LAPIN AMK
Lapland University of Applied Sciences

LEVERAGING BIG DATA IN CREATING SMARTER CITIES

Case City: Tornio, Finland

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Abstract of Thesis

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The Smart City concept has gained wide prominence in recent times due to rapid urbanization and technological advancement. City administrators are exploring innovative ways of tackling contemporary issues in urban areas such as pollution, increasing population and dwindling financial resources. The emergence of data-generating sensors that have the power to collect data from the physical environment is taking the Smart City concept into new directions.

The objective of this study is to explore the concepts of Smart City and big data. The study reviews the application of big data technologies in building Smart Cities. The study compares the different definitions of the Smart City concept provided in academia, industry and government. It also examines the evolution of the Smart City concept and the events that triggered its eventual adoption by cities around the world. In addition, the study explores the technology enablers that have to be in place for the Smart City ambition of any city to come to fruition.

The qualitative research method was used in this research work. The research work made use of both primary and secondary data. The primary data were collected through questionnaire survey technique. The secondary data were collected from research works, case studies and articles conducted on Smart City and big data.

The research results indicate that Smart City awareness is relatively low among the general population of the city of Tornio. A wider proportion of the young population are indifferent about how technology can improve the quality of their lives in the city. The major outcome from the result is for adequate consultation between the city administrators and residents before digital services are created in the city. Consequently, the city risks developing digital services that the residents neither recognise nor value.

Keywords data-generating sensors, digital services, urbanization, big data, physical environment, smart city

CONTENTS

SYMBOLS AND ABBREVIATIONS

BIM Building Information Modelling

BMS Building Management System

CCTV Closed Circuit Television

GIS Geographical Information System

GPS Global Positioning System

ICT Information and communication technology

IoE Internet of Everything

IoT Internet of Things

IR Infrared

LED Light-Emitting Diode

M2M machine-to-machine

RFID Radio Frequency Identifier

1 INTRODUCTION

The background information and motivation of the research work are provided to start with. Additionally, the history of the city of Tornio is discussed briefly. The discussions of the research objectives and structure of the thesis complete this chapter.

1.1 Background and Motivation

The last two decades have witnessed unprecedented growth in two important phenomena i.e. urbanization and information and communication technologies (hereinafter ICT). The emergence of ubiquitous computing has forever tipped the balance in the way services are delivered in cities. Digitization of services has made it possible to understand how people use public spaces and infrastructures. This knowledge is, in turn, used to enhance citizens' experience in urban areas. The result is a city which is interconnected, sustainable, workable and liveable.

The United Nations has projected that 70% of the world's population will reside in urban areas by 2050 (Townsend 2013, 2). This rural to urban migration poses a notable threat to existing city infrastructures and comes with challenges of city planning and administration. Urban planners, architects, city administrators in conjunction with technology companies are constantly working together to explore ideas for future cities. As cities continue to deal with dwindling financial resources, adoption of ICT is a viable option (Airaksinen , Ailisto & Nylund 2015, 8). City administrators are taking advantage of the rapid growth of ICT to create digital services for its residents.

In six thousand years of recorded history, urbanization has always been characterized by long-term strategic goals (Batty 2013, 3). The implementation of ICT in service provision in cities is changing the way services are delivered to the residents. Cities are now shifting from long-term planning to short-term planning, facilitated by technologies which collect, communicate and analyze data in real-time. These new ways of harnessing data are made possible by data-generating sensors with capabilities of collecting and publishing data from the physical environment.

The increasing popularity in the deployment of data-generating sensor technology in cities has been impressive. Sensors are now being embedded in unseemly mundane objects such as street lights, buildings, cars, asphalt to monitor traffic, movement of people, air and noise pollution. In 2015, the world reached an important milestone as the number of Internet-connected devices outpaced the population of humans on earth (Cisco 2016). This army of connected devices will amount for 30.6 exabytes of data by the end of this decade (Cisco 2016). This prodigious amount of data is widely known as ‘’big data’’.

