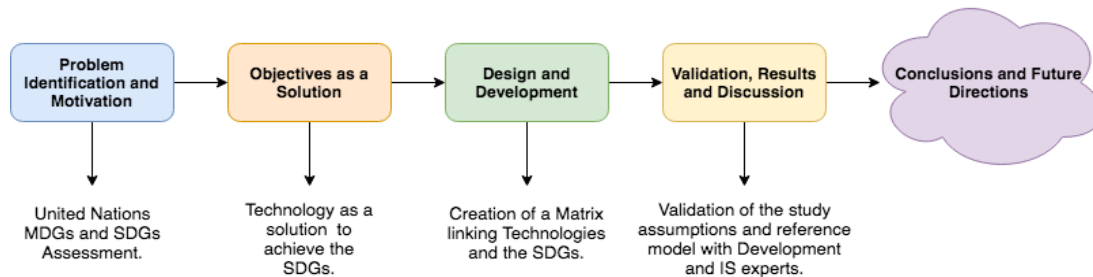


Figure 11- Adopted Research Strategy based on Vaishnavi and Kuechler (2007) & Peffers et al. (2006).

Problem Identification and Motivation – United Nations MDGs & SDGs Assessment

The 1st stage consisted of the analysis of the MDGs programme's results using open-data sources and the 2015 official UN report, followed by a review of the relevant literature on the post-2015 agenda and the SDGs: what goals the UN set, what the relation between those goals is, the challenges and criticisms to their implementation, using mainly United Nations official documents and other relevant studies on the subject.

Objectives as a Solution – Technology as a solution to achieve the SDGs

Different gaps, challenges and issues were addressed in the previous MDGs and present SDGs programme. Based on IS and ICT4D literature review, an overview of the past, present and possible future contributions and impact of technologies was made and each technology addressed was matched to the specific goal(s) it can help achieve.

Design and Development – Creation of a Matrix Linking Technologies and the SDGs

During this stage, a Matrix was developed based on the two previous stages. The result was a model linking different technologies and their respective contributions and impact to each goal, always supported by the literature review.

Validation, Results and Discussion – Validate the study assumptions and Reference Model with field experts on the WSIS 2018.

To validate the Technology-SDGs Reference Model, the chosen method was **qualitative** interviewing. Sixteen experts on Development and Technologies participated in the validation process of the research findings and resulting Reference Model.

By doing these interviews, it was possible to evaluate the assumptions and conclusions of the study, by confronting them with the opinions of the experts on the present and future role of Technology for Sustainable Development. As a result, it was possible to establish a relation between the research findings and resulting artifact, and the experts' inputs.

Conclusions and Future Directions

Finally, the key points and main conclusions of the study are presented, along with suggestions on the next steps to be taken by the international community and SDGs stakeholders. This final moment of the thesis also addresses the limitations of this study and includes some recommendations for future research on the topic.

3.3- INTERVIEWS

To validate both the study assumptions and the reference model, face-to-face interviews were conducted with field experts of the Development and Technology fields coming from different countries and with different academic and professional backgrounds, with the aim of understanding the point of view of each of the interviewees on what role of technology in achieving the SDGs is.

The type of interview script created was semi-structured to meet both validation requirements and specifications and it followed a specific sequence in order to best extract the information relevant to this study: it began a general approach to Technology in the context of Development, then moving to more specific questions to validate the reference model. These weren't close-ended questions; room was given to the experts to express their personal views and experiences. The interview script resulted from the identification of the main research topics and goals previously addressed. Finally, the script intended to be neither too formal and structured nor too informal and conversational (Mann, 2016). According to Blaxter (as cited in: Alshenqeeti, 2014), interviews offer researchers the possibility of uncovering information that would not be possible to access using other techniques (such as questionnaires), not to mention the fact that data coming from interviews can be recorded and reviewed at different times, helping the reporting of results to be more accurate (Alshenqeeti, 2014).

For the purposes of this research, questionnaires would not have been suitable for validation purposes since only experts from the fields of Development and Technology could actually provide the level of knowledge required for the validation of the created reference model. In this particular context, common sense views would not fit the intended purposes.

Find below the interview script used in this research:

1. General Questions on Development and Technology

From the MDGs to the SDGs and in particular during the past few years, the concept of Development has been changing alongside with unprecedented human progress, from an economic-centric perspective to a sustainable approach to human development. Technology has been both a consequence and enabler of this paradigm shift. Rapidly developing technologies have reshaped the lives of communities, families and individuals around the world through providing new goods and services, including to “bottom of the pyramid”, creating new industries and markets, and changing demand for labor and capital in every sector. New technologies have been recognized by the 2030 Agenda as an important means for implementing the SDGs across economic, social and environmental dimensions (UNRSID, 2017).

- 2.1- Do you consider sustainable human development dependent or independent of technology?
- 2.2- What other variables do you believe to be crucial?
- 2.3- According to your experience and opinion, what might be the main role of Technology in achieving the Sustainable Development Goals by 2030?

The governments will identify the need for a rapid acceleration of public investments and services in key areas, especially health, education, and infrastructure. Yet the needed pace of scale up on conventional grounds will seem to be impossible, beyond financial and logistical feasibility. This is, of course, where ICTs come in. They offer the possibility of much faster technology upgrading, training, and service provision at low cost, but only if the systems are quickly designed and deployed. With 2030 targets looming, there will be no opportunity for a slow, gradual, cautious uptake of new approaches (Sach and Modi, 2016).

To realize that potential, leaders within governments, businesses and civil society organizations must be bold and look for every opportunity to foster local innovation, to assist local institutions in becoming part of the digital economy, and to expand local community and citizen access to ICT solutions and the benefits they provide. (ICT playbook, Nethope, Intel, Microsoft et al, 2015).

- 2.4- What is in your opinion the role of development agents and global leaders - governments, NGOs, private-sector and civil society - in leveraging technologies for Sustainable Development?

3. Specific Questions for the Model Validation

Considering the Established & Emerging Technologies addressed in the study:

The established technologies being addressed in the research are: The Internet, Web 2.0 & Social Media, GIS, Cloud and Biotechnology which have proven according to the revised literature to have had great importance and impact in societies by promoting connectivity and access to information and the global economy. On the other hand, emerging technologies such as IoT, A.I, Big Data, Blockchain, 3D Printer, VR and Nanotechnology will progressively revolutionize the way we live and how we interact with each other and the environment.

3.1-What do you believe to be the main differences between the present & future technologies being addressed in terms of their role and impact for Development?

ICT plans should consider opportunities to bypass or leap-frog older technologies altogether in favor of new, more beneficial ones. ICT plans must also balance investments in basic ICT deployment to provide immediate benefits to developing countries, such as remodeling power infrastructure or connectivity, with those that are necessary to grapple with access to scarce resources within changing economic, social and physical environments around the world. (Sach & Modi, 2016)

3.2- Do established and emerging technologies play the same role in the achievement of the SDGs in 2030? If No, what is the role of each one of them? Please, provide some practical examples?

According to an article written by Avgerou published in the *Information Technologies & International Development Journal*, “A common assumption in ICT4D research is that developing countries are at a disadvantage in relation to the ICT innovation experiences in the context of origin of new technologies.

This culminated in the notion of a “digital divide” resulting in a new form of inequality.” (Avgerou, 2010) *Information Technologies & International Development Journal*.

3.3-Will it be possible to deploy these emerging technologies for development without widening the existing digital divide or will they actually be a contribution to close it?

3.4-According to both your experience and opinion, what do you believe to be the most eligible group of technologies for Development until 2030 and why?

3.5- Is there any specific technology you believe to be crucial in achieving the SDGs? Please, provide a practical example.

3.6- Which areas should it be interesting to have technologies developed for in regard to the SDGs or what technologies which are not addressed should be included?

4. STUDY

The present study aimed to help bridge the gap and strengthen the collaboration between the fields of Information Systems and Development through Technology. The main goal of this study was to establish a connection between the Technologies for Development most commonly addressed in the literature and the SDGs, by matching specific technologies to each one of the goals, according to their contributions.

The study had two primary goals; the first one was to understand what field experts perceive to be the role of Development Agents and global leaders in leveraging technology for Sustainable Development; the second one was to validate the reference model.

Technology is an essential tool for social and economic Development according to Tusiime & Byrne (2011), however it has not been fully explored by the academic literature on Development Studies (Hilty et al., 2005). Despite the contributions of the WSIS Matrix (see here: <https://www.itu.int/net4/wsis/sdg/>, consulted on the 23rd of February) or the World Economic Forum's interactive network map linking different social, political and economic challenges to technologies (see here: <https://toplink.weforum.org/knowledge/explore/all>, consulted on the 25th of February) there is relatively little scientific research within the Information Systems and Development fields which specifically relates Technologies for Development and the SDGs in a post-2015 agenda context.

4.1- ASSUMPTIONS

When looking at the literature, different assumptions can be made regarding the role of present and future technologies in achieving the SDGs by 2030:

- New technologies have been recognized by the 2030 Agenda as an important means for implementing the SDGs across economic, social and environmental dimensions (UNRSID, 2017);
- Aligning the International, National and Local levels is crucial to achieve the SDGs;
- Development Agents and Global Leaders play a crucial role in the implementation of ICT4D and overall SDGs process;
- Technology has improved the lives of people and communities in a myriad of ways;
- There is a clear distinction between established and emerging technologies and their role in Development;

- The researched technologies are considered to be the most impactful and relevant for Development purposes;
- Current technologies will continue to be of great importance in the future and most parts of the world still lack access to them;
- The digital divide represents a major issue in the access and use of technology for Development;
- The established technologies addressed in this research will be crucial for the successful implementation of emerging technologies for development.
- Emerging technologies are expected to further revolutionize the world;

4.2 – REFERENCE MODEL

In order to support this study, an artefact in the form of a model was created to match the addressed technologies and the SDGs according to the present and possible future contributions and impact to achieve them. The abstract knowledge that is created in DSR (e.g. design theory) can also be treated as a type of artefact. In general, the term artefact is used in this study to refer to a thing that has, or can be transformed into, “a material existence as an artificially made object (e.g., model, instantiation) or process (e.g., method, software)” (Goldkuhl 2002, p. 5). Many IT artefacts have some degree of abstraction but can be readily converted into something material; for example, an algorithm can be converted into operational software (Gregor & Hevner, 2013).

The purpose of this reference model is to, with help from the experts, understand what the role of technology might be in achieving the SDGs, thus providing Global Leaders, Development and Technology Agents with a guideline of what the next steps to take should be:

- Determining which group of technologies is more effective and necessary to achieve the SDGs;
- Helping interested stakeholders and decision makers decide which technologies to invest on;
- Helping plan and address local challenges with the help of new technologies by providing past and present success stories;

- Encouraging communities and academia to increase their knowledge of the addressed ICT4D;
- Understanding the role of Development Agents and Global Leaders in leveraging technology for Sustainable Development;
- Having guidelines which can serve as a starting point to explore new alternatives for the present and the future in terms of technology investment for Development in a post-2015 agenda context;

The following reference model represents the most commonly addressed technologies in the literature. They were categorized in two groups - Established and Emerging Technologies – and matched with each SDG.

		Sustainable Development Goals																
Established Technologies		1 NO POVERTY	2 ZERO HUNGER	3 GOOD HEALTH AND WELL-BEING	4 QUALITY EDUCATION	5 GENDER EQUALITY	6 CLEAN WATER AND SANITATION	7 AFFORDABLE AND CLEAN ENERGY	8 DECENT WORK AND ECONOMIC GROWTH	9 INDUSTRY, INNOVATION AND INFRASTRUCTURE	10 REDUCED INEQUALITIES	11 SUSTAINABLE CITIES AND COMMUNITIES	12 RESPONSIBLE CONSUMPTION AND PRODUCTION	13 CLIMATE ACTION	14 LIFE BELOW WATER	15 LIFE ON LAND	16 PEACE, JUSTICE AND STRONG INSTITUTIONS	17 PARTNERSHIPS FOR THE GOALS
Internet	I.1	I.2	I.3	I.4	I.5				I.8	I.9	I.10	I.11		I.13	I.14	I.15	I.16	I.17
Web 2.0 & Social Media		WS.2	WS.3	WS.4	WS.5						WS.10	WS.11		WS.13/14/15			WS.16	
GIS	G1	G2	G3				G7							G.14/15				
Mobile	M.1	M.2	M.3	M.4	M.5			M.8	M.9	M.10	M.11			M.13	M.14	M.15	M.16	M.17
Biotechnology	BT.1	BT.2	BT.3				BT.6/7							BT.13/14/15				
Cloud	C.1	C.2						C.8	C.9				C.12					
Emerging Technologies		1 NO POVERTY	2 ZERO HUNGER	3 GOOD HEALTH AND WELL-BEING	4 QUALITY EDUCATION	5 GENDER EQUALITY	6 CLEAN WATER AND SANITATION	7 AFFORDABLE AND CLEAN ENERGY	8 DECENT WORK AND ECONOMIC GROWTH	9 INDUSTRY, INNOVATION AND INFRASTRUCTURE	10 REDUCED INEQUALITIES	11 SUSTAINABLE CITIES AND COMMUNITIES	12 RESPONSIBLE CONSUMPTION AND PRODUCTION	13 CLIMATE ACTION	14 LIFE BELOW WATER	15 LIFE ON LAND	16 PEACE, JUSTICE AND STRONG INSTITUTIONS	17 PARTNERSHIPS FOR THE GOALS
IoT		IoT.2	IoT.3	IoT.4	IoT.5	IoT.6	IoT.7			IoT.9		IoT.11		IoT.13	IoT.14	IoT.15	IoT.16	
Big Data	BD.1			BD.4	BD.5			BD.8	BD.9	BD.10		BD.12	BD.13	BD.14	BD.15	BD.16	BD.17	
VR			VR.3						VR.9		VR.11							VR.17
AI	AI.1		AI.3	AI.4				AI.8			AI.11						AI.16	
Nanotechnology		N.2	N.3			N.6	N.7				N.11	N.12	N.13					
Blockchain		BC.1/2						BC.8		BC.10							BC.16	BC.17
3D Printer								3D.8	3D.9			3D.12						

Table 2 - Reference Model: Established & Emerging Technologies for Sustainable Development

The technologies belonging to each group addressed in the model were categorized according to the literature; the two different technology groups addressed in the model - established and emerging – are cited and used in the literature, namely by the United Nations Sustainable Development (2016). However, there is no agreed categorization for these technology groups.

The following literature review findings link established and emerging technologies with respective SDGs and is the caption of above presented model (see figure 12):

Established Technologies

Internet

I.1- The Internet is enabling people from all sectors of society to benefit from Development. The Internet contributes to the process of eradicating extreme poverty by providing access and participation in the global and digital economy (Internet Society, 2015). However, more than half the world's population still lack access to this technology (ITU, 2017b)

I.3- The Internet enables access to reliable and helpful information worldwide: one such partnership is Research4life, which includes the United Nations and 185 publishing partners and shares essential knowledge resources on health (ITU, 2017b).

I.4- Online courses provide a foundation and alternative to face-to-face learning in remote communities; these courses can prepare many students for future studies (ITU, 2017b).

I.8- The Internet has revolutionized the way we live and work, it has made automation, outsourcing and globally integrated supply and value chains possible. Widespread Internet access could generate around 2.2 trillion \$ in GDP and 140 million new jobs (ITU, 2017b).

It also provides the opportunity for training and skill improvement, leading to a better prepared labor force.

I.5- The Internet can provide women with the opportunity to access information and use it to tackle stereotypes as mentioned by Thomason (2016, retrieved from: <https://medium.com/the-internet-of-women/how-to-use-the-internet-to-include-all-women-on-international-women-s-day-9752b452f32c>, last accessed March 2018).

I.10- The Internet can help reduce inequalities by, for example, providing refugees with access to services, supporting and allowing them to connect to the national and global communities around them (ITU, 2017b).

I.13- The Internet allows the sharing of relevant information for decision makers such as governments to take action on Climate Change and other issues (ITU, 2017b).

I.16- The Internet helps combat transnational crime; the connectivity of devices makes it easier to track criminals and their communications Intent (ITU, 2017b).

WS.2- The Web and Social Media have brought the possibility of using different tools which allow, for example, farmers to get advisory services, as well as the use of Early Warning Systems (Sachs & Modi, 2015).

WS.4- Web and Social Media, provide, along with Internet connection, access to a variety of courses and online education programs to ensure everyone has access to education. (ITU, 2017b);

WS.10- Social media in particular plays a crucial role in disseminating and amplifying the political messages of minorities (ITU, 2017b);

WS.13/14/15- Social Media has the power to reach the general public, therefore it is easier than ever to disseminate relevant information and campaigns regarding climate, water and land life (ITU, 2017b);

Mobile

M.1- According to the GSMA (2016), the contribution of the mobile industry to this Goal is particularly high; 4 out of the 7 targets of this goal focus on things that are highly impacted by this industry. For example, in Zimbabwe the largest telecommunications operator developed a mobile payment system for the retail sector, thus helping alleviate poverty through financial inclusion.

M.4- Mobile phones can provide great contributions to achieve Goal 4, such as reducing the digital skill gap that prevents access to quality education for many or improving the quality of engagement in the learning experience according to GSMA (2016).

M.8- Mobile devices can improve the productivity of businesses by enabling them to access online marketplaces, increasing access to capital and financial services or even allowing

individuals and companies to have a digital presence. The Jiangsu Province of China was one of the first farming villages to take up e-commerce on a large scale, enabling more than 1000 households to join the digital economy (GSMA 2016).

M.9- The mobile industry contributes to the improvement of the efficiency of processes and supports the IoT infrastructure (Sachs & Modi, 2015).

M.10: The mobile industry can serve as a connector to allow economic inclusion and empower people to advocate for their social and political rights via the Web and social media (GSMA 2016).

M.13- Mobile phones serve as providers of emergency broadcasting, helping give early warning in the event of climate-related hazards (GSMA 2016).

Mobile phones bring, alongside with other ICTs, the opportunity to integrate technology, science innovation and services (Biggs et al., 2016).

M.15- Mobile devices offer cost-effective connectivity in comparison to other environmental monitoring solutions (Biggs et al., 2016).

M.16- Through the use of mobile devices, it is possible to identify and address new legal and security challenges; it can also ensure, for example, the proper monitoring of mobile money services to identify suspicious activity and partner with the police (GSMA 2016).

M.17- The mobile industry is a direct contributor to the increase of connectivity, improving the affordability of handsets and other accessories. The mobile industry is recognized among governments as a core enabler for high quality data and improved access to communications around the world (GSMA 2016).

Biotechnology

BT.1- Biotechnology is seen by some as an important tool to end poverty and by others as a threat to be wary of. Biotechnology can lead to the end of poverty in the world through, among other things, its contributions to agriculture, energy and clean water. However, its impact on ecosystems, human health and community acceptance of its use still need to be better studied and understood (United Nations, 2016)

BT.2: Biotechnology has had a profound impact on modern agriculture, from conventional plant breeding, tissue culture and micro propagation to genetic engineering and genetically

modified crops. Biotechnology makes it possible to grow crops in places where it would naturally not be possible and to add nutrients such as vitamins to plants.

BT.5/6- Advancements in biotechnology provide the chance to address challenges such as access to clean drinking water and energy provision. In India, energy generation from waste is being explored through microbial technologies, which are used to remove GHGs and thus purify the water for consumption.

BT.14/15/16: Environmental biotechnology can be used in different contexts, such as biodegradation and bioremediation according to Godwill (2013); it plays a major role in the removal of slurry and other contaminants. Microbial technologies for example play a critical role in regulating the climate, by absorbing greenhouse gas emissions.

Cloud Computing

C.1- Cloud computing can help tackle extreme poverty by serving as a platform for locally-relevant, pro-poor innovation, without requiring significant capital investment (United Nations, 2016).

C.8- Cloud computing is enabling new ICT-based services which will allow, for example, the outsourcing of jobs to developing countries, therefore boosting their economy and the number of high-skilled professionals in those places (ITU, 2017b).