Traditionally, cities have relied on crude data from census, statistics and surveys to make important decisions concerning the city. Big data will forever change the way urban areas are built and managed. Big data will help cities adapt, predict and react to urban issues in ways that were not possible in the past (Glaeser, Kominers, Luca & Naik 2015, 8). Big data is leading cities in new directions by making administration of cities increasingly data-driven, cost efficient, reduce waste and facilitate effective distribution of sparse resources (Deloitte 2015). This smart way of doing things in cities is increasingly referred to as a Smart City.

Smart City is the re-imagination of how a city should function when data collected from the physical environment is used to create digital services to enhance citizens’ experience (Batty 2013, 4). Smart Cities are fixes for the unintended wrong designs of the last century and a blueprint for the challenges of the next one (Townsend 2013, 8). Cities are making use of data-generating sensors in new innovative ways to create digital services for its residents. The prevalent use of smartphones has further amplified the Smart City concept. Smartphones easily allow city dwellers and visitors to access digital services in real-time. Sensors now let automobile drivers know the condition of roads i.e. if the road is covered with ice or water logged through their smartphones. Residents driving through the city can easily locate free parking spaces in the city and thereby saves time and reduce greenhouse gas emission from cars.

Smart metres automatically allocate power resources based on usage in real-time. Garbage collectors know when garbage cans are full and respond accordingly making their job more efficient. Data-generating sensors are also used to track air and noise pollution in real-time, helping city administrators to know which part of the city is most polluted. Smart City is still an evolving field of urban science and it will only get better judging from previous antecedents.

The motivation for this research is the researcher's personal interest in the Internet of Everything (IoE) and its application in cities. All human activities take place in cities. The city of Tornio similarly to any other city is faced with a plethora of issues ranging from migrant crisis to dwindling financial resources. The adoption of contemporary technologies such as big data and sensing technology can help the city tackle its challenges and also provide the city with a competitive advantage in the global economy. The ability of a city to use predictive analytics to quickly respond to changes and foresee the future in real-time is what every city should strive to achieve. The recommendations in this research work will be of benefit to the city of Tornio when designing digital services for its residents.

1.2 Brief history of the case city

The city of Tornio is a municipality that borders with Sweden in Lapland area of Finland. The city with a population of 22,306 (June 2015) forms a twin city alliance with the Swedish town of Haparanda.

In the 16th century, Tornio was a major trade hub in the whole of Lapland. At a time, it was regarded as the largest merchant town in the north. The major export from the city was salmon, butter and animal skin (Vahtola 2009). When war broke out in 1700, the successful trade hub which the city was known for began to decline (Vahtola 2009).

In recent times, the border town status has helped the city in terms of trade relations but did little to affect its development. Industrialization accounts for much of its development in the last few decades. Farming, textile industries, brewery and the stainless steel-making factory became a source of livelihood for the city (Vahtola 2009). The city also boasts of a vocational school and a university of applied sciences. The Aine museum which is also situated in the city has a good mix of varied art collections and exhibitions giving the city a reputation as a cultural city.

(Vahtola 2009.) Tornio was once referred to as the “Gateway to Lapland” due to the fact that most of the trade into Lapland is directed through the city of Tornio. Its position as the northernmost city of Sweden and later Finland also has helped boost the city’s tourism sector.

1.3 Research scope and objectives

The main objective of this research work is to explore the concept of Smart City and the digital services that create a unique experience for the citizens. The research provides an in-depth knowledge of the technologies of big data and analytics and the role they play in creating digital services in a Smart City. The research work initially examines the different definitions of Smart City available. This research work provides an exciting opportunity to thoroughly investigate what constitutes a Smart City.

The study discusses the evolution of the Smart City concept and what has been the main driver of its meteoric rise. The citizens’ experience which is enhanced by the provision of digital services within the city is discussed. The ICT enablers that is put in place or developed for the digital services to work is also examined. Technology is the main driver of the Smart City concept. Big data and analytics is thoroughly explored in relation to how information from data-generating sensors are utilized in the creation of digital services. The research also shed new light on the different digital services that can be deployed in a city. Additionally, Smart City scenarios and their benefits to the city of Tornio is thoroughly explored. In a Smart City, the issue of privacy and open government data is always a tense topic for debate among citizens and city stakeholders alike. These issues and the effects on citizens is carefully examined.