C.12- Production efficiency can be optimized by integrating data with different technologies and by transferring data in real time to the cloud (Cornell University, INSEAD, & WIPO, 2017).

Emerging Technologies

The IoT

IoT.2- The IoT will help bring down world hunger by integrating sensors to, among other things, report faulty water pumps or inform farmers about the weather, soil or crop conditions. It can also help minimizing the waste of resources by automatically starting and stopping irrigation (Nethope et al., 2015).

IoT.4- Smart identity cards with biometric features could be provided for all public school students to improve education access in Nigeria and to monitor teacher attendance in real-time in South-Africa (Biggs et al., 2016)

IoT.6- Through an integrated ecosystem of thermometers, resistant temperature detectors and thermocouples, it will be possible to gather information about water access, treatment and management; for instance, in Bangladesh a biosensor network of 48 arsenic sensors is being used to track water quality (Biggs et al., 2016).

IoT.9- The IoT enables infrastructure asset management and relays that information through the Internet. This makes it possible to integrate and command control systems in real time, enabling rapid response to disasters or conduct fault diagnostics (ITU, 2017b).

IoT.13- The IoT will give, through integrated seismometers, firearm sensors or commercial security technologies effective emergency preparedness (Biggs et al., 2016).

IoT.14- The IoT allow the identification of illegal fisherman in Timor-Leste through radio-based cloud-connected devices (Biggs et al., 2016).

IoT.15- In Africa the IoT has made it possible to track animals and monitor national parks (Biggs et al., 2016).

IoT.16- The IoT has the ability to provide data to understand social, economic and environmental trends taking place within a country which might impact its citizens; see for instance the implementation of Retinal scans in ATMs in Jordan, thus providing biometric cash assistance to displaced refugees (Biggs et al., 2016).

Big Data

BD.1- Big Data solutions are important to alleviate extreme poverty; for instance, in Uganda the UM Global Pulse found that mobile phone credit purchases correspond closely to household consumption data (ITU, 2017b).

BD.4- Big Data analytics can inform developers of online learning platforms about student behaviours, thus leading to the improvement of those courses (United Nations, 2012).

BD.5- Big Data solutions can enable countries to reduce gender gaps in the health, education and labour markets; in Uganda, Global Pulse is using voice recognition software to analyse trends and better understand gender biases, thus allowing the policy and decision makers to take more informed action.

BD.8- Risk assessment processes are being changed by the presence of Big Data-based applications that facilitate the assessment of risks, trends and customer preferences (Narain, 2016, cited in ITU, 2017b).

BD.9- Data from GPS devices can be used for traffic control and to improve public transportation according to the United Nations (N/A, retrieved from <http://www.un.org/en/sections/issues-depth/big-data-sustainable-development/index.html>, last accessed: 8 March, 2018)

BD.12- Global Industries are using Big Data to fully manage the lifecycle of their supply chains; for example, countries are now tracking where tourists put the most pressure on ecosystems or even where they consume basic resources usage like food and water (ITU, 2017b).

BD.16- Sentiment analysis on social media can reveal public opinion on effective governance, public service delivery or human rights (United Nations, N/A, retrieved from: <http://www.un.org/en/sections/issues-depth/big-data-sustainable-development/index.html>, last accessed, 8th of March, 2018)

BD.17- Big Data plays a particularly important role in achieving SDG 17, by strengthening and leveraging the evidence that suggests a need for more effective, responsible, and inclusive Development investments; it can also support national development efforts during or after humanitarian crises, allowing governments to estimate the size, location and composition of their population during a conflict (ITU, 2017b). Big Data offers the possibility of improving the gathering of data on topics formerly ignored by traditional data collection exercises.

Virtual Reality

VR.3- Virtual Reality, along with social media tools, can help with health education, patient care and public health programs - by allowing healthcare workers to share best practices and obtain information about disease outbreaks.

VR.11- Through Virtual Reality, it is possible to create environments that allow direct interaction, facilitating the visualization, communication and evaluation of new design schemes; it can for example help convince multiple stakeholders to address urban design guidelines and plan policies, and also provide a benchmark for further design alternatives.

VR.17- VR is currently being used by the United Nations (2017, retrieved from: <http://unvr.sdgactioncampaign.org/2017/06/14/refugee-realities-bringing-individual-refugee-stories-to-the-oecd/#.WqFa6JPFKL8>, last accessed, 8 March 2018) as a way to advocate change and to provide decision and policy makers with the tools and information to tackle different challenges. For instance, the United Nations VR programme "Refugee Realities" intends to bring individual refugee stories to the OECD through virtual story telling.

Artificial Intelligence

AI.1- AI can be used to collect data on farms, rainfall and acidity levels, providing farmers the information they need to decide when to farm and what to plant (ITU, 2017b). According to IBM Watson (N/A, retrieved from: <https://ai.xprize.org/AI-For-Good/sustainable-development-goals>, last accessed, 8th of March, 2018), AI will allow resource allocation through satellite mapping and data analysis of poverty.

AI.3- AI is thought to be a critical factor in enhancing medical technologies and practices, namely enabling the possibility of robotic surgery and anti-microbial resistance, or providing intelligent clinical analysis and data labelling (ITU, 2017a).

AI.8- According to IBM Watson (N/A, retrieved from: <https://ai.xprize.org/AI-For-Good/sustainable-development-goals>, last accessed, 8th of March, 2018), and despite the legitimate concerns about automation replacing jobs, an increasing implementation of AI and targeted automation with intelligent devices can help increase productivity and improve the work environment, thus leading to economic growth.

AI.12- It is expected that AI will optimize consumption and production levels with vertical green farms, eliminating waste, and vastly improving yields and resource efficiency (ITU, 2017a).

AI.16- It is expected that AI can reduce discrimination, corruption and lead to broad access to e-government, personalized and responsive intelligent services (N/A, retrieved from: <https://ai.xprize.org/AI-For-Good/sustainable-development-goals>, last accessed, 8th of March, 2018); significantly, it can also stay ahead of global cyber threats.

Nanotechnology

N.2- Nanotechnology already has the ability to produce Nanoporous zeolites, which allow efficient dosage of water and fertilizers for plants . Nanosensors also allow the monitoring of the soil and the quality of the plants (Salamanca-Buentello et al., 2005).

N.3- Disease diagnosis and screening are part of the contributions given by Nanotechnology, as well as health monitoring nanotubes and particles which alert cholesterol levels (Salamanca et al., 2005).

N.6- Nanotechnology plays a particularly important role in water treatment and remediation through, for example, nanosensors to detect contaminants and pathogens and attapulgite clay for water purification (Diallo, 2014)

N.7- Novel hydrogen storage systems based on carbon nanotubes, photovoltaic cells, organic light-emitting devices or nanocatalysts for hydrogen generation are some of the ways in which Nanotechnology is used for energy storage, production and conversion according to Salamanca-Buentello et al. (2005).

N.11- Nanomolecular structures can contribute to make asphalt and concrete more robust; they can also make not only cheaper and more durable housing surfaces and coatings but also self-cleaning surfaces with bioactive coating (Salamanca-Buentello et al., 2005).

N.12- Nanocomposites for plastic film coating are used in food processing and storage, applications which allow decontamination of food equipment and packaging (Salamanca-Buentello et al., 2005).

N.13- Air pollution minimization and remediation is also possible thanks to nanoparticle-based photocatalytic degradation of air pollutants in self-cleaning systems or gas separation Nanodevices (Diallo et al., 2014).

Blockchain

BC.1/2- Blockchain allows the world's poorest people to access the global economy and allows farmers in remote communities to have access to a digital identity, thus allowing their integration and access to the global market. BanQu is an example of a Blockchain application which makes all this possible (GSMA, 2017).

BC.8- By allowing remote farmers and other workers to access the digital economy, and facilitating the verification and payment processes, Blockchain is set to be a great contributor to foster economic growth globally (GSMA, 2017).

BC.16- Blockchain might signal the entrance in a new paradigm regarding cyber security, since it ensures identity systems remain portable and private, and also that the information recorded is immutable and vetted, giving less margin for corruption and fraud (GSMA, 2017).

BC.17- The United Nations calls for a multi-stakeholder engagement to develop transparent and replicable policy around solutions that will allow technology to drive the Sustainable Development Agenda to a new level (UNDP United Nations, 2018, retrieved from: <http://www.eurasia.undp.org/content/rbec/en/home/presscenter/pressreleases/2018/blockchain-research-to-support-sustainable-development-goals.html>, last accessed: 8th of March, 2018)

3D Printer

3D.8- The profit margin of Additive Manufacturing - which 3D printing belongs to - is expected to increase to \$21bn by 2021; also, the McKinsey Institute Global has estimated a direct economic impact ranging from \$230bn to \$5050bn by 2025 (Ramalingam et al., 2016).

3D.9- The rapid rates of urbanisation in developing countries and the increase in forced displacements due to conflicts and natural disasters have led Development organizations to look for new alternatives to produce cost-effective emergency shelters and sustainable shelters. 3D printer is seen as a potential alternative to build short-term shelters and housing (Ramalingam et al., 2016).

3D.12- 3D printing will bring enormous advantages in terms of production, eliminating many traditional supply chain costs and reducing waste associated with these traditional manufacturing processes (Ramalingam et al., 2016).

4.3- VALIDATION

This study was validated by field experts and participants in the World Summit on Information Society (WSIS), a conference dedicated to the topic of Technology and Development held in Geneva in 2018.

The conference served as an opportunity to conduct a series of interviews with experts in the fields of Development and Information Systems with the goal of understanding their opinion on the role of technology in achieving the SDGs. Two different goals guided the study validation:

1. Understanding the experts' opinion on the role of technology in achieving the SDGs and the respective roles of Development Agents and Global Leaders.
2. Validating the presented reference model and its foundational assumptions, emphasized throughout the literature review.

A total of sixteen (16) interviewees from different countries, backgrounds and sectors gave their contribution to the present study:

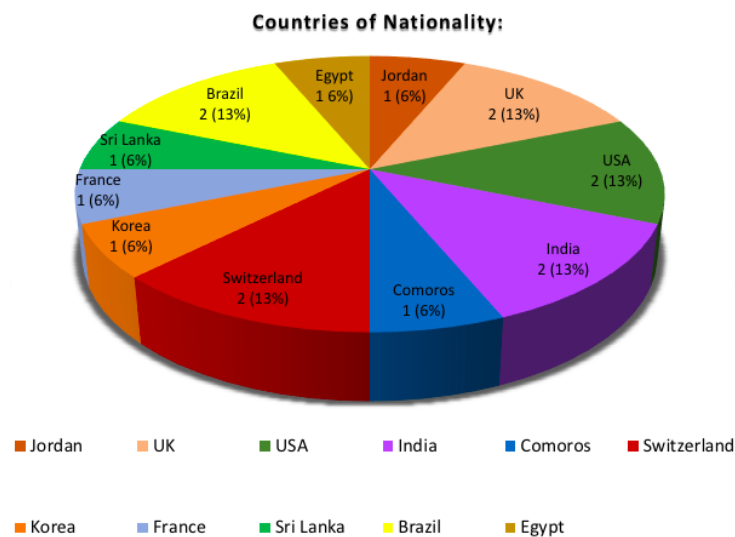


Figure 12 – Interviewees' Countries of Nationality & Origin

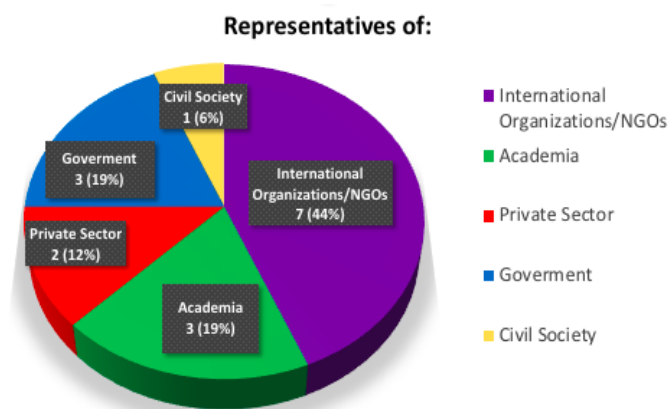


Figure 13 – Interviewees Representing: International Organizations, Academia, Private Sector, Government and Civil Society.

Before and during the WSIS 2018, the sixteen experts were invited to participate in the series of interviews, undertaken with the aim of helping address the study's main questions and validate the created model. All the interviewees attended the WSIS, and their invitation to participate in the study was based on the demonstrated relevance of their academic and professional background in the Development or Technology fields for the research purposes.

The Interview Script was created with the intent of gauging the interviewee's perception of the role of technology in achieving the SDGs in a first moment, and then validating the reference model linking technologies and the SDGs:

- The 1st Section focused on the broader and more general assumptions regarding the role of technology in achieving the SDGs and the respective roles of development agents and global leaders.
- The 2nd Section was focused on more specific questions, which aimed to validate the reference model and its underlying assumptions.
-

The duration of the interviews varied from 20 minutes to 1 hour. From the 16 interviews, 14 were conducted face-to-face at the WSIS, while the remaining 2 were conducted via Skype. Of the 16 interviews, only one was not allowed to be recorded. The qualitative analysis of the interviews was conducted by the researcher and the following process based on the work of Blair (2015) was adopted:

1. Audio Transcription;
2. Open Coding of the answers according to the different points of view and contributions;
3. Categorization of the codes;
4. Comparison of the study's assumptions and relevant researched literature with the results obtained from the analysis of the interviews.

Below is a list of the study participants, with details of their academic background and professional experience, followed by the transcribed interviews:

The Study Participants Backgrounds

Name	Countries of Nationality	Academic Background	Professional Background
Haidar Fraihat	Jordan	Bachelor's degree in Accounting and Management, MBA from the University of Bridgeport in Connecticut (1988), PHD in Management Science from the Illinois Institute of Technology (1992).	Has worked for more than 30 years in 11 institutions, ranging from Government, to Advisory, to NGOs to the UN; worked in 6 countries, author of two textbooks and 30/40 publications.
Tim Unwin	United Kingdom	PHD in the mid-70s on medieval settlement and society.	Worked in Rural India has been heading a research group at the University of London on ICT4D. UNESCO Chair in ICT4D.
Jean-Baptiste Decorzent	Korea/Switzerland/France	Bachelor's degree in Electrical Engineering, Automation and Robotics. MBA from Lausanne Faculty of Business Economics, University of Lausanne. MBA with specialization in Technology Management.	Worked for Swiss Multinational designing robots, changed into international law, working for the international committee of the Red Cross as a delegate for protection and detention in Congo. Changed fields again and worked in telecommunications, working for Ericson at the beginning of the R3G era as a network planner, planning national telecommunication infrastructure. Worked for Nokia, and also as a consultant for the Swiss Government and the UN. Worked with some startups, NGOs and foundations. Currently works as a director at HCash foundation, which is a company focused on Blockchain development.
Chloe Autio	United States of America	University of California, Berkeley, studied economic and technology policy.	Worked for a non-profit organization called Packet Clearing House. Worked on the NGO sector previously. Now working as Public Policy Strategist, Government & Policy Group of INTEL Corp.
Rajendra Shede	India	Chemical engineering graduate at the Indian Institute of Technology in Bombay.	Worked as a chemical Engineer in a chemical industry as a general manager, chosen for the Global Programme of the United Nations, led a programme for the implementation of the Montreal protocol, which. Considered of the most successful programs of the UN. Coordinator Leader of IPCC (Intergovernmental Panel on Climate Change), which won the Nobel Peace Prize in 2007. Has experience In private sector and in the UN; currently runs an NGO.
Paul Rowney	United Kingdom/Namibia	Graduate certificate in advanced manufacturing technology & ICT policy and regulation.	30 years of experience with ICT and 8 years working with the UN on ICT4D. Computer Programmer for 3 years, UNDP consultant on ICT4D, Global Health Desk for UNICEF. Entrepreneur in Namibia (created a foundation).
Nkwah Akongnwi	Comoros	Degree in international economics, master's in Economic and Human Resource Management and in Diplomacy and Technological	Worked with National Organizations and NGOs, focusing on how to use ICTs for Agriculture. UNOCHA Consultant.

		Development; currently doing a PHD in Psychology and ICTs.	
Sonja Betschart	Switzerland	Business background with majors in marketing and management.	Experience in the private sector, namely start-ups. CEO of WeRobotics.
Keith Mainwaring	United Kingdom	Electric and electronic engineering diploma and Master's degree in Communications Policy	Has been working with data communications. Consultant in London on interconnection protocols and interface devices. Consultant for the UK Government. Interface Standard Development protocol developer. Worked with Xisco Systems. Currently an independent ICT4D Consultant.
Prabhuraj Aralimarad	India	Bachelor in Agriculture and PhD in Agricultural Entomology	Professor of Etymology at the University of Agricultural Sciences, India (WSIS 2018 Prize Winner, e-agriculture software).
Shoshannah Richards	Jamaica	Master's in Public Policy from the Hertie School of Governance in Berlin, specialized in digital policy.	Professional experience in e-commerce and corporate responsibility. Project Manager at SheLeadsIt, which is focused on combining corporate actions with social improvement.
Helani Galpaia	Sri Lanka	Computer Science Undergraduate, graduate in technology studies and policy	Management Consultant in the US. ICT enabled Development in Sri Lanka with LIRNEasia.
Brahm Panwar	India	Graduate in Science, Post graduate in computer science and MBA degree	Software developer, system designer, worked for private sector, worked for UNICEF in 1995, since then has been focused on using technology for Development purposes. Focusing on different programs for education, health and beneficence for over 20 years now
Alexandre Barbosa	Brazil	Electrical Engineering, Master's in Computer Sciences, an MBA, Doctorate and post-Doctorate in Administration.	Professional and Academic Background in the context of socio-economic Development. ELAC Development involvement and also the UN SDGs programme, Manager in the Brazilian Network Information Center
Laerto Cleton	Brazil	Master's in computing science.	Worked for Siemens, worked 5 years in Germany. Worked for academia for almost 6 years. Joined the Federal Government. Currently Director of Telecommunication Services Department.
Marlyn Tadros	Egypt/United States of America	PHD in Comparative Literature	Has been teaching Internet and emerging technologies for more than 10 years. CEO of VirtualActivism.

Table 3 -Study participants backgrounds

Interviews Transcription

General Questions on Development and Technology

3.1- Do you consider sustainable human development dependent or independent of technology?

Haidar: I think that the world population doubles every 40 to 50 years, and therefore we cannot sustain the economic and social dimensions of life without a new extraordinary tool and resource. Technology is the best way to play that role, because in my opinion humanity has basically run out of cards in their sleeves when it comes to how to sustain the 7 billion who exist on Earth now, who will perhaps be 10 billion in our lifetime or in our children's lifetime. So technology is a saviour, in my judgement, to sustain Humanity.

Tim: That's a bit of a myth; the SDGs are fundamentally driven by an economic growth agenda. They only exist to give UN agencies a role, they are not going to do anything to reduce poverty. Technology is irrelevant, the whole notion of SD is flawed. Sustainable means something is maintained, development is something that is changing and growing. ICT4D have increased growth but have also massively increased inequalities. The SDGs are purely a way to cover the cracks. In the end our capitalist system is at the heart of inequality. They tend to define development and associate it with growth, but development is about reducing inequalities. Technologies have the potential to do good and harm, depending on its design purposes in the first place. By looking at the ICT4D, they have actually increased Inequalities. We will never achieve the SDGs. We can't achieve the SDGs, that's a construct. Can't answer the question since it's not dependent or independent.

Jean-Baptise: Technology has only 1 purpose, to serve people. I don't see how it can be independent. Technology has only 1 purpose, to serve people. Can't answer yes or no. Technology will enhance, technology will empower us to reach the SDGs, but we are already behind, we set very challenging goals, if we don't reach them doesn't matter. I don't believe we can get close to the SDGs without Technology. The Global issues are so complex that today without the help of technology we cannot achieve the SDGs.

Chloe: It is definitely dependent. It is really impossible I think to push the SDGs without leveraging ICTs and Internet connectors, access to information, education, communications, social media: being empowered through technology.