1.4 Structure of thesis

The overall structure of the research work takes the form of seven chapters. A concise but detailed introduction, a brief history of the city of Tornio, objectives and scope were described in this chapter. Chapter two begins with the discussions of the research questions and methodology. Chapter three introduces the concept of Smart City. The definition, evolution, citizens' experience and Smart City ICT enablers are discussed. Digital services and case studies are examined. Chapter four is concerned with big data and analytics. Sensor technology and the different digital services that can improve citizens' experience in the city are thoroughly explored. Chapter five presents the analysis of empirical data collected from surveys. Chapter six is devoted to Smart City scenarios. Chapter seven concludes the research and outlines areas for future research.

2 RESEARCH QUESTIONS AND METHODOLOGY

This chapter focuses on the research questions and research methodologies. Three research questions are discussed in order to accomplish the objectives of the research work. Finally, the research methods used in this research work is presented.

2.1 Research questions

Three research questions are presented and described to achieve the objectives of this research work. The research questions are as follows:

1. What constitutes a Smart City and why there is need to build Smart Cities?

‘Smart City’ has been a buzzword thrown around by big multinational firms such as IBM, GE, Cisco. Recently, it has been popularized by politicians as part of their campaign manifesto. This study explores different literature for the origin and meaning of what truly qualifies a city to be called a Smart City. As cities around the world continue to grapple with dwindling financial resources, the unequivocal reasons why the need to start building Smart Cities is thoroughly examined.

2. How are data generated in a city used to create digital services? How does Open Government data spur innovation?

Data are generated from different sources in a city. The research work will thoroughly investigate how data generated in a city are used to create digital services for the citizens. Furthermore, the research will also analyse how data generated from different sources is collated, structured and engineered to improve service provision in the city. The role open government data plays in the innovativeness of a city is fully explored as well as the privacy issues that are associated with it.

3. How are citizens involved in the creation of services in the city?

The study will analyse citizen engagement in the creation of services in the municipality. Creation of services in a city should involve all the city stakeholders such as residents, business owners, university environment and frequent visitors. The research work will seek answers on how much input does the residents have in service creation in the city.

2.2 Research methodology

The research includes a theoretical and practical part. First, Exploratory research is carried out and it involves a literature review or organising target group interviews in a locality. This method is useful in this research work since the research is largely based on literature. The exploration of a new concept may test the workability of an already existing comprehensive study and help determine the best procedure to accomplish the task in future. The research work includes recommendations and suggestions on how big data could be leveraged in creating smarter cities.

For this study, the case study approach is used to explore how digital services will improve citizens' experience in Tornio municipality. The case study is favoured more in analysing contemporary events because it concerns observations and interviews of the main actors involved in the event (Yin 2009, 11). A case study can be defined as an experimental study that examines a contemporary phenomenon extensively from the standpoint of its authenticity especially when the boundaries between phenomenon and reality are not that conspicuous (Yin 2009, 18). A case study offers an extensive range of variables to the researcher. In this study, the literature review of similar case studies of Smart City implementation in other cities is extensively used. This in-depth study will help determine which Smart City technology can be implemented in Tornio municipality.

The research work adopted both primary and secondary data sources. The primary source of data is obtained from interviews, observation and surveys.

The secondary sources are derived from books by well-established authors, articles, reports, youtube videos and freely available government data.

Participant-observation is when the researcher is an active observer in a case study situation and may actually be a participant in the events being studied (Yin 2009, 111). The researcher has been a resident of Tornio municipality since 2013, which therefore qualifies the researcher either as an active observer or participant. The participant-observation techniques present unique opportunities for the researcher in terms of data collection in a case study but also has major flaws. Central to these opportunities, is the ability of the researcher to perceive reality from the perspective of someone who is part of the system rather than from an external observer viewpoint (Yin 2009, 112). The major flaw of the participation-observer is the potential of the researcher being biassed.