Rajendra: Human Civilization has to realize we only went through 15 years of the MDGs programme. I strongly believe SDGs are not only for Human Civilization, we cannot take us out and say we achieved the SDGs, it is for all life on the planet. Unless an earth worm is healthy we cannot get our food. Technology does play an important role, indigenous technology, way of thinking, processes, IoT, thinking they are all technologies. We are dependent on it, but I think the word is not correct, technology is a tool to achieve the SDGs. We are not slaves, we are not dependent on it, if it is not there, we can anyway achieve the SDGs, with it we can achieve them faster.

Paul: ITU guidelines and other similar are often misunderstood by local governments in developing countries, the case of Namibia for instance. It's not a technology issue. It's independent. The challenge we have is to not allow technology to lead development. Technology is an enabler not a driver. We can leverage it as a tool to improve services such as health or education.

Nkwah: Actually, we are in a globalized world, we cannot talk about development without mentioning technology due to the fast-moving world we live in. Development depends on Technology. People use technology to facilitate development, the more you have access to technology the more you will develop. One of the goals in the SDGs is actually the development of technology infrastructure, so we are talking about a direct link.

Sonja: It is dependent, you can't make it independent because technology is an integral part of our life, businesses and development processes. To achieve the SDGs there are a big number of technologies which can help address them. Technology makes it easier and more efficient to achieve Sustainable Development.

Keith: It has at least to be practically, going forward, dependent. You could have human sustainable societies without technology. Technology will help, it's a matter of defining Sustainable Development. If we take sustainability we have renewable resources in and then clean outputs, non-polluting outputs, taking this the goal of sustainable is rather difficult to achieve without proper regulation. Efficiency in the use of energy, material resources, technology will help but won't help solve the whole problem.

Prahburaj: Technology is fully helpful and essential for present human development.

Shoshannah: It is dependent on technology because tech development and digitalization in particular affect pretty much every sector. In Jamaica there is a push to digitize all the records. It is a fact in education and health and also private life, the two cannot be separated.

Helani: Infrastructure, things you can't provide yourself, improve people and bring them out of poverty. Dependent, and it is increasing. ICT side of things, we are at a stage we can't do without. Particularly the measurement of Sustainable Development. Satellites, people using mobile phones.

Brahm: Technology is an accelerator, cannot say it is dependent or independent. Considering the agenda of letting no one behind. Somehow it is impossible to leave no one behind.

Alexandre: Barbosa: Tecnologia É um elemento habilitador do desenvolvimento social e económico. Tem um papel muito importante nas práticas culturais e sociais. A resposta é sim, e tem um papel preponderante no acesso à informação e conhecimento que impacta o desenvolvimento social e económico. Neste novo paradigma em que vivemos, torna-se dependente. É inevitável que os cidadãos tenham acesso às tecnologias.

Laerto: Nos termos da nossa realidade actual considero dependente da tecnologia.

Marlyn: Some are dependent, and some are not dependent. Technology is in everything, the MDGs actually had a goal which talked about the role of ICTs in SD. I think it was clearer there. I don't think it is a yes or no answer. It has a role but not in every single goal. Some goals can be judged in this way others not. We can alleviate poverty or gender equality without technology for example, there are a lot of things we can do without technology in the narrow sense. (mentioned in 2.3 in the broad sense of technology, that SDGs to be achieved are dependent upon technology).

3.2- What other variables do you believe to be crucial?

Haidar: Well, another dimension is basically having Leaders who will divert resources to peace rather than war. All the resources used for war, maybe 10% of that would be enough to feed the entire globe. So we want technology and we want more sensible leaders who don't spend money on wars and killing each other.

Tim: Reducing inequalities in the World. SDG 10 does have a little bit about that. But there is nothing about technology reducing inequalities. ICT4Ds are part of SDGs as you know.

Jean-Baptiste: N9 and 17, partnership for the goals. Without collaboration and partnerships, we have already failed, no matter the SDG we are talking about. Banks, international organizations, telecommunication companies, service providers. We need partnerships. Goal N17 is the most important one.

Chloe: Multistakeholder and collaborative models where industries, governments, civil society collect and share information together. Collaborative learning and implementation of programs is really important. Unilateral intervention is less impactful.

Rajendra: Personal behaviour, the way we look at the traditional technologies, in this world of bitcoins and robotics, we tend to forget tradition. Human civilization is at least 10 to 12 thousand years old, when we started doing agriculture. We have learnt from nature and developed our own type of technology back then, just because we have a smart technology doesn't mean we should ignore acquired and stored knowledge back then.

Paul: Africa in particular needs national ownership. We outsource resolution to donors. There is not an alignment between international organizations and national governments. They leverage technologies in a different way. Global organizations push the development agenda.

Nkwah: SDGs are for people, governance therefore is essential, it can provide access to education. One of the blockers of development is the access to education. Governance should give access to education, access to education is also access to technology. Good access and good governance are also essential.

Sonja: Understand the needs of countries, understand them, take time, research. And then from a business point of view, it is necessary to make it viable. For Sustainable Development, one has to have a business approach, how do I combine the need with the value I can create and how technology can play a role in it.

Keith: There has to be the will to do it. Information campaigns to encourage people and projects related to achieving these goals, then government and local authorities following through. Unless there is public pressure things won't happen.

Prahburaj: In Agriculture for instance, they are poorly educated, they know the basics of farming, but regarding technology they lack the control to align these 2 fields. They also need technology which helps them access this information in real time. Technology should be sustainable, economic and accessible to the farmers.

Shoshannah: Governance, Critical thinking on how we define SD going forward. For instance, AI and the IoT will make the SD progress in different ways. You can see differences between people to access opportunities. Inequality should be tackled, it is very important. SD will be very different not only between countries but within countries. The 1 billion happy programme is very interesting. It's about creating a world where robots emulate humans and for us to move forward.

Helani: Human Action, human activity will determine whether we live in a sustainable world or not. Economic and social incentives. The right incentives are essential for SD.

Brahm: Policies, coordination among other stakeholders, the problem of many interventions globally is that there is a force in isolation and having a protocol emission and policy it will allow the implementation the technology to achieve the SDGs.

Alexandre: Todo o mundo vai enfrentar um desafio maior que é o desemprego, desenvolvimento tecnológico, indústria 4.0. Isto implica que os Governos tenham de ter um

mínimo de trabalho para gerar renda às pessoas. A questão de educação e desenvolvimento de habilidade digitais, nos países do hemisfério sul, ainda há imensos passos a ser ultrapassados. Uma visão de desenvolvimento sustentável, esta educação vai afectar o padrão de consumo que temos. Se mantivermos o crescimento populacional neste ritmo e o mesmo padrão de consumo, iremos ter muitos problemas, a água como exemplo. O paradigma dos skills digitais e a educação para o desenvolvimento sustentável deve ser sustentada por políticas assertivas a nível dos indivíduos e organizações que encaminham este processo juntamente com a tecnologia.

Laerto: Funding, é preciso haver recursos para promover o desenvolvimento sustentável, um desenvolvimento que implica inclusão, e essa inclusão está associada a um custo. Os recursos naturais, preservação é essencial no contexto de sustentabilidade.

Marlyn: I like the variables that the MDGs and the SDGs have in place, they are great indicators. And they are extremely relevant to know to what extent for example gender equality was achieved within a specific context.

3.3- According to your experience , what might the main role of Technology be in achieving the Sustainable Development Goals by 2030?

Haidar: This is a very wide question because technology has its role in achieving the SDGs in all of the goals, from Poverty, to education, to health, to industry, to employment, to women empowerment, to land, sea, air, oceans. So technology can be in each and every SDG to achieve the Global agenda.

No, it's not the end itself, but it's all of the above. It is an enabler, a connector, a tool, a lever, it is an energizer, motivator, it is a game change, a disruptor. It's all of these things together. It's not only a tool of course. We need people need to basically be creative on how to deploy technology to achieve our human agenda.

Tim: Much of global capitalism today is run by companies, they are interested in 2 things, increasing market and getting cheaper labor. It's very important for them to say they contribute to the SDGs, so they can increase profit. It's not about helping the poor and marginalized. It's all about how technology can enhance economic growth, will that end poverty? It won't. If 60% of primary schools in Africa don't even have electricity, how do talk about giving them computers? We will have 4 billion instead of 3 billion connected to the net, but what about the rest? The poor will then try to catch up with technological development, while the rich will always have the latest technological tools.

Jean-Baptiste: Here we speak specifically about ICTs. We don't connect people, ICT provide access to information, which is the biggest revolution that humanity has ever faced.

We don't know if we are at the beginning or the end. Access to information allows people in the emerging and frontier markets to find their own solutions. ICTs are attached to the financial system, it can empower new means of transmitting values through Blockchain or mobile money to allow financial inclusion. Mobile money is fantastic for financial inclusion. Technology plays a major role as an enabler and connector to find new solutions for our current problems.

Chloe: Empowerment, a tool for economic, educational empowerment. It helps achieve Equal access. It is a tool, a tool for empowerment.

Rajendra: Technology makes the road to the SDGs efficient. Efficiency, Resources, to achieve anything you need resources, unless all these resources are there.... Time is also a

resource, technology helps us achieve the SDGs faster. We should be able to manage it, so technology helps us monitor and measure, administering, and tackle the SDGs in a more efficient way.

Paul: Expanding the reach and collection of information. In rural areas for instance, technology can provide the necessary information and tools to access these areas with the necessary resources and tools. Connecting data and bringing real time information to be analysed.

Nkwah: Technology is the medium, we have the ideas and results, technology is in the middle of the development process. It is an enabler and facilitator to attain the SDGs. Technology is a tool to reach ideas, it is a catalyst for SD.

Sonja: Technology can really be an accelerator, it will allow things which we were not able to address before. With robotics, with drones you can do things that were not possible before, and cheaper, whether it is nature conservation or human related issues, it can provide these services at a most more accessible price.

Keith: Efficiency of using resources is the keyword. 2 areas are critical: energy and transport, there are many applications which allow them to improve. Autonomous vehicles can benefit a lot from this, reducing traffic, light control to reduce traffic congestion, automate functions and this way technology can actually help create a better system than today's one with happier people.

Prahburaj: Technology should be accessible to end users, must be understandable and usable. It should be independent of governments and other organizations. Governments should support these technologies' implementation and the initial founding. There should be public-private partnerships.. We cannot connect to many farmers. So, the NGOs act at the local level and the entrepreneurs act at a different level. Technologies become important in rural empowerment and employment.

Soshannah: It depends on how we use technology: Are we going to approach technology as a tool to enable the goals we set forth or are we going to allow technology to develop whether regulated or not regulated with or without any sort of strategic vision. It is not about what we want technology to look like necessarily, but what world we want and how we define Sustainable Development, therefore using technology for this purpose, a means to achieve an end. Technology is seen with a lot of fear by people in my opinion. It has been used since the dawn of time. Humans in the future might come and think we were/are not very sophisticated.

Helani: Technology is in a way everywhere, it is in the delivery of services first, if you are talking about health or maternal health, even basic things like reminding mothers about the vaccination of their child, technology has a role. In poverty it has a role of reducing it. First it is delivery and then monitoring of services. What is making the life quality in cities better? Sensors, Wi-Fi, buses, transports; in developing countries people can wait up to 2 hours for transportation. In Geneva we take things for granted but in developing countries there is a lack of these foundational technological services.

Brahm: As an accelerator, for example to use as a means to help communities, help facilities, help education and improve its quality. It has a broad range of contributions. Take for example learning. A lot of people in classes is not effective, technology can help provide e-learning and improve education.

Alexandre: A tecnologia já é reconhecida pelas UN, OCDE, Banco mundial como sendo um habilitador para o desenvolvimento sustentável, porque acelera o desenvolvimento social, crescimento económico e desenvolvimento sustentável, estes três pilares podem ser fortemente

impactados pela tecnologia. Estes 3 pilares estão presentes em tudo, educação, saúde, agricultura, processos e indústria entre outros. Ai a discussão é o que é efectivamente a tecnologia, o mundo produz hoje em dia uma quantidade de dados absurda, dando margem para os países pegarem nesses dados e monitorizar de forma efectiva o desenvolvimento. A monitorização em tempo real da desflorestação da amazónia por exemplo, o dado é uma tecnologia em si que favorece o desenvolvimento de políticas, a robotização, a transformação digital dos processos sociais e de negócios está a mudar drasticamente. A forma como você consome, a indústria apoiada nestas tecnologias. Estamos em um momento da Internet por exemplo, que é a Internet do consumo, e daqui iremos passar para a Internet dos processos, moldando os processos industriais e produtivos, ficando a depender como um componente critico. Ela está presente em muitas dimensões. É preciso pensar a tecnologia não só como um componente tecnológico em si, ou electrónico, mas como sendo dados e um processo.

Laerto: Tem um papel central, ela viabiliza o alcance dos SDGs. Por exemplo, inclusão bancária, inclusão de pessoas mais pobres. O uso de dispositivos móveis está espalhado pela população, e isso ajuda a incluir as pessoas neste sistema, permitindo aceder a ferramentas como crédito por exemplo e outros serviços electrónicos, pagar e receber pagamentos. A inclusão é uma grande contribuição que a tecnologia traz e é essencial para alcançar os SDGs.

Marlyn: 2 ways: Supportive role, which means I can support poverty alleviation. I can also use technology. You cannot have any health programme without technology, everything is somehow dependent on technology now, if we talk about it in this way is definitely important. It's not only a supportive role when technology is mentioned in its broad sense, it's an integral role to the SDGs. Definite importance.

3.4- What is in your opinion the role of development agents and global leaders (governments, International Org/NGOs, private-sector and civil society) in leveraging technologies for Sustainable Development?

Haidar: Government- First of all, government is a regulator; if they regulate well, that will be reflected nicely on how technology can be deployed for Development. If they are lousy in regulating, we will have all sorts of problems and issues. So government regulations are important. Also, governments are thought leaders. Governments also have leaders, the leader of the government or the head of state is an inspirer on how technology and innovation can achieve the outcomes.

Civil Society- They have a role. The role of civil society needs to be defined more in my judgement, because the relationship between the Civil Society and the NGOs is more competitive rather than cooperative. They basically are fighting for resources and survival rather than a noble cause. I could be radical in my judgement but this is my judgement.

United Nations- They have a role in basically providing the best practices to the world on how technologies can be deployed to help achieve the SDGs.

Tim: Simple answer is, they should focus on encouraging all involved in this cause to serve the interests of the poor and most marginalized rather than the rich and powerful. Historically they use technology to stay in power. If we want everybody in the world to benefit from these amazing technologies, we have to focus on the poor and marginalized, street kids, women, minorities, above all else.

Jean-Baptiste: All of them play different roles. ICT is just a tool, it is not a means to achieve something. It's a tool that can enhance solutions and how to find them.

About health, the issue is we have national health systems, we try to provide health, but the issue is about confidentiality, security and with Blockchain now, it is different from centralized data-bases. We don't know yet, we are exploring it, the European Commission and other countries are very open-minded about its contributions. They have the observatory, they are working on the role of Blockchain to improve the health system of countries. The foundation has a very light role. It is necessary to bring governance. It intends to empower the community, entrepreneurs. Governments have many different roles to play in society, one thing for sure about ICTs is governments need to come up with a legal framework to help these thousands of good entrepreneurs around the world to develop new technologies which will have an impact on people's life. They need to take more risk, nothing is perfect, if they cannot take risk, who can?

Chloe: The root of this question is about investing time in research to understand what is needed. Currently there is a huge gap of access to technologies. Being able to provide the right research and connections to understand what the problems are is key, it will then require collaboration between leaders and also field work to understand what the problems are. Being connected to the right people and hearing them is crucial to provide the right solutions.

Rajendra: The role of young minds is very important. The youth of today are the policy makers, NGOs, private sector and government works of tomorrow. They can help by actually acting within their campus and by starting project-based learning. The government's role is passive, they should encourage people to take action and create incentive policies. Governments can play a role in making the education system focused on achieving the SDGs, making young people market-ready and now SDGs-ready.

Paul: Governments need to be part of this process, and try to understand national agendas and priorities, which is always a big challenge. Look at education and health in Namibia. We have technology, partners, corporations, governments. Everyone is interested in the solutions, but it doesn't go beyond the incubation phase. We fail to institutionalize change, there is a resistance to change. Leaders want change, they want to take part in the digital economy and use ICTs. Corporations want to sell these solutions, there is a big block of population involved in this process of education. They are not helped in understanding the global picture. Countries in Africa are miles apart from the process and lives of western countries. You start off with pilot institutions and you bring it to the field and it fails because people don't adapt to the process and change. There is a lack of implementation and operational alignment between these stakeholders.

Nkwah: NGOs they are here to implement, help implement, help diffuse, do research. Government make the decisions, they are there to develop new ideas and to think. Like a chain a cooperation, a collaboration between states, ngos, international organizations. have the policies, how technology can help populations.

Collaboration between these stakeholders. We have the policies, we have the implementation, they must collaborate to together understand how to use technology for development. ICTs have an impact on human beings. We need the collaboration and control on ICTs to be used for human development.

Sonja: I will speak from a business point of view and from robotic technologies. We have the industry and global drone hardware. They are not so interested in developing countries, it is not a big market. They want profit. The governments on the other hand in these countries don't have the means to implement these technologies, they don't know about them. Industries don't do anything to bring them closer to governments.

NGOs might know and try to implement technologies but haven't got enough power to change things from a development point of view. You invest in markets to get known, in Switzerland and Europe they invest in technology start-ups, that's missing in developing countries, that increases the digital divide. For GIS for example you have very bad quality and expensive data, and robotics such as drones can improve a lot this technology approach. Technology can provide support and education tools, but it has to be accepted and allowed by decision makers and governments. They are very redundant on new technology because they are afraid. Governments should also be re-educated. We don't know about a certain technology, so we block it, thereby increasing the digital divide. Partnerships are needed among all these stakeholders.

Keith: Innovation, you always have innovation. We need policies at high level to change things. Policy is very important. Civil Society should be the one pushing the governments to create relevant policies. This is nevertheless an euro-centric approach to the question. The government should support and provide initial funding, they should promote technologies alongside agriculture community. develop partnerships with NGOs and corporate groups for successful technology implementation. Technology can act at the local level, and entrepreneurs at higher level should join forces and make it more sustainable.. These technologies can actually empower and help economic growth.

Shoshannah: They have an integral role to play. The reason for that is business is over here and government is over there. What we know, according to studies, and focusing on the US context. Government has the role of using technology for development purposes. Its businesses and small businesses should be drivers of development. Government and policy makers are the ones who set the regulatory environment to determine what things will continue, what red lines will be set up. They should look at themselves as standard setters, as innovators, on how to emphasize the role of government on development. Not being the ones who constrain things but as the ones who allow things to flourish.

Helani: If you traditionally look at the development matrix, they have different roles. Governments' role is to regulate, if you look at reforms and provisioning of communication services, well governments don't have to be the ones doing everything, a lot happens actually in the private sector. Government maintains a role as a regulator, the pricing is done right so people have alternatives. The role traditionally played by governments has changed positively. The private sector has to come up with new technological alternatives and scale up those. Governments should support these, allow multiple companies to provide services. Civil Society has 2 roles, making it reach marginalized groups, they are there to hold government and private sector accountable, when it harms more than expected, Civil Society raise their voices and call for regulation and banning. Government regulate, bring people to the table and the private sector has to innovate.

Brahm: Partnerships, if all the stakeholders work together, it is possible to achieve the SDGs. Coordination can be led by the government; the others cannot operate without the approval of government. It is then the government's function to bring organizations and institutions together.

Alexandre: Estes atores, cada vez estamos a viver mais, WSIS como exemplo a necessidade da intervenção de múltiplos atores, governo, sociedade civil, private sector, organizações internacionais. Todos eles têm vontade de se engajar no bem social. Em países que ainda tem indicies de exclusão social muito grandes, como é o caso da América Latina. Como fazer para avançar na inclusão digital? O governo tem um papel fundamental na regulação, permitindo o sector privado intervir de forma equilibrado e dinâmica no acesso a zonas mais periféricas e não só nas metrópoles. A barreira de custo (impostos) é extramente importante também.

Qual a principal barreira? O custo, os cidadãos de baixa renda não podem pagar tal. O governo tem como papel por um lado actuar na dinâmica de competição e por outro reduz o custo de tração do serviço, devido às políticas de lucro do sector privado. Ele pode trabalhar para trazer tributos/impostos menores de acordo com o acesso, renda e outros factores. A importância da inovação. No Brasil há mais de 3000, mas apenas 6 dominam o mercado de provedores da Internet, o resto são provedores locais onde os grandes não chegam. O empreendedorismo nestas áreas está a crescer muito. Nestas pequenas localidades o sector privado tem o papel de inovação e aceder às necessidades destas populações e áreas mais remotas. A sociedade civil, dá voz à sociedade e tem o papel de influenciar positivamente as políticas públicas através de uma pressão positiva. Estes atores devem trabalhar em conjunto no âmbito da inovação. Países muito fechados tenderão a não favorecer a inovação (não tem tanta abertura para tal).

Laerte: Tem um papel central na medida que as soluções em mercado, não conseguem resolver todos os problemas, elas esbarram na fronteira da sustentabilidade dos negócios, impedindo o mercado de preencher determinadas lacunas. O papel do governo é implementar políticas que ajudem neste fim. Isto pode ser feito de várias formas, através de criação de negócios, redução de barreiras regulatórias, dando mais liberdade ao mercado. Há espaço para estes 2 tipos de política, de desregulamentação, dando liberdade ao mercado de expandir, mas isso tem limites, e aí é necessária uma intervenção mais estatal, mais direta para equilibrar. Isto aplica-se não só na inclusão, mas noutras áreas como as questões ambientais.

Marlyn: The roles are different, if we talk about governments and UN we talk about access to technology and **penetration**. If we talk about the private sector, that is a supportive role, and the government should also encourage private sector. The role of civil society is one of innovation and implementation. No matter how much the UN does, if government doesn't have or give access to the people (civil society) people won't then be able to do anything.

3. Specific Questions for the Model Validation

3.1-What do you believe are the main differences between the established & emerging technologies addressed in terms of their role and impact on Development?

Haidar: Well, I think that while we speak technology is changing, it's changing by leaps and bounds, it's ever-changing, that's the nature of technology. It has proliferated in the past from military to civilian, now it's proliferating from corporate to individual and therefore we have a more widespread involvement in the advancement of technology, so the delineation or demarcation between established technologies and emerging technologies for me is not such a great thing because even established technologies are changing. Even frontier technologies, they are based on established technologies. But if I want to put both of them together, the established technologies and the frontier technologies, I think that... (pause) Before I say my point, I need to clarify something: what is called the emerging technologies, it is different in judgement, what an academician thinks of an established or new technology is different from the notion of a corporate, or let's say a journalist or a government official. So these terminologies are here for... what can I say... they are not very operationalized, they are used

by various groups in different connotations. So, for me, to give you a clear answer, I don't believe in the demarcation of these two types of technology.

Tim: I don't see it as two groups, I see it as a continuity of change. They have basic things in common: integration. Now everything is much more integrated, for example telephones. We are on our way to becoming cyborgs.

I see a set of processes, but there is a missing process which is affecting all of us, which is us being human cyborgs. It's already too late, we are already human machines. This is where the future is going unless we do something now. Global corporations are driving this agenda towards profit and not really Sustainable Development. Technologies are designed by people for a purpose. I see them as Continuity of evolution of this increasing machine-human interface. Technologies are always designed by people for a purpose.

Jean-Baptise: They are different, but some of these established technologies are evolving, those that are not will die soon. If it comes to ICTs, mainly mobile telecom, we have 4g today and 5g coming. Are they established? No, they are always evolving not stagnant. Quantum computing, which you forgot to mention, is a very important and powerful technology for the future. Combining A.I with Blockchain and quantum computing can be very powerful but also very dangerous. The Internet is also changing every day, we have web 2.0 and will soon have web 3.0. All these technologies you mentioned as established are changing.

Chloe: All of these emerging technologies require power and bandwidth, you need stronger connectivity to use emerging technologies in comparison to the established. The established technologies actually enable the data for the emerging technologies, somehow the emerging are dependent upon established ones.

Rajendra: First emerging technologies are meant to make the world more efficient and faster. Second, extending intelligence, we have some kind of rational limitation of thinking, these emerging technologies can allow us to know more. Third, emerging technologies introduce judgement aspects we previously couldn't master in terms of technology usage.

Paul Rowney: If you look at the established technologies, web and social media, these engage people globally in the access and exchange of information. The way we used to interact back then and now changed a lot thanks to the development and improvement of technology. We have the possibility of now sharing all the information on the net. I fear that the information might be used against us. Knowing too much about someone can be harmful for the person. Social media and the Internet have empowered people, they have enabled oppressed countries population to access information and share it faster (Arab revolution example), but that in itself doesn't bring global change. Governments are now looking to regulate these technologies. The new technologies, I think the cloud is great. That's how we manage what we do. In Namibia the government look at data sovereignty, they don't want information to escape the country, they want to constrain it at the national level, all the information can go global thanks to the cloud. Data Sovereignty is a big issue within governments in Africa now, which are not interested in the cloud because of this exposure. Government information should not go out of these countries, so putting new regulations is necessary. Emerging technologies will drive us to a new era of technology in developed countries, developing countries are behind, they are not talking about the technology revolution or industrial revolution. There is a fear of the divide between the north and the south. Kenya got an amazing mobile payment system for example.

Nkwah: The second-generation technologies, as I like to call them. Technology will never replace human beings. We need technology governance. Technology needs to be based on governance. Emerging technologies can make human beings even more dependent on

technology. In the medical field, it is possible to be very precise. Technology can be a complement. Post externalities of technologies, it allows us to have control over things we couldn't have before.

Sonja: In development today, a lot of issues can't be addressed with existing technologies. Let me give you an example regarding GIS. Drones allow us to collect better, more reliable and accurate GIS.

The issue now is with data analytics, due to the excessive amount of data that exists. Somebody needs to analyse these images. It is important to train people to use these technologies, a lot of images are captured and need to be analysed. This is where AI comes in, with algorithms that can detect trees that have been damaged for example; instead of humans wasting days analysing 20000 pictures, AI can do it in 1 day. It's all about combining these two groups of technologies. If we don't use emerging technologies we won't be able to correctly address the issues we are facing nowadays both from a development and data points of view (you're shifting the problem of having no data to having excessive data, emerging technologies can play a role here).

Keith: Established technologies are based on interpersonal communications, transmission of messages; the Internet when it started allowed using email, access to data, like a library. Emerging technologies are much more about automation and machines involved, sensors, actuators, process control through these machines. Big Data is rather speculative in terms of data usage, and may present concerns regarding security; good for researchers but represents danger for the general public. The main difference I see is more about the machine communication vs human communication. Most things are based on what comes before.

Prahburaj: There is a difference, the established technologies formed a foundation for any new technology to be created around. Established technologies are enablers of emerging technologies. They should all be integrated and provide powerful tools for the dissemination of information.

Shoshannah: I am in two minds about this: on the one hand, emerging technologies have more power than established in terms of seamless connection. You just exist in a world where everything is connected thanks to the IoT, a connection between reality and virtuality. On the other hand, in order for people to use these technologies for development purposes, people have to have access to Internet, persistent problems with connectivity in rural/urban areas divides developed / developing world. I think there is room to talk more about it_ Internet index, quality and relevance of Internet connection. This is a requirement to effectively use emerging technologies. How many people have access to them, how many really understand how these technologies work; we run the risk of creating the same faultiness that the industrial revolution created.

Helani Galpaia: Yes and No. We are at a point where Internet and GIS have been around for a long time. There is a lot more known things in the established technologies and not so much about emerging technologies. We know the economic impact of mobile phones to a certain extent, the market can work better, people can find jobs faster, we know that disaster warning can be done better and so on. However, we don't know how to scale it up so everyone can have access to it. We know positive things that can come with sensors, AI can do good but also harm. The amount of knowledge and capacity to handle these 2 groups is different. It's about understanding how much they will impact the way we live, our business models. Real world functioning and barriers of Internet usage will be a big discussion, how rules and regulations will be applied to 3d printing products coming from UK and printed in India. Cross-Border collaboration and rules are necessary.

Brahm: We have to have a mix of both. There are a few bottle necks in the technologies and innovations of emerging technologies. If you use established technologies, we are maintaining these technologies and by moving to more advanced technologies such as Blockchain we can assure that ownership is guaranteed to individuals. Also, we can't just jump into the emerging technologies from the established. Definitely emerging technologies are becoming more intelligent in terms of automation and machine learning, which can help do predicting analytics. Dropout of children from school, disaster prevention and mitigation. Big data can help make effective use of that data. They serve as a complement.

Alexandre: Este primeiro grupo (established) é fundamental para criar um ambiente favorável, para que o outro grupo emerging de forma mais robusta e sólida. A Internet da produção, as tecnologias georreferenciadas tiveram um avanço e consolidação grande. Estas tecnologias tão consolidadas nos processos sociais e industriais, havendo consequências positivas e não tão positivas. Cloud Computing habilita muita inovação, a quantidade de sistemas e apps baseadas na nuvem é fantástico, mas isto não quer dizer que estes componentes tecnológicos ofereçam a infra-estrutura e segurança necessários para a sua disseminação. Eu tenho várias coisas inovadoras na nuvem, as questões da cybersecurity são uma das principais preocupações. As empresas que estão a operar neste novo paradigma, para que possam confiar nesta infra-estrutura digital (papel da cybersecurity). Tecnologias consolidadas na medida em que cidadãos, empresas e governo as usam de forma generalizada. Mecanismos de ação diferentes para cada um destes grupos (são uma diferença importante entre estes 2 grupos tecnológicos). As redes sociais tornaram-se universalizadas em diversos países. À medida que se fala em redes sociais, a questão da soberania dos dados pessoais passa a ser uma preocupação corrente, as empresas destas redes tem mais informação sobre um cidadão que o próprio governo, isto traz questões de soberania dos dados, ex do facebook que é quase um país que tem informações sem fronteiras sobre quase todos os países do mundo. Estamos a mover-nos para uma nova infra-estrutura tecnológica. AI já era discutida anteriormente, havia era uma série de limitações práticas. As técnicas de aprendizagem de algoritmos etc, cada vez se está a tornar mais comum. A Internet das coisas começa a ser uma realidade, com carros autónomos, robots utilizando machine learning e estes AI algoritmos, criam-se situações de alta complexidade e níveis de eficiência muito grandes. Este segundo grupo está a iniciar um novo ciclo. Big data, existe uma crença (gosto de chamar dados orgânicos, tudo o que fazemos no mundo digital deixa rastros, foram desenhados, e só existem quando resulta de uma ação ou evento, ou ao contrário de dados administrativos, dados grandes não é necessariamente big data). Big data é o contrário dos dados e informação pré-concebida. Big data é a possibilidade de usar dados e retirar insights relevantes. No contexto do desenvolvimento, existe a crença de que através de monitorizar telefones e redes sociais, pode haver um grande contributo para alcançar os 17 SDGs. O Brasil sofreu da crise da dengue e zika, através de redes sociais as pessoas comunicavam a ocorrência destes eventos, foi então criado um mapa usando dados com os reports que eram partilhados sobre estas pragas nas redes sociais, assim quase é possível em tempo real acompanhar os surtos e pragas de mosquitos. Através de web scrapping, é possível retirar grandes informações. É possível por exemplo acompanhar o acesso dos invisíveis à educação e infra-estrutura social por exemplo, Big Data permite por exemplo entender no contexto das empresas se estas estão a operar no mundo digital e de que forma.

Laerte: Por um lado a grande esperança e por outro grandes preocupações. As emerging, concordo com essa separação, vem demonstrando um potencial enorme em alavancar novos negócios, aumentar produtividade. Nunca tinha pensado sobre isso, mas creio que é um processo semelhante, evolutivo.

Por outro lado (evolutivo vs revolucionário, a Internet foi revolucionária de acordo com várias opiniões), a AI, IoT e Big Data podem trazer uma nova era revolucionária, trazendo outro paradigma.

Marlyn: Using the present Technologies for SD. Leveraging the role of ICTs to achieve the goals. There are differences and a continuation at the same time. Technology is moving beyond just me and the computer, being me and everything around the computer, some form of AI. For any technology there are ethical issues and certain limitations that we need to take into consideration, especially with our experience with past technologies.

3.2- Do established and emerging technologies play the same role in the achievement of the SDGs by 2030? If not, what is the role of each of them? Please provide some practical examples.

Haidar: No, they will not be the same. They are not the same to achieve each of the SDGs. For example, one SDG will be more achievable by established technologies while another SDG will be better addressed by a frontier or new technology. For example, Blockchain is a frontier technology which can help in financial inclusion and so on, while for example Facebook and Paypal are established technologies and they also help financial inclusion. But, for example, Blockchain is for high tech people, for enthusiasts and so on, while the others are not. Basically, I'm finding difficulty in saying that this category of technology helps more than the other. They both help achieve the SDGs.

Tim: No, they are all part of this process to increase this integration between humans and machines. People define them in different ways. What is A.I and Machine Learning, we can have a long discussion about what this is all about, and the IoT, which is a progression of the Internet. You are now just a piece of data. But a very powerful piece of data, which people can sell for another person to exploit. This morning, you think you signed into your laptop but your laptop signed into you.

Jean-Baptise: Established technologies are very well used in western countries (rich countries). Emerging technologies are heavily used in developing and emerging markets. Why? I give you an example, mobile money. We could believe these countries cannot implement them, but I give you an example. You can be in a remote area of Kenya and pay with mobile money. We saw last year in Switzerland a system like this being implemented, why is not being used? We have billions of investment in infrastructure such as ATM and financial systems, which makes it harder to implement and use these emerging technologies in western countries' systems. The least Developed countries can't afford to invest in the banking system, they can't afford to put fiber optics nor heavy and robust infrastructure as the western countries, therefore these emerging technologies are crucial to help them create their digital infrastructure. When we design any technology or app for developing countries, it also works very well in western countries. In developing countries, you face many challenges, access to electricity and energy, connectivity access. When you design an application or service, financial service for example, they are designed in a way that they are robust, they work very well in western countries where there is a well-prepared infrastructure.

Chloe: They aren't the same, established technologies are the building blocks of empowerment, social media, mobile technology, Internet. They enable the emerging technologies and over time, they might end up being equal.

Rajendra: This question is irrelevant, technology is not only for SDGs, it is for other aspects, growth and development are two different things, this is not development, this is growth.

Development entails sustainability. Suppose you produce more and more plastic, this is development, but not sustainable, only growth. Technologies are not meant for Sustainable Development, someone is developing them not for the context of Sustainable Development. People are developing technology for greed and to generate profit and more money. Technology has to be used and applied for Sustainable Development, but initially it is not created for development purposes.

Paul Rowney: They are part of the same technological evolution. The Internet itself opened the world up to the digital revolution we live in today. A.I won't exist without computing power and the importance of people building the foundational blocks of A.I. What can be used for good can be used for bad.

Whatever happens it can be a risk to society, robots are already being built with A.I. I'm scared about the future of my kids. 3D printers are brilliant, you can franchise a design and print it directly from a source, you can then print it on a hospital somewhere. We still need to change.

Nkwah: They play a role, they play the same role, that's why today you have iPhone 4 to X, the goal is the same: to make a call and be on the Internet. The thing is you can't give an iPhone X to someone who has never used iPhone 4. There is a process behind technology usage and implementation. Flexibility is important. With emerging technologies, we can achieve the SDGs faster.

Sonja: We are using the base of established technologies and integrating emerging technologies to make sense of them.

Keith: Slightly different. Established technologies are used to get things going between people and the strategy and policies around these technologies, both are part of that process, but emerging technologies and automated ones might be the ones providing the solutions which will allow us to be more efficient

Prahburaj: They play the same role.

Shoshannah: They have the same role. In terms of capabilities they have different roles, emerging technologies are more sophisticated and can be used for a wider range of purposes. Technology is something we would use to achieve our vision, so yes they are aligned.

Helani: All of these technologies are going to help in the short term to achieve the SDGs. If you talk about jobs, these emerging technologies will change this fundamentally, people will lose jobs, but new ones will arise. Cognitive jobs will prevail. The way jobs are done will change, most countries might not be ready for these changes. If we don't retrain our people to adapt to challenges, how can we achieve income and poverty targets? Thousands of people are employed as electricity workers, the IoT can disrupt this reality, and we know it is coming.

Brahm: With emerging technologies we can achieve higher impact and higher outcomes, if you don't use Blockchain, big data, the IoT we won't make good use of technology, these are the enablers of more advanced technology usage. We have to move to emerging technologies.

Alexandre: Acho que são complementares. Em alguma medida o primeiro grupo está consolidado, mas deixam algumas limitações que levam ao 2º grupo, que poderá resolver alguns destes problemas. Estes 2º grupo ainda irá ser consolidado e irá gerar novas consequências. Mas de uma forma geral, eles servem ambos para alavancar os SDGs em 2030, estas tecnologias vão efectivamente ajudar a alcançar os objectivos.

Laerte: São novas contribuições que não existem. Quando olho para esta lista, deparo-me com coisas que ainda não existem ou estão pouco implementadas. As established já dispõem da infra-estrutura necessária para o seu desenvolvimento. Como suporte a várias das tecnologias emergentes. Infra-estrutura e telecomunicações é a base para poder desenvolver e potencializar do uso das emerging Technologies.

Marlyn: There will always be emerging Technologies, the question is, what will we do with them and how will they be a contribution to SD without being a gimmick, the case of Virtual Reality which I believe having no potential contribution to achieve the SDGs. So, using a technology without doing it just because its cutting edge. It's not about the role of technologies themselves, but it is the role we ourselves attribute to these groups of technologies for Sustainable Development purposes, this is the real challenge and issue.

3.3-Will it be possible to deploy these emerging technologies for development without widening the existing digital divide or will they actually help close it?

Haidar: I think the more spread technologies are, whether they're frontier, established, ICTs... the more it will bridge the Digital Divide, because people, well, they see the value, the added value of new technologies; people are smart, they will go and utilize it. So it's not like we are going to wait until we bridge the digital divide and then we will introduce technology to the people. No, in today's world people hear about things, whether they are in villages, or rural areas, deserts, forests, you name it... and they're quite informed, not necessarily as much as the people who live in metropolitan cities and so on, but the divide is already bridged: maybe 20 years ago it was, let's say, I don't know, 80%, now it is reduced to 10%. So there isn't a serious problem in Digital Divide, it exists but it's not as serious as it used to be 20 years ago. Now will the Digital Divide be a hindrance to the introduction of modern technologies? The answer is no. We should proceed with our technological advancement and its application, and the Digital Divide has a different mechanism of bridging itself.

Tim: The notion of digital divide is problematic for a wide range of reasons. The Digital Divide represents the world system we live in, the rich are rich because the poor are poor, there have to be poor people for others to be rich. Advancing technologies is going to make that worse unless they can make profit from the poorest people. The 1st billion should be connected, which are the poorest and most marginalized and not the rich. The exciting challenge is to develop new business models to enable companies to provide services to the poorest and serve the interests of the poor and most marginalized. We need to go and listen to people on the field and understand their true necessities. Language and conceptualization is at the core of people's empowerment through technology. We have them telling us what they want, not us designing technologies we think they want to reduce the digital divide. We need to go and listen, to actually live in a poor village in the DRC and really see what it is like. There is a problem in technology conceptualization. They must be involved on the process of understanding what technologies they want (poor) and design it based on that premise. We have to understand how to use it to help the poor. The question is, talking about how ICT4d can empower poor and marginalized, this is the type of language we should use rather than bridging the digital divide.

Jean-Baptiste: I am not scared nor concerned. I am not very concerned, because through ICT we have connected billions of people around the world. We will make progress. ICT is there to close the digital divide as well. Figures are not good, but for example you have smartphones, which are decreasing their price constantly.