For the purpose of getting diverse views from different respondents in the city, the questionnaire technique is utilized. A questionnaire survey is carried out in order to collect citizens' opinions and views on present digital services in the municipality. Respondents were also asked about their views on future Smart City technology for the municipality. In chapter four, the process of organizing the questionnaire survey and how many respondents participated in the survey is discussed.

3 INTRODUCTION TO SMART CITIES

This chapter presents a general overview of the Smart City concept. The different definitions as well as what qualifies a city to be called a Smart City are discussed. The origin of Smart City and what factors are responsible for its sudden popularity is investigated. The chapter also examined how digital services improves citizen’s experience in a Smart City. An in-depth analysis of ICT enablers and infrastructures are explored. Finally, the study analysed different cities that have already adopted the Smart City approach to city management.

3.1 What is a Smart City?

The Smart City concept attracts many definitions but a universally accepted definition is lacking. The word “smart” can be associated with different meanings and this is one major reason for the absence of a standard definition of the Smart City concept. However, the definitions of Smart City all share a central theme i.e. improving citizens’ experience and quality of life using digital services. While this study does not offer a single definition of Smart City, it relies on an extensive literature review for the definitions provided in this text.

An Analysis of different literature reveals that the Smart City concept is centred on three fundamental areas i.e. Academic, Industrial and Governmental (Mosannenzadeh & Vettorato 2014, 685). In the academic domain, the concept of Smart City has been used to describe an all-inclusive urban society where technology and social innovation is the main focus. Notable among the definitions provided in academic and science literature is given by Vienna University of Technology et al*.* (2007, 11) maintaining that “A Smart City is a city well performing in a forward-looking way in these six characteristics (Smart Economy, Smart People, Smart Governance, Smart Mobility, Smart Environment and Smart Living), built on the ‘smart’ combination of endowments and activities of self-decisive, independent and aware citizens”. This definition takes into account what constitutes a Smart City by highlighting six characteristics that need to be in place before a city can be labelled as a ‘Smart City’.

Industry giants such as IBM, Deloitte and Cisco offer a more practical stance in their definition of a Smart City. IBM defined Smart City as a city that uses ICT to remodel their main systems and enhance the outcomes from available limited resources (IBM 2009, 9). A further definition is given by Deloitte (2015, 3) as a city using technology in innovative ways to support population growth and manage scarce resources.

In government literature, emphasis is placed on financial, administrative and environmental aspects of the city. The European Commission (hereinafter EC) is the executive arm of the European Union and promotes its general interest. The EC (2015) defines Smart City as “ A place where the traditional networks and services are made more efficient with the use of digital and telecommunication technologies, for the benefit of its inhabitants and businesses”. This definition highlights the need for cities of the future to be human-centric supported by technology meant not only for greenhouse gas reduction but also improvement of business activities.

A more holistic definition by Smart Cities Council et al*.* (2015, 9) defined Smart City as “A smart city uses ICT to enhance its livability, workability and sustainability”. This definition is described in simple terms to include three processes to make the Smart City concept possible, namely, collecting, communicating and crunching (Smart Cities Council et al*.* 2015, 9). Collection is the process of collecting data from data-generating sensors, communication involves sending and receiving data through wired and wireless networks and crunching is how these data are analysed to react and predict situations in real-time (Smart Cities Council et al*.* 2015, 9).

Despite the many competing definitions, it is worthy to note that the definition of Smart City abounds due to different stakeholders interest (Mosannenzadeh & Vettorato 2014, 687). In summary, the definitions from different literature signify that Smart City in its simplest form means an urban area that seeks to utilize ICT in solving human issues.

3.2 Smart City Evolution

The Smart City concept has its origin in the Smart Growth movement which became popular in the mid-1990s (Goetz 2004, 45). The Smart Growth movement advocated for new sustainable policies for planning urban areas (Harrison & Donnelly 2011, 1). In recent time, the phrase ‘Smart City’ has been popularized by multinational companies such as IBM, Cisco and Qualcomm. The Smart City concept has since evolved to mean any implementation of ICT services in urban spaces to improve service provision and administration.

The use of time analysis is utilized to analyse periods in recent history where possible events might have kick-started and influenced the Smart City concept. The Smart City process started right before the turn of the 21^{st} century.

In the year 1997, the Kyoto protocol was adopted in Kyoto, Japan to commit countries to reducing greenhouse gas emission in order to protect the environment (Cocchia 2014, 25). The Kyoto Protocol was signed into law by United Nations member countries (with a few exceptions) totalling 192 parties (Cocchia 2014, 25). The member countries were required to come up with policies and regulations to reduce CO_2 emissions in their respective countries. The Kyoto Protocol has greatly influenced how government perceives their cities in terms of urbanization. The Kyoto protocol has been one of the main drivers of the Smart City concept, it provided a leeway for the testing of ICT services in curbing the menace of global warming.

In the year 2000 and beyond, the use of the Internet in our daily lives increased significantly (Cocchia 2014, 25). The proliferation of mobile devices such as personal computers, smartphones, wireless sensors and advanced telecommunication networks has further increased Internet penetration to the remotest parts of the world (pewglobal 2015). The Internet is unarguably one of the greatest inventions of mankind. This widespread use of the Internet has influenced every major industry from the education sector to the transportation sector. Disruptive technologies are now changing the way service is provided and delivered in many sectors. In the urban space, digitisation of services and an unprecedented access to information in real-time has given rise to Smart City interventions in cities around the world (Deloitte, 2015). The services that were once performed by humans are now being automated by the use of machines and sensors (Townsend 2013, xii). The use of the Internet to access vital information and machine to machine communication are critical main drivers of the Smart City concept. There are now smartphone applications for locating friends, restaurants and anything fun within a city (Townsend 2013, xiv). As Townsend (2013, xiv) rightly pointed out that “People are building Smart Cities much as we built the web – one site, one app and one click at a time”.

IBM popularized the Smart Planet concept in the year 2008, calling it the “the system of systems” (IBM 2009, 9). IBM promised governments to make traffic congestions in cities a thing of the past by leveraging cloud computing and big data technologies (IBM 2016). The government of cities such as Eindhoven in Netherlands partnered with IBM to implement a traffic management solution (IBM). Partnerships such as this help city governments to achieve the Kyoto Protocol benchmark on greenhouse gas emissions. Multinational technology companies such as Cisco, Qualcomm, Siemens, Ericsson followed suit by bringing out products geared towards the Smart City initiative. It is worthy to note that, for Smart City goals to come to fruition, a robust ICT framework is essential.

3.2.1 What constitutes a Smart City?

The main constituents of a Smart City are those urban domains that are essential to the creation of Smart Cities. Every human activity happens in cities and creation of a Smart City is not limited to technology only. Vienna University of Technology et al. (2007, 11) defined Smart City as “a city well performing in a forward-looking way in these six characteristics (Smart Economy, Smart

People, Smart Governance, Smart Mobility, Smart Environment and Smart Living), built on the ‘smart’ combination of endowments and activities of self-decisive, independent and aware citizens”. This definition is more encompassing and general at the same time. The definition highlights six characteristics which are considered to be the constituents of every Smart City project. Smart Economy includes the competitive advantage of cities, innovativeness, entrepreneurship, productivity, international outlook and effective labour market. Smart People refers to the social connections such as openness, integration and interaction. Smart Government includes citizen participation in decision-making, open government data and transparency. Smart Mobility refers to effective location services, ICT services, good transport system, local and international accessibility. Smart Environment means pollution-conscious environment, sustainable resource management and environmental protection. Smart Living is more holistic and refers to a city with a good quality of life, healthy conditions of residents, the safety of residents, low crime, elderly care and good social amenities. (Vienna University of Technology et al*.* 2007, 11.)

3.2.2 Why is there a need to build Smart Cities?

As the majority of the world populations migrate to the city, city administrators are seeking answers to common urban problems. Urbanisation in the 21st century is plagued with several issues such as over-population, pollution, dwindling financial resources, poor infrastructures and declining growth.