New challenges arise however, how to actually recharge smartphones if there is a lack of electricity? It will never be perfect, that is not the goal.

Chloe: That really depends on how they are applied, things like AI and the IoT are more easily accessible and more applicable than technologies like VR or Blockchain for example on agriculture. The key issue in this question is how industries are using technologies.

Rajendra: They can help close the divide. The role of International organizations such as the UN is very important. The UN can bring communities together and make them think in an organized way to reduce the digital divide for instance. For example, mobile telephones are everywhere, the gap between developing and developed countries using mobile has been minimized, if we develop in a more sustainable way, the digital divide could be closed, applying programs and initiatives from the ITU which are the same as those of the UN.

Paul Rowney: It won't necessarily widen or close it, won't change it much. The divide is there, in the developing countries if they chose they can't catch up. Transforming societies by educating the youth, it's all about leadership and how it is used in terms of technological education. Technology won't increase or decrease really, unless systems and governments in these countries change. It's a systematic transformation that has to take place. Rwanda and Singapore both had leaders who stayed in power for a long time and followed the change process. Long term leadership (presidents for life) can be a barrier for change. There is not an ecosystem which enables skills to move from a place to another, this could help growth. It's a social, economic and political challenge for developing countries mainly.

You bring technology, you train people to use it and add value somehow, every business is open to this if the value proposition is fair. China and Japan for instance want to move from producing others' products to produce their own products, and Africa are at the bottom, and have to create their own roadmap. It's easy for an African company to subcontract someone from abroad, not using and investing in skills to be developed and taught to people in Africa, this is a limitation for example. If it is difficult to travel from a country to another, that makes everything more difficult, which is what happens in Africa for instance. Smart passports for example are useful, you lose the physical passports and make things easier for travelling purposes.

Nkwah: From what I know, technology to developing countries, we always take second generation technologies. Second generation technologies are costly. You can't jump steps on technological implementation, you can't bring an iPhone x to a place where people can't use an iPhone 4 for instance. We can't talk about second generation technologies without talking about first generation. Developing countries need to start on the first generation technologies and then progress to the second generation technologies.

Sonja: Difficult question. We try to contribute to close it, but the technology in developed countries is going faster. To close the Digital divide, we need investment from governments, they have to take action. For robotics, technology is advancing and advancing. Technology moves so fast that widening issues might emerge due to the fast pace of technology development, implementation and usage. The fact the private sector is profit driven makes the investment difficult and reduces their interest in emerging markets.

Keith: I think they might actually be a contribution to close it. The problem is that you can't just take the technologies from the developed countries and transfer them to developing countries. That is not actually the solution in terms of development. They have labour but not capital to invest. A lot of new technologies are actually much more accessible, if you are going to put in a new water system. To meet the Sustainable Development goals, it is probably more difficult for the developed countries because they have all the over

consumption issues, and its infrastructure and is difficult to change into a sustainable society without collapsing existing infrastructure, which is currently not sustainable. The Digital divide is easier to close in developing countries somehow due to the lack of policy regulation and other infrastructure limitations, you can more easily achieve a sustainable society thanks to these. Heavy infrastructure in developed countries is actually a barrier to close the digital divide and implement new technologies. Developing countries just have to build new infrastructure with the current knowledge we have.

Prahburaj: They will close the Digital Divide, for example, the Internet of things and A.I they enhance the present ICTs technologies, they will help the end user understand things better and also be more user friendly, at least in Agriculture, where the IOT will connect the farm to weather parameters and other things. Present technologies are connected and the solutions which follow will tend to be more easily aligned and integrated.

Shoshannah: This is very much related to the previous question. Whether or not they contribute is going to depend on the infrastructure. Skill requirements will be influential. It's not about the developed and developing countries, it's also about generational issues, elders vs young; elders don't have the skills to use these technologies for instance, that's a divide. The Digital Divide is not only about country level, but also micro level, such as age or gender for example.

Helani: They exist because real world inequalities exist, unless you address both, it is of course either it will get worse or remain. Technologies can however help immensely in closing this Digital Divide. If you use it to fight corruption, provide food, it depends on how we decide to deploy these technologies to close the inequalities.

Brahm: Whether we use established or emerging technologies, the digital divide is altogether a different context, it's not only dependent upon technology, it also depends on policies and laws for example. There have been so many incidents keeping girls away from technology for example. Boys take more degrees for instance than girls despite the changing scenario over the past few years.

Alexandre: Esse é um grande problema, nos países do global South, ainda existe uma exclusão digital muito grande, e que por outro lado pode dificultar a inclusão dessas económicas neste novo paradigma. Mas de alguma forma estas novas tecnologias podem facilitar a inclusão desses excluídos. 4G por exemplo, é uma forma de acelerar essa inclusão, parte, no entanto, do governo, private sector e sociedade civil. Alguns países, como exemplo da república do betão muito interessante. Cada vez a tecnologia está mais disponível e com melhores preços, por si só a tecnologia não irá resolver o, é necessário a intervenção do governo e outros stakeholders no processo de inclusão social. A tecnologia cabeada que é complexa e cara, foi excluída e substituída por redes móveis, e o paradigma nos países em desenvolvimento pode passar por aqui a nível de desenvolvimento tecnológico.

Laerte: Eu não sou muito otimista em relação a isso, as novas tecnologias estão a chegar, precisam de financiamento de recursos, as empresas vão tentar fazer negócio o que é normal. Para os países em desenvolvimento vai ser difícil, não será possível acompanhar, iremos importar soluções que achamos que possam ser boas, é possível desenvolver algumas linhas, mas a nível de desenvolvimento a diferença é muito grande (north and south divide, digital divide). No Brasil por exemplo, estamos a tentar reduzir o Digital Divide através da inclusão dos serviços digitais existentes hoje, além disso, o trabalho na parte da literacia (educação), ajudar as pessoas a usar a Internet e as tecnologias. Muitas pessoas não compreendem nem entendem que benefícios podem alcançar. Vai ser difícil que mesmo tempo que se fecha o digital divide, manter-se minimamente atualizado em relação às emerging technology, vai ser difícil.

Marlyn: They will be a contribution to widen the gap because most developed countries are still not up to date, just look at the statistics, there are 4 billion people not on the Internet. If this is happening, there is a Gap already on technology access and usage. Remember, there is a huge cost associated with any new technology, the infrastructure and the production cost of the technology itself.

3.4- What do you believe is the most eligible group of technologies for Development until 2030 and why?

Haidar: In my judgement they are complementary. We cannot live in a world with only established technologies and we cannot live in a world with only ever-changing technologies.

So we have always new technologies. Some of them will be matured and well established and stay, some of them will come and go. This is the natural flow of things. So, in my judgement, they integrate each other, they complement each other, whether we're talking about individuals, or corporations or the economy.

Tim: All and none. The SDGs are not achievable. They have been designed by UN agencies to give them a role to measure and so on. I was at the mobile world congress. Making the world a better place, but for whom? It's all about creating products to fit rich and powerful needs, and not so much using and creating technology to truly help and focus on the needs of the poor. We need to design technologies on the behalf and for poor people. All this is to facilitate data, maximizing you as a piece of data not you as a human being.

Jean-Baptise: Very simply, emerging ones. The established ones, we couldn't use them to tackle current global issues, so I believe emerging technologies can be our hope for the future

Chloe: I think A.I has the capability to impactfully help achieve the SDGs. Right now, if we propose and deploy the right policy frameworks with caution, it has the power to be the most efficient and effective way to democratize technology for development. Particularly if used by the right people and context. Emerging technologies might give a bigger contribution.

Rajendra: Difficult to say.

Paul Rowney: 3D printer, I love it from an engineering point of view. Hopefully design for Sustainable Development, particularly on health. Big Data and A.I analytics they have been growing in importance in addressing social and economic inequalities in places like Africa, it can help investments to be made and estimated. We don't have information that can be used in favor of the global change process we live in. Infrastructure is also essential to open up the country (in the end, the emerging technologies).

Nkwah: Because you can more easily manage them, firstt generation technologies (established).

Sonja: Anything related to data and AI will make the difference. Acquiring data in a better way and analysing it faster and better with AI. Emerging technologies might provide better outcomes. For instance, robotics help address 8 of the SDGs only with drones. New technologies have to do with data mainly (their role is to analyse, store and use data). Data is one of the key issues and keywords on this topic. It will also help measure the impact of the SDGs.

Keith: The solutions I see are based on IoT solutions with logical processing and logical behaviour, artificial intelligence and therefore emerging technologies.

Prahburaj: Emerging technologies (mentioned the IoT).

Shoshannah: Technologies such as A.I are even more prominent than we realize. We talk about it as a coming thing, but it's already here it's about what it is going to become in the future. I can't tell which one is more important. That will depend on many factors, for instance I live in a developing country, if a hurricane comes all we have is a battery-operated radio, it will be dependent on other factors, climate change, human problems using technology.

Helani: The Internet has been a clear winner, adopted by a large number of people, and brought great improvements. There are so many unknowns about the first group, like how to stop online harrasment. In the first group, mobile and Internet, the second group, the potential is huge, big data for example, we try to understand how poor people live, understand mosquito spreads... these all are recorded from mobile operators. But a lot of these are not at scale. In west Africa people could learn and understand how people move for example. There is a lot more we don't know and need to understand, and there might be great potential benefits, but they are not scalable yet.

Brahm: They help make use of the established technologies, not only in development agencies or NGOs, even in the private sector. If you google it there are so many companies digitally transforming the world. When we talk about identity it's serious. Coordination is important to bring these emerging technologies.

Alexandre: O Segundo grupo tem potencial de causar um impacto maior, falamos do big data, O UN global pulse e a data pop alianca, flow minder que são organizações que usam estas tecnologias para o desenvolvimento. Estas tecnologias do segundo grupo têm um potencial muito grande em ajudar os governos a alcançar os SDGs. O primeiro grupo por exemplo, pegando o O GEO referenciamento por exemplo, cada acção é colectada pelas empresas, e esses dados são posteriormente usados em desenvolvimento de políticas importantes. Os 2 tem coisas importantes, cloud computing é fundamental por exemplo. O poder do Facebook de saber o que você está fazendo, é difícil dizer qual o grupo prioritário, o Blockchain por exemplo é uma tecnologia promissora no processamento de dados e pagamentos por exemplo.

Laerte: As tecnologias do presente, ou established. (argumento suportado em questões anteriores).

Marlyn: I think connectivity is very important, just having access to a computer is a huge closer of the knowledge gap, the worst that I see are Technologies like VR, which are just a gimmick. Established technology from this connectivity point of view might be more relevant to achieve the SDGs. Look at the Arab spring, the very fact of connectivity, access to other people, access to education, there is an issue in the gender gap, but not in all countries, connectivity and access are extremely important to these technologies (established and consequently for the emerging).

3.5- Is there any specific technology you believe to be crucial in achieving the SDGs? Please name it. (You can talk about different technologies and their contributions and role in achieving the SDGs.)

Haidar: Yes, I think the energy technology and the water technology are crucial. In my judgement, Energy technology is N1, Nanotechnology is promising, water technology... but in terms of revolutionizing the world, I think the IoT is the one, because it has impact not only on economics but also on the social well-being of people, as well as the quality of life and welfare of individuals and societies. It's my judgement that new technologies will help, let's

say, minimize conflict and war. Some of the reasons, in my judgement, why people go to war is because they are misinformed or they are ill-informed. So technology, and in particular information technology will help, basically, make people empowered by information, therefore there will be less tendency to war. People will have a reason to understand each other more; furthermore, smart weapons, as much as we hate them, they are still weapons but smarter weapons, they will kill less people because they are, basically, more surgical. We have seen that, here and there... against this is my personal opinion, but in my judgement we have dumb weapons, we have blind rockets, we have, you know, thick-layered atomic bombs, they call it dirty bomb, and we have smart drones and so on... So, again, I think technology will help minimize war damage.

Tim: They can all be used. Blockchain, people tend to confuse it with cryptocurrencies; Blockchain won't solve everything, there are actually other technologies which can solve these same problems. This is a technology to pursue to a role for funding. Everyone is going to say, I can solve that, give me some money. We have moved from ICT4D to D4ICT, which is not the right approach to undertake. Governments support and accept technology organizations to solve their development problems, which they think will be solved, but won't. Civil Society need to pay their stuff and survive and use development to build their ICT empire. This is wrong.

Jean-Baptiste: Blockchain is very promising, if we talk about financial inclusion of course it can help. Blockchain is very secure. Blockchain is just a tool, without political will it will never happen.

Chloe: AI and the IoT at least for the Zero Hunger, No Poverty, think about the use of these technologies in agriculture, precision farming, remote monitoring, and implementation of drones to supervise crops, measure soil and water content, helping farmers with these types of tasks. Nr 12, can be enabled by technology, reducing pesticides, making us think on how to effectively use resources in the right way along with technology. Healthcare, precision medicine, give relevant results about people's diseases and improve diagnosis results.

Rajendra: GIS technology is extremely useful. We are focusing more and more on natural resources, natural conditions, soil conditions, water conditions. GIS provide relevant data to make decisions on resource management. Nanotechnology is also very important, for instance it has existed in nature for thousands of years. The fact a tree can pump water from the ground to the upper parts of the tree is a natural type of technology application, in this case nanotechnology, it existed in nature. I would also say cloud computing to bring people together.

Paul: Information exchange, web 2.0 and Social media. We need to change the way we teach children. We have a professor who doesn't know everything who teaches kids to think they know everything. Peer learning and online education. The biggest change enabler is the openness of knowledge around the world. It's not a lack of ability, it's a lack of opportunity. By enabling the change in the educational system, we can have a revolution in developing countries, which can allow people to enter in the same race as developed countries. Learning tools, virtual tools, interactive learning, cross social media platforms, content and teaching people in their own language. Forcing people to learn things in English for instance and if they don't know English it is a limitation for this process. Technology can help translation to another language and then increase accessibility to these people.

Nkwah: I think the Internet of things, from a developing country's perspective. For me Internet technology can provide access to all others. If I know about nanotechnology I go to the Internet. It gives access and connects things.

Sonja: Data related technology, AI, Big Data.

Keith: Depending on your definition of sustainability, technology will only be marginal in achieving the goals. If we are talking about a society where everything is totally based on renewable resources and doesn't cause any environmental damage, the deployment of technology to achieve such a society is marginal. If you don't have regulations you're not going to be able to do it, to allow for example chemicals to be used and other things. The government makes sure there is no waste, and technology can help these processes become more efficient. It's a bigger problem really. You have different types of growth, you can't just take the wealthy countries' model and change it, that would not be sustainable.

Prahburaj: Technologies should not be looked at individually for their role, they should all be integrated in order to provide meaningful solutions and results.

Shoshannah: I am tending towards saying big data, and also thinking of A.I, we can really have concrete numbers and evidence about different phenomena with Big Data. We have a lot of questions which can be answered through Data, in terms of tracking and anticipating. Data analysis will be even more important on policy and development. AI just for the fact it goes hand in hand with big data, I just see it growing, becoming more and more obvious.

Helani: Each of them has a role to play, either big or small. GIS, the ability of an ecommerce company to find the address of a delivery. We try to make delivery chain efficient thanks to it, each technology has their own roles and impacts. Blockchain, what if the computation costs are broad? We can eventually use it to prove the ownership of a piece of land or the change of ownership. At scale, many of these will have a role to play.

Brahm: Connectivity, the Internet and IoT, connectivity allows the development of infrastructure, bring things together. It is crucial to deploy and apply all the other emerging technologies for example. It helps improve connection between not only people but also things. You cannot implement emerging technologies without good connectivity.

Alexandre: As ICTs, nós na NIC temos a visão de 3 coisas: 1. As tecnologias que permitem o acesso à informação, Internet, web 2.0 & social media, mobile que possibilitam os cidadãos ter acesso à informação e conhecimento e vão tocar nos 17 objectivos e tem um poder enorme no acesso à informação sobre todos os SDGs. 2. Tecnologias específicas para contextos específicos, registo clínico electrónico que pode ser acessado para atender os cidadãos. 3. O uso das tecnologias para a monitorização de cada um dos objectivos, desta forma é possível entender como o programa está a desenvolver-se, ai temos o acesso à informação, aplicações tecnológicas e tic para a monitorização.

Laerte: Sem dúvida a Internet, é uma das cruciais, web 2.0 , redes sociais tenho as minhas dúvidas. Tecnologias móveis. Quando eu olho as estabelecidas, de um modo geral são todas importantíssimas. Os resultados das emerging só agora começam a surgir, com IoT é possível aumentar produtividade de culturas, e isso vai influenciar a reeducação da fome, mas isso não aconteceu ainda, essa promessa ainda não foi alcançada, por isso fico mais ligado às estabelecidas. As preocupações das emerging como privacidade, protecção de dados, estas tecnologias podem levar-nos a uma evolução que não imaginamos hoje, Big Data e inteligência artificial.

Marlyn: Connectivity related Technologies are going to give us the majority of these SDGs. It doesn't depend only on civil society (I see from this point of view), it depends on governments. Access is very important and should give us connectivity. If I want to do a campaign for sanitation, I can do it without the Internet, but I can do it even better with the Internet.

3.6- Did I miss any relevant technology in my research? In which areas would it be interesting to have technologies developed with the SDGs in mind or what technologies which are not addressed should be included?

Haidar: No, no, that's pretty much all of it, but maybe instead of saying GIS we might say, let's call it the peaceful use of outer space, of outer space technologies. GIS is only one application of them.

I think all of them, with varying degrees; for instance technology is very important for goal 1, and 2; they are quite important for the goal of health and education; they are of mild importance for goal 5, women issues; they're very important for industrialization and employment and so on.... But I cannot find a particular goal where technology will not be instrumental.

Tim: Different answers to it. Much of the problem is due to neo-liberalism. Giving power to the private sector, that's what governments do, they think they can solve their problems better than they do. They don't focus on the poor and most marginalized. Only governments theoretically have responsibility for all their citizens. Don't expect the private sector to do all the job, they are looking after profit, which is fine. Don't expect them to serve the poor and most marginalized, we have to give more power back to Governments and international organizations, only governments theoretically have responsibility for their citizens. Governments can't do everything, that's where regulators come in, to regulate in favour of the poor. Look at the different regulatory environment between the US and Europe, there is an increased tension between them due to different interests. Even in research, the most human centred design, it's all about creating test pilots and lab tests they think are great, but those things serve only the rich instead of collecting information from the poor to design and innovate on technologies. Using partnerships effectively is not happening on the behalf of the poor and most marginalized.

We need more efficiency in mitigating the dark side and outcomes of these technologies, child abuse, violence for example which are extremely horrendous, most people don't understand how dark it is. SDGs are going to fail, they failed already.

Jean-Baptise: Quantum Computing, Blockchain will be able to access and help achieve different goals. Blockchain is here to empower solutions we already have and to take what we have in terms of banking and financial systems to the next level. Today there are other technologies also. Mobile infrastructure is also changing through technology, other technologies will benefit from ICTs, there are only 2 start-ups that produce diamonds using laser beam producing much purer diamonds, built at the atomic level. It will help direct telecommunications, it can transfer far more energy without heating issues and achieve telecommunication infrastructure like never before.

Chloe: Connectivity, with the right tools, guidance and people can be an enabler for development. For instance, the introduction and use of social media namely Facebook, people tend to be stuck inside Facebook, as it is the Internet, but it's not, there is much more on the Internet than Facebook. Knowing the right things to connect to, namely for goals number 5 and 10, because having access to Internet is not synonym of empowerment. FB for instance doesn't have the power for enabling education and accessibility such as the Internet itself for example. Empowerment of women and girls access Facebook, they like posting and sharing their experiences but there are so many other tools people could be using such as education programs, YouTube channels and other online tools to provide the right tools and knowledge

to actively contribute to others and really empower people to fight for their purposes and goals.