Cities are also dealing with traditional urban problems and one of the most pressing issues is the problem of global warming. The increase in temperature is already being experienced in most countries. To halt the effects of global warming on earth’s climate, reduction of greenhouse gas emission needs to be taken seriously. Cities are tasked with the burden to find measures in tackling the effect of climate change. (Tokoro 2016, 1.)

The implementation of Smart City projects to curb the issues faced by cities is gaining traction. Smart Cities utilize ICT to improve service provision in cities. Water and waste management, telecommunication, transportation, electricity and other social interventions can be fully enhanced to create eco-friendly urban areas which the main goal is to reduce greenhouse gas emission. The suggestion that building such cities in different locations around the world will boost the expansion of low-carbon urban areas worldwide and ultimately end global warming is widely endorsed. (Tokoro 2016, 1.)

There are other reasons why it is important to start building Smart Cities. The ever increasing strain on social amenities and services due to an upsurge in the diversity of the urban population urges to build Smart Cities (Green 2011, 13). Migrant crisis currently being experienced in much of Europe could be managed effectively with Smart City technology. Sensors embedded in buildings can easily let city administrators determine the occupancy rate in certain areas of the city. This will also facilitate the effective distribution of scarce resources.

The dwindling financial resources currently faced by cities is putting pressure on the provision of basic social services. Smart City promises to “do more with less” helping cities to free up resources for other urban projects. Increasing pressures on transport infrastructure due to urban population growth is giving way to Smart City interventions (Green 2011, 13). Mobile applications such as Uber is helping city dwellers access real-time ride sharing service, therefore, reducing CO_2 emission in the city (Uber 2016).

The miniaturization of computer components, declining cost of sensors and cloud services has been instrumental in the adoption of Smart City. These topics are explained further in the following sections of this research work.

3.3 Smart Cities’ ICT Enablers

The ICT enablers necessary for the implementation of digital services in a city are determined by the Smart City program adopted by the city. However, there are certain ICT enablers which have to be in place for a successful implementation of the Smart City concept. This section will examine the different ICT enablers that make service provision in a city ‘smart’. ICT can make transformational changes to cities. Buildings are more efficient, neighbourhoods are more livable and safer, water and energy services are more economical.

3.3.1 Instrumentation and control

In a Smart City, the physical environment is monitored and controlled using a process called instrumentation and control. Instrumentation refers to those smart devices deployed for different city-wide services. These could be smart meters for electricity, water and gas; sensors to monitor air and noise pollution; sensors embedded in asphalt for parking and traffic monitoring and closed circuit monitors. Instrumentation is the foundation of a Smart City project. Data-driven informed decisions made in a city to effectively allocate resources and cut costs are derived from instrumentation. (Smart Cities Council et al. 2015, 71.)

According to Smart Cities Council et al. (2015, 71), the process is two-fold. Instrumentation collects data about the physical environment while control remotely monitors these smart devices and take necessary action. For instance, the fire alarm in a building can be remotely switched off, if the smart fire detector device in that building confirms the alarm to be false. A city making the transition to being ‘Smart’ leverages on the right data to make better-informed decisions. (Glaeser, Kominers, Luca & Naik 2015, 11.)

However, due to the magnitude of data generated in a city, the privacy of citizens must be well respected. Emphasis must also be placed on the security of data collected in order to prevent data falling into the wrong hands.

3.3.2 Connectivity

The instrumentation process discussed previously is not complete without effective communication between devices. In recent times, the Internet of things (hereinafter IoT) has become a worldwide phenomenon where the physical world has become a type of information system itself (Mckinsey 2010). Devices embedded with sensors can now seamlessly communicate with one another without human intervention. A robust network infrastructure is needed to facilitate effective communication between devices. Cities can choose from a wide variety of communication channels which includes fibre optics, microwave transmission, Wifi and cellular. These communication channels will carry real-time data generated from sensors embedded in physical objects. (Al Nuaimi et al. 2015, 10.)