Rajendra: We are forgetting a traditional technology, based on traditional knowledge which is accumulated throughout the years, these are the technologies from traditional knowledge extracted from the observation of nature. Humans have copied a lot of technological applications from nature, biomimicry. We are starting to neglect nature, and we should rely more on nature to develop technologies. Partnerships are very important, see the goal 17, the goal is to leave no one behind, if you want to do this, partnerships are crucial. For instance, Apple and Microsoft need partnerships with business and agricultures or countries need partnerships between them. Achieving the SDGs is one thing, but leaving no one behind is another, that's why goal 17 is so important. Cloud Networking is crucial to connect and enable this partnership.

Paul: Dynamic Spectrum Location. We are allowing spectrum operations, this will enable 5g. We never will bridge the next 4 billion utilizing 5g. What it does is you need to give the spectrum to some people and you allow them to access it with a license. It allows Internet access on a local level. The industry wants to implement the 5g, but that might not be the solution to close the digital divide. Mobile operators don't want it, and governments allow it because they pay. It is necessary to have more technologies for communication. Otherwise there are only 3 worldwide providers of these services, which limits the entire world to it. Without wifi the Internet would not be what it is today, if people had to pay daily for what they used online. It's a human problem, we got brilliant technologies that can change the world, however it is not happening, and it is not a money issue. Problem is at management and execution level, blockers should be removed from governments, civil society or private sector, people should embrace and accept change, and it will only happen if this foundational/root issue of management/operational level is changed.

Nkwah: Technology which has to do with agriculture could be improved, one of the SDGs is to end hunger, then agriculture is a crucial goal where technologies should be more and more used, innovated and implemented.

Sonja: Decent growth and economic growth, a lot of different initiatives work on this. To create economies out of new technologies, you can create new markets in developing countries thanks to drones or other technologies. There is a market for that. Technology has the power to create new markets, new jobs. Economic growth must come out of technology, I personally believe this.

Keith: Don't think you missed any.

Prahburaj: No, I don't think so. IoT and A.I, Nanotechnology, so they have to be integrated these new technologies.

Shoshannah: Machine Learning, I like the idea behind Blockchain which is about cryptocurrencies, it can be deployed for many different purposes, I'm just curious to know more about this technology and its payment solutions, which is a common problem in the developing world. I think we have learnt to use technology for convenience, but as humankind we have not yet found its purpose for overall satisfaction. How can these tools really be deployed for personal satisfaction, and will it impact how we will push our future? How can these tools really be deployed for personal satisfaction is the question we should be asking ourselves.

Helani: A lot of technologies used for commercial purposes can be used for development. Think about their role for it. People are making use of our data to sell more and reach customers better and more efficiently, now imagine technologies applied to inequalities and

where they live or to provide credit. Initially technology will reach developed countries, rich people and mainly male. If it can be used to address development purposes in their contexts is the challenge, we face currently.

Brahm: It has been represented as an accelerator (technology), the problem is the implementation. Technology sometimes proves to be not the best solution to solve the SDGs. For example, the online safety of the children, you can't do it without stakeholder alignment. The private sector plays a major role in making use the emerging technologies for social good, and implement an algorithm itself which will recognize the type of user for example. It is hard to however implement this due to lack of coordination. SDGs have identified the use of technology in achieving different goals, however it cannot be achieved without a proper coordination, partnership and addressment of different components which might contribute to these issues at country level. Bring this to education system, good health, provide employment opportunities. I believe all important technologies were addressed.

Alexandre: Os 2 grupos foram mapeados de forma efetiva no que diz respeito às tecnologias abordadas. Agricultura e automação tecnológica na produção agrícola é fantástico, é possível monitorizar a qualidade do terreno, presença de agentes químicos. A biotecnologia tá muito avançada, a área de segurança também (contexto do brasil), educação, saúde precisa de um maior uso das tecnologias para ajudar a avançar estes sectores.

Laerte: Não acho que falte ser mencionada nenhuma. Basicamente estas tecnologias estão associadas às ICTs, eu acho que elas representam um eixo importantíssimo, mas não são o único eixo, existem outras tecnologias que não só as ICTs que complementam aqui. Nesse fórum, eu acho que existe um esforço grande de associar os SDGs com as tecnologias. Mas acho que outras contribuições vêm de outros sectores também, completando aquilo que pode ser o contributo trazido por este modelo. Não deve ser forçada uma visão artificial daquilo que é o papel das tecnologias para alcançar os SDGs, outros sectores poderão ser também importantes.

Marlyn: I have a bias toward poverty, which means, I always feel not much is done to truly reduce poverty, while I believe in the role of technology to alleviate poverty, I also believe in very tangible, physical things happening to people living in poverty.

Look at Bill Gates, his foundation doesn't work only on technology, it attempts to bring different types of technologies to African countries, he is the man of technology, yet he doesn't use VR or robotics, any of these, to go and help the health and well-being of people around the world. All of these are achievable without ICTs but ICTs should always be present and have a strong role in it. When I say I'm doing robotics because I love a drone, and I create an organization for drones, what are you going to do with the drones? This is a fantastic technology, not a gimmick, but when I say I want to use VR to create empathy, and that's trying to twist technology, and it should come and be used naturally. I think you covered most of them pretty much.

4.4- RESULTS

The first part of the study focused on the more general topic of Technology for Development, namely on what the role of Technology might be in achieving Human Sustainable Development and what the role of Development Agents and Global Leaders is in leveraging it:

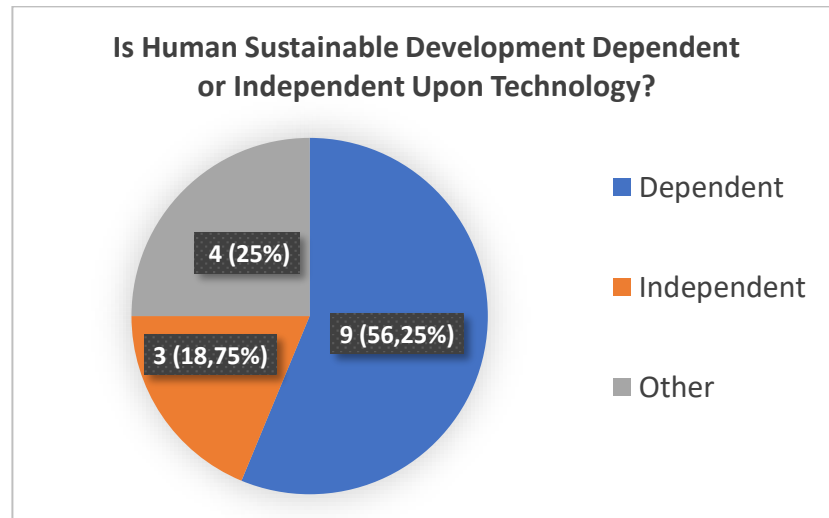


Figure 14 - Results: Human Sustainable Development dependency on Technology.

Nine experts believe that Human Sustainable Development is dependent upon technology. Three participants believe its achievement is not dependent on technology, while the remaining four (4) offered a more nuanced point of view and approach in answering the question: the two main arguments given were that (1) development can be enabled by technology without being fully dependent on it and (2) in the form of a criticism to the viability of the SDGs programme, which will be further addressed in the discussion section of this study.

According to the experts, the following variables are crucial to the successful achievement of Human Sustainable Development such as:

- ❖ Diverting resources and national budgets for Sustainable Development purposes;
- ❖ Reducing inequalities;
- ❖ Collaborating and partnering with stakeholders;
- ❖ Personal behaviour and the ability to learn from past experiences;
- ❖ National ownership and agenda alignment between International Organizations and National Governments;
- ❖ Governance and access to education;

- ❖ Understanding the needs at the local level;
- ❖ Having a Sustainable Development approach in businesses;
- ❖ Technology and education for all;
- ❖ Capacity for critical thinking and developing digital literacy skills;
- ❖ Creating the right incentives and assertive policies;
- ❖ SDGs implementation and monitoring guidance;
- ❖ Taking action.

When exposed to the question “what might the main role of Technology be in achieving the Sustainable Development Goals by 2030?”, the following answers were given:

- ❖ It is an enabler and connector of problems to solutions for Sustainable Development;
- ❖ It has the role of empowering the economy, education, and equal access;
- ❖ It has the role of improving efficiency and timeliness in achieving the SDGs;
- ❖ It plays the role of a facilitator and mediator of the development process;
- ❖ It has the role of an accelerator, providing services faster and at a more accessible price;
- ❖ It helps make the usage of resources more efficient;
- ❖ Technology has to be accessible, understandable and usable for development;
- ❖ Technology should not look how we want it to look like, but instead reflect the world we want, how we define Sustainable Development and how we use technology for this purpose;
- ❖ Technology helps make use and sense of the large amount of data produced every day, for development purposes;
- ❖ Technology enables the inclusion and makes it possible and easier to achieve the SDGs
- ❖ Technology currently has the role of enhancing economic growth rather than reducing poverty.

According to the study participants, the main challenges and issues faced by development agents and global leaders in their quest to leverage technology for Sustainable Development are:

1. The alignment of global agenda with nation-specific priorities. For instance, in a certain country, X, a specific technology can play an important role for development purposes, which might not happen in country Y, with different social, economic, and environmental contexts. Therefore, technology development, commercialization, and use must account for these specific characteristics and local needs;
2. Correctly understanding and applying the Information and Communication Technologies for Development (ICT4D).
3. Over the past years the massification of technology production, dissemination and use are making the concept of ICT4D blurred, with it increasingly becoming Development for ICTs (D4ICT) – which doesn't have human Sustainable Development at its core, but rather commercial purposes and interests, meaning that far too often the private sector, governments and civil society are using the concept of development to further their ICT interests while it should be the other way around. ICT4D entails the production and use of technology to truly serve the interests of the poor, minorities and marginalized, therefore reducing poverty and inequalities;
Sustainable Development
4. Creating the right incentives and ecosystem around science, technology and innovation (by enabling, for example, free and open access to information on a global scale, or by introducing policies that attract and allow businesses to give their contribution in leveraging technology for Sustainable Development), while fostering an environment of trust among stakeholders of different social sectors through the use of regulatory and governance best practices to ensure fair competition in the technological sector;
5. Creating a balanced regulatory environment while at the same time addressing security management (cybersecurity) and the capacity building issue is necessary to make legislation and regulation work for both digital and technological markets.

Finally, according to the results, different roles could be identified for each society sector represented in the study as far as their ability to help solve the aforementioned challenges:

International Organizations/NGOs:

- ❖ The United Nations should spread the best practices worldwide regarding how technology can be deployed to achieve the SDGs;

NGOs have the role of conducting research at the local level and engaging locally with the communities.

Governments:

- ❖ Employing technology, science, and innovation to help society achieve better outcomes;
- ❖ Empowering communities and creating an innovation ecosystem for entrepreneurs to develop new meaningful technologies, which will have a positive impact on people's lives;
- ❖ Creating incentive policies and encourage people to take action, changing mentalities and behaviours through funding and collaborative initiatives within society;
- ❖ Regulating markets and their competition by cutting down unnecessary expenses, increasing investment and offering services at lower prices, while enforcing fair **taxes to the private sector** and enabling the creation of new businesses with sustainable models;
- ❖ Fostering inclusion through technological innovation and providing access to affordable and modern technology tools, mainly in developing countries.

Private Sector:

- ❖ Collaborating and engaging with governments for development purposes;
- ❖ Providing emerging markets with new alternatives and solutions to achieve the SDGs, not only the developed countries;

Academia:

- ❖ Preparing future leaders for Sustainable Development;
- ❖ Giving young minds the know-how, skills, and tools to achieve the SDGs.

Civil Society:

- ❖ Cooperating with other sectors in addressing local challenges;
- ❖ Giving voice to the poor and most marginalized.

The second part of the study had the purpose of validating the reference model linking the specific Established and Emerging Technologies to each SDG. The following results were obtained:

What are the main differences between the established and emerging technologies?

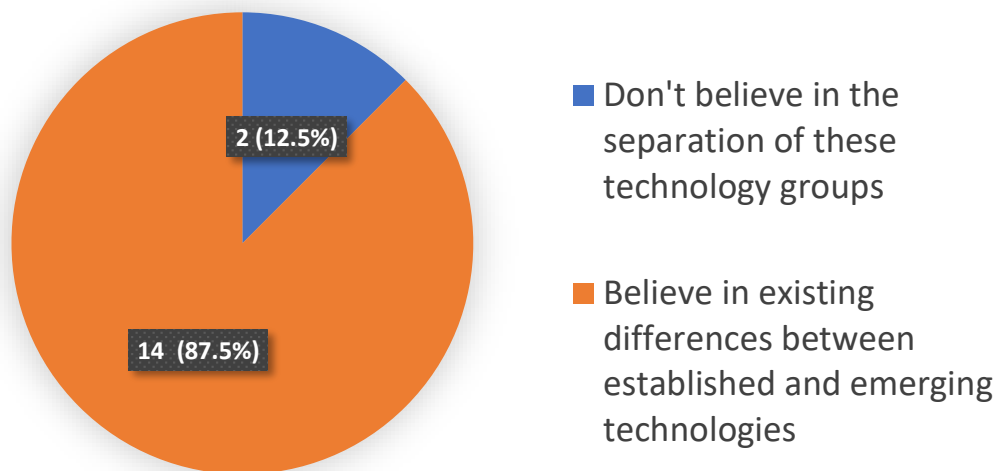


Figure 15 - The existence or not of differences between established and emerging technologies.

The main differences identified by the experts were:

- ❖ Despite being different, established technologies are also evolving; those that are not will soon become obsolete;
- ❖ Emerging technologies require much more power, bandwidth and connectivity;
- ❖ Emerging technologies are dependent upon established technologies;
- ❖ Established technologies are enablers of emerging technologies.
- ❖ Established technologies, mainly web 2.0 and Social media, engage people globally in the access and exchange of information;
- ❖ New technologies can bring a new level of exposure and access to information, which brings new challenges such as data sovereignty issues and related regulatory policies, mainly in developing countries;
- ❖ Emerging technologies can make humans even more dependent upon technology, thus making technology governance necessary;
- ❖ The progress of emerging technologies will allow us to control things that we couldn't before;

- ❖ Established technologies are about interpersonal communication, while emerging technologies are much more about automation. The main difference is essentially machine communication vs human communication.
- ❖ Human Communication (established technologies) Vs Machine Communication (emerging technologies);
- ❖ Emerging technologies are more powerful than established ones in terms of seamless connection;
- ❖ The amount of knowledge and information that exists in regard to established and emerging technologies is different;
- ❖ By using established technologies, we are maintaining these technologies and by moving on to more advanced technologies such as Blockchain we can assure that ownership is guaranteed to individuals.
- ❖ Emerging technologies are becoming increasingly intelligent in terms of automation and machine learning, which can help do predicting analytics.
- ❖ The infrastructure needed for each of these groups is different;
- ❖ Emerging technologies can increase productivity;
- ❖ Technology is moving beyond human-computer relationship to everything around the computer;

When asked the question: “Do established and emerging technologies play the same role in the achievement of the SDGs by 2030?”, the following results were obtained:

Do established and emerging technologies play the same role in the achievement of the SDGs in 2030?

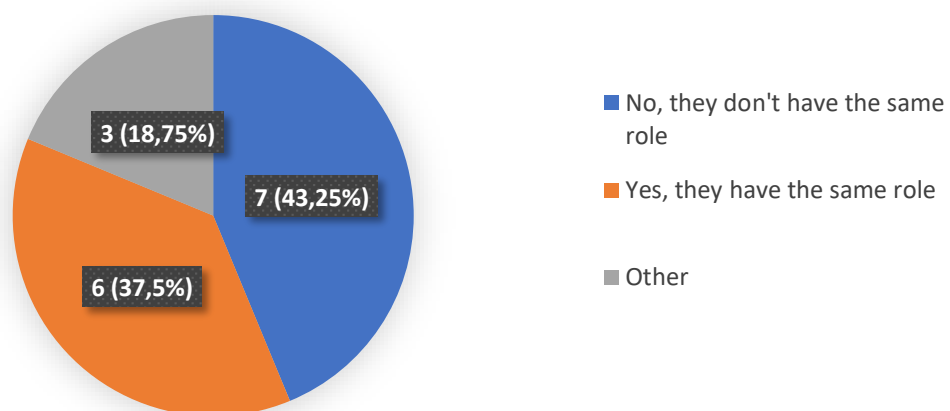


Figure 16 - The role of established and emerging technologies in achieving the SDGs.

The arguments given for the No answers were:

- ❖ Technologies have different purposes, usage and complexity levels, therefore technologies such as PayPal or Blockchain, despite both being used to improve financial inclusion, have different roles to play.
- ❖ Established technologies have the role of connecting people and facilitating global communication, while emerging and automated technologies might provide the solutions which will allow us to be more efficient.
- ❖ They have different capabilities; in general, emerging technologies are more sophisticated and can be used for a wider range of purposes.
- ❖ When it comes to the job market, emerging technologies might bring even bigger challenges regarding automation of tasks and job replacement.
- ❖ Established technologies are very widely used in western countries. Emerging technologies are heavily used in developing and emerging markets;
- ❖ Emerging technologies will bring contributions which do not yet exist. Established technologies have already got the necessary infrastructure for their development and deployment, and also serve as a support for emerging technologies.

The given arguments for the Yes answers were:

- ❖ They are part of the same process of increasing human-machine integration;
- ❖ They are part of the same technological evolution and development process. The Internet itself opened the world up to the digital revolution we are currently experiencing;
- ❖ Technology should be used and aligned with human vision to achieve its goals.

Experts who didn't directly answer Yes/No and gave other arguments:

- ❖ Creating and using technologies should not be based on the fact they are cutting edge, but instead on their contributions and potential for development;
- ❖ The base of the established technologies is being integrated on emerging technologies to make sense of them.
- ❖ Technology is not initially designed and created for development purposes;

The digital divide is one of the main topics of concern among the International Community; based on this fact, the following question was asked to the field experts on Development and Technology:

Will Emerging Technologies Help Close or Widen The Digital Divide?

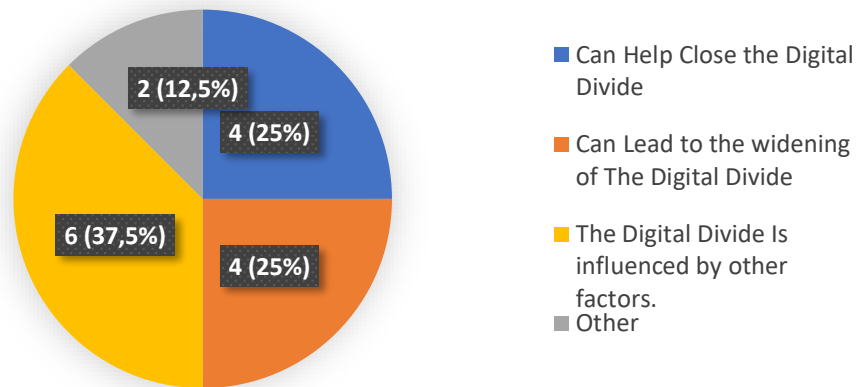


Figure 17 - Emerging Technologies impact on the Digital Divide.

The arguments given by the experts who believe emerging technologies can help close the digital divide were:

- ❖ The more spread technologies are, the more it will bridge the Digital Divide.
- ❖ The digital divide has its own mechanism of bridging itself.
- ❖ The role of International organizations such as the UN is very important in bringing communities together and making them think in an organized way to reduce the digital divide;
- ❖ Emerging technologies can enhance established ones. In Agriculture for example, the IoT connects the farm to weather parameters and other important information. Established technologies are increasingly becoming interconnected and the solutions they provide will tend to be more easily integrated.

Those who believe emerging technologies can widen the digital divide argued:

- ❖ Technology in developed countries is advancing faster. To close the Digital divide, investment and action from governments is necessary. The widening of the gap might occur due to the fast pace of technology development, implementation and usage. The fact that the private sector is profit-driven makes it difficult to see much investment in emerging markets on their behalf;
- ❖ Developing countries will find it difficult to keep the pace of development; they might tend to import relevant technology tools but from a development point of view there will still be a gap;

- ❖ There are still nearly 4 billion people who do not have access to the Internet, mainly in Developing countries. There is a huge cost associated with any new technology, the infrastructure and the production cost of the technology itself.

The main arguments given by those who believe the digital divide is influenced by other factors were:

- ❖ The Digital Divide represents the world system we live in. Governments and private sector together should be trying to find new ways and new business models that can provide services to the poor and most marginalized;
- ❖ Systems and Governments in these countries are the ones responsible for closing the divide. Transforming societies by educating the youth is all about what leaders do to incorporate digital skills and technology into education;
- ❖ Whether or not they contribute is going to depend on the existing infrastructure. Skill requirements will also be influential; the digital divide is not only about global and national level issues, it is also about micro issues such as for example elders vs youth -a lot of older people don't have the skills to use these technologies;
- ❖ It is not only dependent upon technology, it also depends on policy and laws, which are responsible for safety and security of information.

Other answers:

- ❖ The Digital Divide should not be a main concern because through ICTs have already connected billions of people around the world;
- ❖ For instance, as far as agriculture is concerned, technologies like AI and the IoT are more easily accessible and more applicable than technologies like VR or Blockchain; one of the most relevant issues regarding this topic is how industries are using technology.

What is then, according to these experts, the most crucial group of technologies for Development until 2030?

What is The Most Eligible Group of Technologies for Development until 2030?

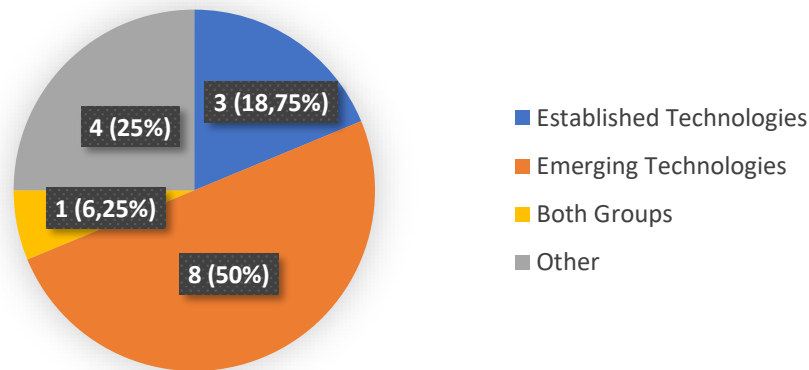


Figure 18 - The most eligible group of technologies for Development until 2030

Arguments in favor of established technologies as the most crucial group of technologies for development:

- ❖ Ease of management and use;
- ❖ Connectivity is crucial, therefore having access to a computer itself is already a huge step to closing of the knowledge Gap;
- ❖ Technologies that promote inclusion – as is the case with established technologies - might have higher potential for Development purposes.

Arguments in favor of emerging technologies as the most crucial group of technologies for development:

- ❖ It is not possible to tackle present global issues with only established technologies;
- ❖ A.I has the capability to help achieve the SDGs. However, deploying the right policy frameworks might be the most efficient and effective way to democratize technology for development;
- ❖ 3D printing, Big data and A.I have grown in importance when it comes to addressing social and economic inequalities in Africa. These technologies can help investments to be made and estimated;
- ❖ Data plays a crucial role, and emerging technologies which directly use and are based on it will be crucial to help measure the impact of the SDGs. By improving data gathering and analysis, A.I can have a huge impact on Development;
- ❖ The solutions identified are based on IoT solutions with logical processing and behaviour as well as artificial intelligence - therefore emerging technologies;

- ❖ Emerging technologies help make use of established technologies, not only in development agencies or NGOs, but even in the private sector;

Arguments in favor of both technology groups:

- ❖ They are complementary. One of them isn't more important than the other. The flow of technology relevance, usage and diffusion across users will determine if a certain technology will be considered an established or emerging technology, or simply become obsolete;
- ❖ Technologies from the first group are more linked to data generation and the technologies from the second group are more linked to the usage and transformation of data into relevant information.

Other answers:

- ❖ The SDGs are not achievable, and technology is designed for the rich above all, only when its design is focused on the poor and most marginalized may it have use and purpose for development;
- ❖ The specific answer to this question has to do with such diverse as factors context, country, tools used, human usage and skills to use technology for example;

The experts were then asked: “what specific technology do you believe to be most crucial in achieving the SDGs?”

The table below lists the relevant technologies and their main features according to the study participants:

Technology	Arguments in favor
IOT	<ul style="list-style-type: none"> - Has the potential to influence economy and the welfare of individuals and societies; - Can be implemented for precision farming and remote monitoring, as well as measure soil and water conditions; - Can have bigger impact in Developing Countries.
Nanotechnology	<ul style="list-style-type: none"> - Has existed in form of nature for thousands of years;
Web 2.0 and Social Media	<ul style="list-style-type: none"> - It allows rapid and efficient information exchange;
Mobile	<ul style="list-style-type: none"> - Connectivity Enabler;
A.I	<ul style="list-style-type: none"> - Precision Medicine Enabler such as helping with diagnosis;

Internet	<ul style="list-style-type: none"> - Can enable all the other technologies; - Connectivity Enabler;
Blockchain	<ul style="list-style-type: none"> - Digital Security Enabler; - Helps Financial Inclusion; - Proves ownership of land;
GIS	<ul style="list-style-type: none"> - Crucial in helping decision-makers use and manage resources; - Measuring natural, soil and water conditions; - Helps distribution chains be more efficient;
3D Printer	<ul style="list-style-type: none"> - Can revolutionize production processes;
Big Data	<ul style="list-style-type: none"> - Crucial in helping make sense of data and use it meaningfully to help decision-makers;
Cloud Computing	<ul style="list-style-type: none"> - Brings people together; - Makes collaboration easier;
All of them	<ul style="list-style-type: none"> - Technologies don't simply exist in and of themselves, they should be integrated;
Other	<ul style="list-style-type: none"> - Technology will only play a marginal role in achieving the goals; - Regulation is crucial for technology to be enabled and help achieve the SDGs;

Table 4 – Relevant addressed technologies features by the experts

Finally, in the last stage of the study, the experts were asked which other technologies could have been addressed in the model, the answers were the following:

What Technologies might Have Missed in the study?

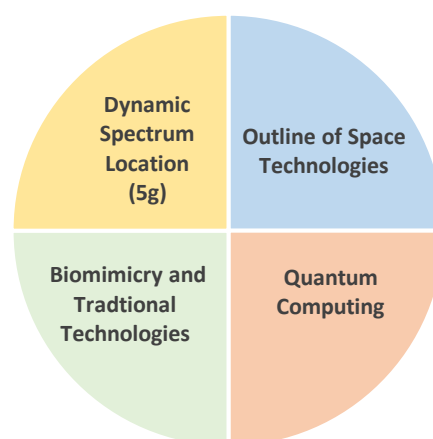


Figure 19 - Other relevant emerging technologies not addressed in the study.

4.5- DISCUSSION

The present discussion is divided into two main sections, which reflect the research process undertaken:

1. The first section is dedicated to addressing the general topic of technology's role in achieving Sustainable Development, and the role of Development Agents and Global Leaders in leveraging it;
2. The second part of the discussion specifically addresses the role of established and emerging technologies in achieving the SDGs according to the model validation results and the reviewed literature.

4.5.1- Leveraging technology for Sustainable Development: The role of Development Agents and Global Leaders

A new age of Information has arisen; according to Dzidonu (2010) technology is increasingly becoming a major tool to transform economies and increase the living standards of nations, while creating new opportunities and challenges for humankind and the environment. A Global call-to-action has urged only nations but also entities from every sector to collaborate and discuss the role of technology in achieving Sustainable Development (“We are at a historic crossroads, and the directions we take will determine whether we will succeed or fail on our promises”) (United Nations, 2014, pp.3).

Based on this transition moment from the MDGs to the SDGs, and in a crucial moment to reflect on the next steps to be taken, this first part of the study addresses what the role of Technology might be in achieving Human Sustainable Development and how Development Agents and Global Leaders can effectively use it.

The current globalized world we live in reflects what technology has enabled in recent years. Technology is now an integral part of most human activities as we know them, and it affects our everyday lives. Neither the Millennium Development Goals (MDGs) nor presently the SDGs could be achievable without the contribution of science, technology, and innovation (Ely, Zwanenberg, and Stirling, 2011). This is also the opinion of more than half of the study experts, who believe human Sustainable Development to be dependent on technology. The main arguments given were that despite the known merits of technology in this context, there are other ways to achieve the SDGs such as educating people for sustainability and having the

right mindset not to allow technology to become the end of development itself. Also, the participants emphasized the importance of defining Sustainable Development and its purpose, and then putting it into practice through proper regulation and policies.

As an example: the “eco-social policies”, which stipulate that economic growth from a sustainability point of view must also be “green”, allow for the creation of employment and reduction of environmental damage by shifting behaviors or providing the right incentives for a sustainable management of resources and adaptive capacities of individuals and communities (UNRSID, 2017).

Technology can be a tool and enabler for development without development being fully dependent on it. According to one of the experts, the discussion around the SDGs goes deeper to its founding roots, purpose and programme architecture, which from the start might have compromised any achievement of the SDGs. Different factors can help address this point of view, ranging from the transparency of the international funding addressed by Denney (2012), the fact it was a top-down exercise and left out many countries in the process, namely in Africa, which was covered in detail by Transparency International (2012) and Easterly (2009), or the lack of alignment between international and national level goals, as mentioned by McArthur and Rasmussen (2017). Despite the improvement on some of these limitations in the transition to the SDGs, there still remains among skeptics the opinion that not enough is actually being done to truly bring extreme poverty and world hunger to an end or to reduce inequalities, goals which are at the core of the SDGs.

According to Asah (2015) there are inconsistencies in the architecture of the Development Agenda and its guiding principles such as the different conceptualizations and viewpoints on what Sustainable Development entails (which, according to Du Pisani (2006), has been the case throughout history) and the higher relevance given to western worldviews and constructs of the Sustainable Development concept than to the issues and debates around the social, economic and environmental needs of the so-called Global South.

Only one study participant actually believes that Human Sustainable Development is only dependent upon technology to a certain degree. If each goal is considered individually, it can be inferred that: some goals do actually have technology development and access as targets (such as goal 8 during the MDGs and now Goal 9 in the SDGs), some goals can actually have better outcomes with the help of technology such as for example goals 3, 4, 5, 9, 11 and 13, which were chosen for a Huawei (2017) SDGs Benchmark for having targets strongly connected to ICTs, while other goals might not necessarily need, be so dependent or

connected to the use of technology for their achievement. This is a rather complex and multi-dimensional issue because the achievement of each goal might be dependent on many different variables such as geographic location, country level needs, infrastructure, resource allocation, policy, technology access, governance, education or societal and environmental context, to name some of crucial variables for Sustainable Development addressed by the experts. These elements should be considered when prioritizing the SDGs according to each national agenda priority.

These variables for Sustainable Development can be overviewed and organized in three different but complementary levels: International, National, and Subnational or Local level.

Starting with the International and National level, many changes are currently taking place in regard to the SDGs programme and its different Development dimensions, for which the best practices for financing and resource management are being addressed by the United Nations agencies and partners.

For instance, the Intergovernmental Committee of Experts on Sustainable Development Financing created in the context of the post-2015 agenda a document which focuses on trying to create a financial strategy to help mobilize resources and their effective use to achieve the SDGs (United Nations, 2014a). This document brings forward some of the previously addressed challenges and limitations faced by the MDGs in this regard. From a strategic point of view, country ownership, leadership, and a supportive international environment is crucial for an effective mobilization of resources according to the United Nations (2014a). Each country must be responsible for its own Development while the international community's role is to provide the necessary support and an enabling environment; this will then lead to a second stage, where government policies are at the core of a robust SD financing strategy. These public policies will, in turn, allow all the other sectors to operate within this framework guided and strengthened by effective policymaking and its resulting policies, transparency, accountability and good governance (United Nations, 2014a). This way, synergies can be maximized between financing streams such as private and public finance - and their respective investment decisions – and the creation of new mechanisms and instruments at the national level to give answer to social needs, and public goods investment across all three dimensions of Sustainable Development (United Nations 2014a) Sustainable Development

While the alignment at the international and national levels crucial, no action can be truly undertaken towards the achievement of the SDGs without “our ability to make them a reality in our cities and regions” (UNDP & UNH, 2016, pp.6).

According to the UNDP and UNH (2016), the success of the SDGs initiatives is dependent on the extent to which the international community and national governments will enable, prepare and support the “localization” of its activities such as: raising awareness, implementing and monitoring the SDGs while engaging multi-stakeholders and encouraging citizens to participate actively in the SDGs.

Understanding local level needs and empowering local communities by providing them with the necessary tools, such as education and the 21st-century skills, will allow societies to be more ready to face not only local but also global challenges in the future (Filho, Mifsud & Pace, 2018).

According to Filho et al. (2018), education is a key variable in the Sustainable Development process, however, it applies not only to youth, but also to adult education and its role in reshaping the system as we know it today and replace old models and practices with lifelong learning perspectives and approaches of education for sustainability.

Sustainable Development This new 21st-century paradigm for educational change entails not only formal education but also non-formal and informal education. The European Council (2006) created a recommendation on key competencies for lifelong learning, which then started to be used and implemented by governments, from learning foreign languages and developing digital competencies to developing a sense of initiative, entrepreneurial spirit, cultural awareness, and expression. (Filho et al., 2018).

As an example, open access to data and information combined with online courses can provide free and accessible education for all, and is, according to the World Bank (2015), a means to help governments take decisions that truly reach the poor and most marginalized.

Education itself is a catalyst for development, which according to UNESCO (2015) was recognized as not only an end in itself but also a means to achieve the global development agenda goals; education helps strengthen the notion that SD is only possible through comprehensive cross-sector efforts, and only then will it be possible to unlock its transformative power within countries.

The alignment of International, National and Local levels, combined with the lifelong learning approach to education for Sustainable Development and the effective contribution of each one of the society sectors (International Organizations/NGOs, Governments, Private-Sector, Academia and Civil Society) can help pave the way to dignity and the subsequent achievement of the Sustainable Development Goals.

Technology has changed society, economy, and the environment, and has played a crucial role in the transformation that the planet has experienced in the last decades. On the one hand, the promise of science-based technology and innovation offers a new hope for a sustainable world without poverty and inequalities, on the other hand the use of technology to sustain the consumerism of resources and the capitalist system demand for a continuous production of wealth and growth (Vergragt, 2006).

Despite the technological progress undertaken over these past few years, namely in the field of Development, "a related painful paradox is that despite the ongoing technological revolution the majority of the world population still lives in abject poverty" (Vergragt, 2006, pp.1). This reality is in part based on the premise that development is a process of structural changes that will require a series of historic steps that the developing nations have to follow in order to reach the present levels of mass consumption of the developed world (Brito, 2014; mentioned in Hazboun, 2014). While technology has been recognized by the 2030 agenda as an important means for implementing the SGSs according to the UNDP (2017), technology has not yet been sufficiently addressed regarding its conception, creation and implementation for development purposes as well as who should be responsible for it (Vergragt, 2006).

For instance, and focusing on technological forecasting, which is itself considered a scientific discipline, its purposes and uses focus much more on the technological development itself and the profits it might generate than on the functions that may fulfill society's needs (Vergragt, 2006).

This approach resembles an issue previously addressed by one of the study participants, who mentioned that the focus on technology development itself for business purposes had become more important than a sustainable approach to technological development based on national and local needs. In turn, these issues will lead to topics such as electronic waste or the development of gimmick technologies that don't bring any real value and contribution. Unfortunately, this discussion will have to be conducted in another research context.

It is widely acknowledged among different sectors and organizations that technology has proven to be an enabler and a crucial tool for development as it was previously addressed in the literature review and further validated by the study results.

Promoting participation and inclusion in the global economy, raising the voices of minorities and enabling the production of new sources of energy to making cities and communities more resilient, and improving health services and access to education, technology has had an immeasurably positive impact on modern societies. The aforementioned are merely some of the past and present contributions brought by technology.

The alignment of the International, National, and Subnational levels is of great importance; with it, it is possible to create an enabling environment to foster education, innovation, science and technology as engines of a transformative agenda toward Sustainable Development (European Commission, 2015).

For this purpose, Development Agents, Global Leaders, and societal sectors play an important role and have responsibilities not only in leveraging technology for development but also in creating an ecosystem that stimulates the achievement of the SDGs.

According to UNDESA (2015), having an impact on a Global scale will depend not only on the effectiveness of multi-stakeholder partnerships but also on the ability to manage and share knowledge about the issues, processes, and solutions being promoted. According to the United Nations (2016), socio-economic development is inextricably linked to technological change, as technology, society and institutions co-evolve. To successfully achieve the SDGs Development Agents, Global Leaders and different Societal Sectors must work together to create an environment in which science, innovation, and technology will match social, economic and environmental needs, thereby enabling their contributions to reach beyond constituents and communities and to have a positive impact on a global scale (UNDESA, 2015).

Tackling the main challenges faced by Development Agents and Global Leaders to leverage technology for Sustainable Development, knowledge-sharing and the promotion of cooperation and partnerships between international organizations, governments, the private sector, academia and civil society is crucial (United Nations, 2015a). The study results demonstrated that Technology alone will not lead to the achievement of a sustainable path and each and every one of these stakeholders at all levels has important roles to play in leveraging technology for Sustainable Development.

At a Global level, the United Nations and other international and non-governmental organizations, have the role of spreading best practice worldwide on how technology can be deployed to achieve the SDGs. And according to Evans (2012), they also have the role to

gather and share data and knowledge, support Intergovernmental decision making and finance and support country-level implementation of the SDGs.

Being the adopters of the SDGs, governments have the responsibility to take the lead in collectively tackling the world's most pressing Sustainable Development challenges, however, the range of possible contributions of the business sector shows that public and private roles and responsibilities are increasingly becoming intertwined (Agarwal, Gneiting, & Mhlanga, 2017).

According Agarwal et al. (2017), the private-sector has increasingly demonstrated its interest and commitment to Sustainable Development by supporting policy development that matches their actions while looking to even the odds and overcome the competitive disadvantages of unilateral sustainability actions.

Companies should focus not only on what the SDGs can do for them but also what they should do for the SDGs, by looking at how core commercial practices such as wages and taxation either detract from or enable a world with reduced inequalities, through the exploration of new sustainable business models or by removing barriers to sustainable business behaviour (Agarwal et al., 2017).

According to the United Nations Development Group (UNDG, 2013), it is crucial that civil society fully participates in the design of post-2015 policies in order to create functional national systems by fostering advocacy and positively influencing policy development, identifying priorities and proposing practical solutions and alternatives.

Civil Society has the role of giving and raising the voice of the poor and most marginalized. It should advocate for the application of human rights conventions and bridge the communication gap between society and remaining sectors, mainly the private sector and governments, in order to mobilize resources and work towards local development.

Education has been introduced in this section as one of the major drivers for Sustainable Development, and the preparation of the present and future generations; goal 4 of the SDGs, reflects the importance attributed to Academia's contribution in achieving the SDGs and leveraging technologies for this purpose. According to the Sustainable Development Solutions Network Australia/Pacific (SDSN, 2017) the Academia sector, namely Universities, should also:

- Provide students with the knowledge, skills and motivation to understand and face the challenges of the SDGs;

- Empower and mobilize young minds;
- Provide academic or vocational training to implement SDGs solutions;
- Enhance opportunities for capacity building of students and professionals to address challenges relating to the SDGs.

Academia has been playing a crucial role in advocating and promoting innovation through advancing technological research and sharing their findings with the public (Vidican, 2009).

Universities have the role of contributing to community development and coherence by advocating their core ethical values of equity and transparency. Through their interaction with the local government they can develop programmes that involve and engage young people and the local community in general in SDGs-related activities.

According to UNDESA (2015), to realize the potential contribution of each and every society sector in facing the 21st century challenges, the international community has increasingly recognized the importance of embracing a Global Partnership to deliver on all of the SDGs and facilitate an intense global engagement, bridging the path of cooperation between the International, National and Local levels and among Development Agents and Global Leaders, and, together, walk the road to dignity 2030.

4.5.2- The role of established and emerging Technologies in achieving the SDGs: a model validation

The overall assumption carried throughout this study that established and emergent technologies are two distinct groups is, according to 87,5% (14) of the study participants, valid.

Only 12,5% (2) of the study participants actually do not believe in the separation of these two groups of technologies, the argument given being that technologies are part of the same processual transformation and therefore an emerging technology of the present might turn out to be an established technology in the future.

Linearity is not often considered in the literature, but rather exponential progress. According to Kurzweil (2005) and Moore's Law, technological progress is exponential and innovation will be used by humankind to overcome its challenges.

Also, the Diffusion of Innovation (DOI) theory from Rogers (1995), which argues that technology innovation and diffusion follow a lifecycle from the invention of a technology to the moment it comes obsolete, existing technologies might cease to exist and give place to new technologies in a continual process. These theories complement the argument given by these two experts, according to which technology should not be considered or placed in groups since it's all part of the same process. Even though it is a different research topic and there is a much more complex discussion around this subject, many different theories exist in regard to technology progress and evolution.

However, and according to Biggs et al. (2016), when considering emerging technologies such as the Internet of Things, Artificial Intelligence or Big Data, untapping the potential of these technologies for Development can only be possible by having a solid data foundation, infrastructure, bandwidth and connectivity. In other words, emerging technologies are dependent on established technologies, which are the responsible for the generation of large amounts of data and information (Independent Expert Advisory Group on a Data Revolution for Sustainable Development, 2014), in order to make a real impact . The World Bank (2016b) underlines the importance of Internet access for example as a means of not only bridging the digital divide but also leveraging the technologies of the future based on the above presented premise. Moreover, the target 8 of the SDG 9 focuses on increasing access to the ICTs, namely the Internet and mobile devices, therefore recognizing and supporting the importance of the established technologies in achieving Sustainable Development (Huawei, 2017).

Most of the established technologies addressed are part of the so-called information age we have been living in over the past decades, where access and exposure to information have become a reality through the use of the Internet, Web 2.0 and mainly social media. Allianz (2010), is predicting a 6th Kondratief cycle, where emerging technologies might play a crucial role in changing sectors and industries such as healthcare, energy industries, products and services, and transportation. According to one of the study participants, this 6th Kondratief cycle might be represented by the age of automation and robotics, where technology is moving from a human-computer relationship to everything around the computer.

What exactly does this entail for Development? Do these technology groups play in fact the same role in the achievement of the SDGs?

There is no consensus among the study participants on the role these two technology groups play in achieving the SDGs:

- On the one hand, those who believe that they play the same role are actually accepting the premise that technology is a processual transformation and thus no separation exists between the two addressed groups.
- On the other hand, experts who believe these technologies play a different role in achieving the SDGs believe in the existence of different purposes, complexity levels of usage and degree of contribution. In theory, established technologies play the role of mediator, facilitating the communication between different stakeholders, who can share their strategies and policies for development with one another, while emerging technologies might provide new solutions to tackle the existing challenges around the SDGs, which are known but not yet properly addressed.

A practical example: Paypal and Blockchain both play important roles in financial inclusion, despite being different types of technology with different purposes, usage contexts and complexity levels.

Sectors such as manufacturing, transportation and construction might be among the most impacted sectors by emerging technologies, mainly in their job markets and due to the structural changes that will come with the advancement of technology, both according to the study experts and the United Nations (2016). Among the experts there is a divergence when it comes to the context of use and deployment of both established and emerging technologies:

1. Due to infrastructure complexity and expenses, emerging technologies are more commonly deployed in emerging markets, where the cost of implementation is lower, and no robust infrastructure is needed for it to work. A great example is the successful implementation of mobile payment systems in African countries such as Kenya (GSMA, 2016).
2. However, the existing governmental and regulatory barrier in the developing countries, where governments do not have the means to access technology and integrate it on national agenda plans, makes it difficult for emerging technologies to reach the emerging markets. By the same token, the private sector finds it difficult under these circumstances to introduce new technologies in the emerging markets, which lack the governmental support and incentives and therefore the necessary STI ecosystem.

The widening of the digital divide might take place in a scenario where developed countries have the necessary means, infrastructure and ecosystem for emerging technologies to be deployed and disseminated, while the developing countries lack the necessary regulatory environment and the means to successfully implement and deploy technology for Sustainable Development. This issue will lead to the next topic addressed in the study: will these emerging technologies help close or actually widen the digital divide?

One of the foremost concerns among the experts regarding this issue is the fact that technology is designed and produced without Sustainable Development purposes. As previously discussed, the private sector is driven solely by profit, therefore technology design, production and dissemination will be based on this fact leading to mass production of devices at the expense of 'green' concerns in order to drive up profits.

This issue raises the discussion about which principles technology innovation and creation should abide by: according to the experts, it should first and foremost respect Sustainable Development best practices, and secondly help solve the local problems of developing countries. According to Mustaquim & Nyström (2014), information systems and technology design itself should be based on Sustainable Development practices, which is the foundation of Green IT.

Despite the different perspectives introduced by experts in this regard, the majority believe that the Digital Divide is influenced by other factors, namely the fact that it is a reflection of the world-system we currently live in.

There is a common agreement about this among the study participants and the reviewed literature, with institutions such as the United Nations (2016), The World Bank (2016b) or the European Commission (2015) all agreeing on the importance of the role of governments in implementing the necessary policies and fostering an environment that enables the STIs, an education for Sustainable Development and the use of technology at the service of inclusion to thrive.

It is acknowledged that, over the last decade, the number of Internet users has tripled, from 1 billion in 2005 to nearly 3.2 billion in 2015 (World Bank, 2016b). Based on this fact, the following question arises: to what extent will emerging technologies enable the accessibility, connectivity and affordability of the established technologies?

According to the experts, we're facing quite a paradoxical situation from a technology infrastructure implementation point of view: it is true that emerging technology solutions might be easier and require less complex and expensive infrastructure to be deployed in developing countries - which is an argument in favour of the contribution of emerging technologies towards closing the digital divide - however, the emerging technologies are, as previously addressed, dependent on the usage and dissemination of established technologies, which require more robust infrastructure. From this perspective, even if emerging technologies have the potential to close the digital divide, the technology basics have to be in place. As an example, how can smartphones and computers be used without proper electricity or how can Internet access be provided without existing bandwidth and connectivity?

The aforementioned factors, along with the fact that technology production and use happen in developed markets first, might also contribute to the perpetual existence of the digital divide. In the end, the digital divide phenomenon extends beyond the discussion around technology access; it is an issue that is again dependent on a structural change at the international, national and local levels to fight inequalities.

Moreover, the digital divide is not only a representation of the existing global inequalities, but also a representation of the generational gap between elders and youth, which could only be bridged through education. Only by effectively combining structural and system changes, education for Sustainable Development and creating the right STI ecosystem through global cooperation will it be possible to extend the use and benefits of technology for all.

The previously addressed topic provides a direct link to the present and future importance of leveraging the established technologies on a global scale, thus preparing the world for the upcoming technological era where IOT, A.I, Big Data, Nanotechnology or Blockchain will unlock new opportunities and solutions for Sustainable Development.

The potential of established technology, according to experts, is based on its superior ability to enable connectivity and inclusion compared to emerging technologies. However, established technologies alone cannot tackle the existing global challenges. For instance, A.I and Big Data have played an increasingly important role in addressing social and economic inequalities in developing countries. Emerging technologies, as previously addressed, are crucial in order to make sense of large amounts of data and they therefore have a crucial role to play in regards to generating and collecting large amounts of data on devices and in the cloud.

The potential contributions of each of these technology groups is nevertheless subject to different variables such as country, context of use, financial resources or human skills to use a specific technology; these should be accounted for by decision makers, namely governments, to decide on the most appropriate group or specific technology to deploy to achieve each of the SDGs in alignment with the national agenda (Ely et al., 2011). Despite the experts' belief in the bigger contribution that emerging technologies might bring for Development purposes, these two groups are in fact complementary, and only by effectively combining these data collection and analysis technologies will it be possible to harness the data revolution and its important role in keeping track of the SDGs-related initiatives (CSIS, 2017).

Capacity building is thus recognized by both study participants and the international community as an important means to broaden education development at the national levels by showing the potential outcomes of investing in literacy and numeracy in primary education as well as educating adults with the 21st skills for lifelong learning to make sense of complex issues such as choosing, using and managing technologies for development purposes (CSIS, 2017).

Connectivity is increasing, with the number of connected devices comprising the Internet of Things estimated to double to over 20 billion by 2020; in addition, according to the Friends of Europe et al. (2017), around 90% of the data today was originated over the past two years. By having the right governmental support and policies, youth and adults educated on Sustainable Development, and by harnessing the data-revolution, it will possible to make sense of both established and emerging technologies and improve their field efficiency at the local levels, while monitoring and analyzing the outcomes for improved performance at the national and international levels.

Despite the contribution of the field experts, and as discussed above, the role of emerging and established technologies and their potential is dependent on how development agents, global leaders and different societal sectors together plan to deploy and use each of these technologies individually and as a whole in order to meet national agenda challenges and achieve the SDGs.

It has been largely argued throughout the present study that technology is mainly a tool at the disposal of humankind; therefore, Technology Assessment (TA) is a crucial practice to be undertaken as an attempt to anticipate and analyze the implications of technology projects and to provide different options for decision makers (Ely et al., 2011).

The introduction and use of technologies in developing countries has long been recognized as a practice that does not always take into consideration cultural contexts and preferences according to Ely et al. (2011), which leads to low adoption of these tools in important sectors such as the health, energy or agricultural sectors. The United Cities and Local Governments (2015), along with some of the expert opinions, believe that for an effective deployment and use of technology, a “bottom-up” approach is crucial, by addressing local needs and assessing which technologies can help tackle corresponding challenges.

While emerging technologies are believed to be the most crucial group of technologies in the creation of solutions to existing Sustainable Development challenges, their foundation requires a robust data ecosystem and integration, which in turn can only be harnessed through the diffusion and use of established technologies on a global scale. However, and according to the Friends of Europe et al., (2017, pp.22) “without a plan that addresses the digital divide, technology will deepen inequalities”, therefore, the role of established and emerging technologies to achieve the SDGs is dependent on how Development Agents and Global Leaders together can foster an ecosystem of STI through collaboration, policy making, regulation and education to enable not only the potential of technology as a tool but also to empower humankind as the main drivers of Sustainable Development.

5. CONCLUSIONS

The transition from the MDGs to the SDGs brought new challenges and opportunities for international development in an increasingly globalized world, where alignment and collaboration between developed and developing countries is now a key variable to achieve the Sustainable Development Goals. Development went from a top-down exercise based on an economic-centric approach to a collective effort that applies the ideals of universalism and sustainability to tackle social, environmental and economic challenges, and reduce poverty and inequality on a global scale. Development Agents and Global Leaders such as the United Nations, International Organizations and Governments are responsible for putting these principles into practice and for setting the guidelines and goals of the international agenda while considering national and local level needs and challenges. These entities have the role of establishing the best practices to achieve Sustainable Development and of providing the necessary support for the implementation and monitoring of the SDGs.

Technology is, according to both the revised literature and the experts who participated on this study, one of greatest hopes for humankind to effectively address the 21st Century Challenges. However, technology alone will not be sufficient to solve the problems and challenges we face. In order to successfully expand and enable the potential of these tools for development, several other variables have to be brought together by Development Agents and Global Leaders such as:

- ❖ Governments to effectively mobilize financial and natural resources according to Sustainable Development practices. Through technology, it might be possible to effectively improve resource management, avoid waste and reuse materials in an efficient way;
- ❖ Regulations that foster Science, Technology and Innovation through the implementation of flexible policies that create incentives and explore new technological solutions, as well as creating policies that ensure fair competition, the security of data and information and encourage businesses to adopt sustainability best practices. Regulations can and should also play a crucial role in making technologies more accessible and affordable, through taxation policies on the private sector.
- ❖ Education Programs for Sustainable Development, as a way to provide the current and future workforce with the 21st Century skills necessary for success, such as digital literacy, critical thinking, flexibility and adaptability, allowing people to rapidly adapt

to new working environments and to be able to effectively use technological tools not only for professional purposes but also in their everyday lives.

- ❖ Engage citizens and local communities in SDGs and technology related activities; this will lead to the rapid dissemination of sustainability best practices alongside and greatly increase awareness on technology can be used for the good of society and to improve people's lives, mainly those of the poor and marginalized in remote communities.

Technology has been used to creatively give answer to some of our most complex challenges throughout times and will in the future be our hope to solve rising issues we might come across. Technological innovation has allowed the development of complex tools such as computers, mobile phones, cloud computing or the Internet, which then enabled a whole new spectrum of technological inventions such as the Internet of things, big data, artificial intelligence or blockchain. Technological progress, despite the two different approaches introduced in the discussion section - where technology progress is seen as a processual transformation by some experts (meaning there's no separation of the two addressed technology groups), while other experts see clear differences between these two groups, defending that established technologies are the main enablers of emerging technologies, providing and creating a data foundation to make sense of the latter, while providing the necessary connectivity and bandwidth for emerging technology tools to be used. Emerging technologies, however, offer a new hope for humankind to automate the digital and human world we live in, which was not possible with the use of only established technologies. The required infrastructure to use established technologies and emerging technologies was also subject of discussion and differentiation; established technologies require more robust and physical infrastructure than emerging technologies.

The present study has shown that, overall, emerging and established technologies play different roles in achieving the SDGs: emerging technologies are expected to provide contributions to the improvement of production processes, transportation and energy production and management within cities through the advancement and integration of the IoT and Big Data, with the help of the Internet and mobile devices, which allow an effective use of these tools.

The current challenges faced in a variety of fields and sectors in regards to energy and material production, urbanization, mobility or environment protection cannot be solved by the sole use of established technologies, therefore the design, production and deployment of emerging technologies is being made with the focus on addressing these new challenges introduced throughout the research, which are directly related to the achievement of the SDGs.

Artificial intelligence, along with machine learning, may unlock the potential of robotics; alongside 3D printing technology these may revolutionize the industrial sector and production processes; however, challenges related to workforce displacement and a shift in the skills required in the work environment remain a global concern. Despite technology advancement, according to Ngo (2015) there are, nevertheless, new horizons to be discovered through the study of nature. Biomimicry practices have helped the advancement in scientific fields such as nanotechnology and biotechnology, which will be crucial to overcome Sustainable Development challenges in agriculture, health and energy. Technology has been used as a tool throughout millenniums by ancient civilizations, from the discovery of fire all the way to the creation of efficient technology tools for engineering practices in agriculture and irrigation systems (Fabian, Tan & Ohio, 2015). Along with the study of nature, ancient civilizations and their technology advancements might provide relevant clues and contributions to the advancement of technology in our time.

According to both the literature and the field experts, technology is a crucial factor in the achievement of the SDGs , in the present and the future. Technology is considered by both the relevant literature and study participants a powerful tool and enabler of development, but only by gathering international, national and local efforts toward Sustainable Development best practices can it help overcome barriers such as the digital divide, while preparing the present and future generations to effectively keep up with the rapid world progress and technological change we are facing today, and effectively use these tools to tackle the 21st century global challenges and simultaneously improve the economy, the environment and society.

5.1- SUMMARY OF THE DEVELOPED WORK

A paradigm shift when it comes to Development took place with the transition from the MDGs to the SDGs (United Nations, 2014b). According to Fukuda-Parr (2016) the SDGs have an inclusive and universal approach to Development and are in alignment with Sustainable Development purposes, which stipulate that all nations should take part and collaborate towards Development, leaving-behind the top-down approach of Development carried during the MDGs programme until 2015. Universalism should be, according to both the United Nations (2014b) and the European Commission (2015), the foundation of Sustainable Development. There are, however, different opinions concerning the viability and purpose of the SDGs programme itself: while authors such as Unwin (2017) or Easterly (2009) believe the purpose of the MDGs and the SDGs are not truly focused on ending extreme poverty or reducing inequalities, the UN (United Nations, 2015b) believes significant improvements were made during the MDGs, as per their 2015 Report.

Technology is unanimously believed to be crucial for Development – different literature sources belonging to the UN, the private sector, academia and the experts who participated in this study all agree on that. There are, however, different opinions in regard to the most appropriate way to use technology to achieve the SDGs, which is represented in the reference model validation. Established technologies are seen by the World Bank (2016b) and GSMA (2016) as the major drivers of connectivity and the best means to effectively enable the digital and global economy; these technologies, however, rely on heavy, expensive and robust infrastructure, which is not accessible for developing countries. Emerging technologies are, according to the Biggs et al. (2016) and the United Nations (2016), the great hope for human progress and development, and they might shape the next technological era. For this to occur, a solid foundation and a widespread use of established technologies all across the globe is required according to the CSIS (2017), which remains a significant obstacle to achieve the SDGs.

Without the right approach and intervention of Development Agents, Global Leaders and Society Sectors in creating an STI-based ecosystem through regulation and policy implementation, fostering education for Sustainable Development and aligning agendas for development, technology might not reach its ultimate potential, and might even contribute to widen the existing global inequalities, namely the digital divide.

5.2- LIMITATIONS AND RECOMMENDATIONS

From a literature review point of view, it was not possible to analyze all the existing materials either from open data sources, namely from United Nations, its organizations and partners, or academic articles in the field of development, information systems and technology.

Despite the vast amount of quality sources used in this research, there were still other potentially relevant materials that could have been explored, but the present research was merely intended to be an overview of the topic.

From a methodological point of view, the present study could only be validated with the contribution of field experts on either Development or Technology. It could not have been achieved otherwise. Finding the experts and interviewing them was certainly one of the biggest challenges this study posed.

The limited amount of time given to conduct the research and the fact that only a few specific entities/people could give their contribution to it made it very challenging to effectively collect the necessary information from the right sources. Fortunately, the WSIS provided the right opportunity to gather the information necessary for this study, making it possible to interview experts and practitioners of Development and Technology from all over the world. In a future similar study, it could be interesting to have a larger team of researchers in order to collect more interviews for analysis, or even to take a more quantitative approach to the topic to complement this mostly qualitative study.

From a data collection and measurement point of view, the conducted interviews and their script – which was designed to validate the reference model - ended up proving a bit limited in the sense that it could have taken a deeper dive into the relationship between each one of the addressed technologies and corresponding contributions and each of the SDGs, which leaves an opportunity open for a more detailed exploration of this topic.

Despite the availability, cooperation and interest shown by the experts interviewed, and the sincerity of their answers, their opinions are nevertheless a product of their personal experiences, which can on the one hand contribute to the diversity of the study results, but on the other hand limit it to personal realities. Since this study was made only by one researcher, its outcomes are also dependent on his interpretation.

Finally, the present research focused primarily on the positive impact and contributions of technology for development, which means that an opposite approach to the topic – focusing on the negative aspects of technology in this context – could be undertaken, providing a broader overview of the role of technology in achieving the SDGs. The beliefs and opinions and opinions featured in this research are strong and convict, but different perspectives always make a discussion richer, whether or not one agrees with them.

5.3- FUTURE WORK

For a future study of this topic, it could be interesting to go deeper and provide further data on the relationship between these technology groups and their contribution to the SDGs by creating a network model using data mining techniques.

Such a study could be undertaken by the United Nations and its partners, as a way to improve how technology impact is assessed, which according to Ely et al (2011) is not being done effectively. By gauging technology impact through an effective assessment, it might be possible to account for social, environmental and economic factors to optimally use technological resources for Development.

Another research opportunity, as previously mentioned, is to specifically focus on each one of the technologies mentioned in the study and analyse their contributions and impact at the local, national and international level. By combining the two aforementioned recommendations, the United Nations and its partners could, in the future, generate enough data to produce relevant reports on how technological progress and implementation is impacting the world and the different regions and countries, what successes and failures are taking place and what the best options for the implementation of technology are according to the obtained results and the respective conclusions.

After concluding this study, a new question arises in a post-2030 context: Will the combination of the SDGs programme, an effective deployment of technology for development with a lifelong learning approach to education, supported by a successful alignment between International, National and Local levels be enough to help us achieve Sustainable Human Development? We'll find out in 12 years.

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