It is unlikely for any city to rely on a single communication system judging from the citywide solutions unified together in the Smart City ecosystem. Multipurpose communication channels offer cities more options and cost-saving measures than single purpose dedicated networks. Cities can collaborate with private companies to invest in building or maintaining citywide networks. (Smart Cities Council et al. 2015, 73.)

3.3.3 Interoperability

The heterogeneous nature of the Smart City ecosystem indicates that different technologies will need to communicate with each other. Interoperability as the name implies means products and services from various technologies or service provider are able to communicate with each other freely. Interoperability offers numerous benefits to the city. It helps cities avoid being ‘locked-in’ to a single service provider or equipment manufacturer. Another benefit is the opportunity to build projects in sizeable installments, with assurances that all products will work together seamlessly. Lastly, interoperability provides a city with increasing opportunities to choose from when deciding on products or services to purchase for a Smart City project. (Smart Cities Council et al*.* 2015, 26.)

As noted by Smart Cities Council et al*.*(2015, 26), Open standards are the key to interoperability. Open standard simply means standards which have been backed and developed by experts in a particular industry and open for all to use (Smart Cities Council et al*.* 2015, 75). Cities are in a better position to minimize expenses and control their risk when they adhere to open standards. However, there are many standards related to urbanization and implementing this might be a daunting task for cities (Smart Cities Council et al. 2015, 75).
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3.3.4 Security and privacy

The major challenge facing Smart City is the issue of security and privacy. Data generated from sensors and all other sources stand a big chance of containing confidential data about the citizens and government in general. This poses several risks to the entire city population if these data are compromised. It is important for cities to create policies and practices to protect citizens from unauthorised access to their data. (Al Nuaimi et al. 2015, 9.)

The government of cities should publish privacy rules for the city and make it public in order to reassure citizens that their rights are not being violated. The privacy rules should let residents of the city know which data sets are owned by the government or the residents. The rules should also inform residents which data sets are private and would require authorization before sharing it; which data can be shared with the city or any outsider such as a third party (Smart Cities Council et al. 2015, 78.)

Cities should implement a security plan into the design of services from inception. This document should be holistic and cover both cybersecurity and physical security of assets. The citizens ought to be educated on risky online behaviours that could make them vulnerable to cyber-attacks (Al Nuaimi et al. 2015, 9-11).

3.3.5 Data management

Smart City applications generate a prodigious amount of data in a variety of format from multiple sources such as buildings, traffic, energy, environment and people (Al Nuaimi et al. 2015, 10). Huge amounts of data are generated on a daily basis in real-time from citywide Smart City applications; they are collected and stored on reliable and scalable system for later analysis. In order to keep the confidentiality and integrity of data intact, a comprehensive and effective data management features need to be implemented (Al Nuaimi et al. 2015, 10-11).

In a Smart City ecosystem, data is regarded as a major asset and is made available to systems and stakeholders including the citizens. The integrity of the data needs to be safeguarded as it is used by different Smart City applications from various department. This data could be made public so developers can build Smart City applications that will benefit the residents of the city. The importance of data in creating successful Smart City interventions cannot be underestimated. (Al Nuaimi et al. 2015, 10-11.)

As stated by Al Nuaimi et al. (2015, 10), data management is a combination of policies, practices, architectures and procedures that accurately manages data through its entire lifecycle in a consistent fashion. Since data come in different formats and multiple sources, it is important that data are processed, aggregated and cleverly abstracted using advanced data management technologies. The city’s threshold to quickly respond to changes in real-time is greatly enhanced with an effective data management plan. This will also help cities save cost and quickly roll out new Smart City applications when the need arises. Most important of all is; A data management plan makes it easier for cities to enforce privacy laws, security and best practices. (Al Nuaimi et al. 2015, 10.)

3.3.6 Computing resources

The current financial climate is making city administrators explore cost saving measures when it comes to the provision of services in the city. The deployment of Smart City solutions will require substantial financial resources from the city budget. Computing resources will account for a large part of this budget. However, recent trends in the cost of acquiring computing resources are promising due to the sharp decline in the cost of cloud services (Business insider, 2014).

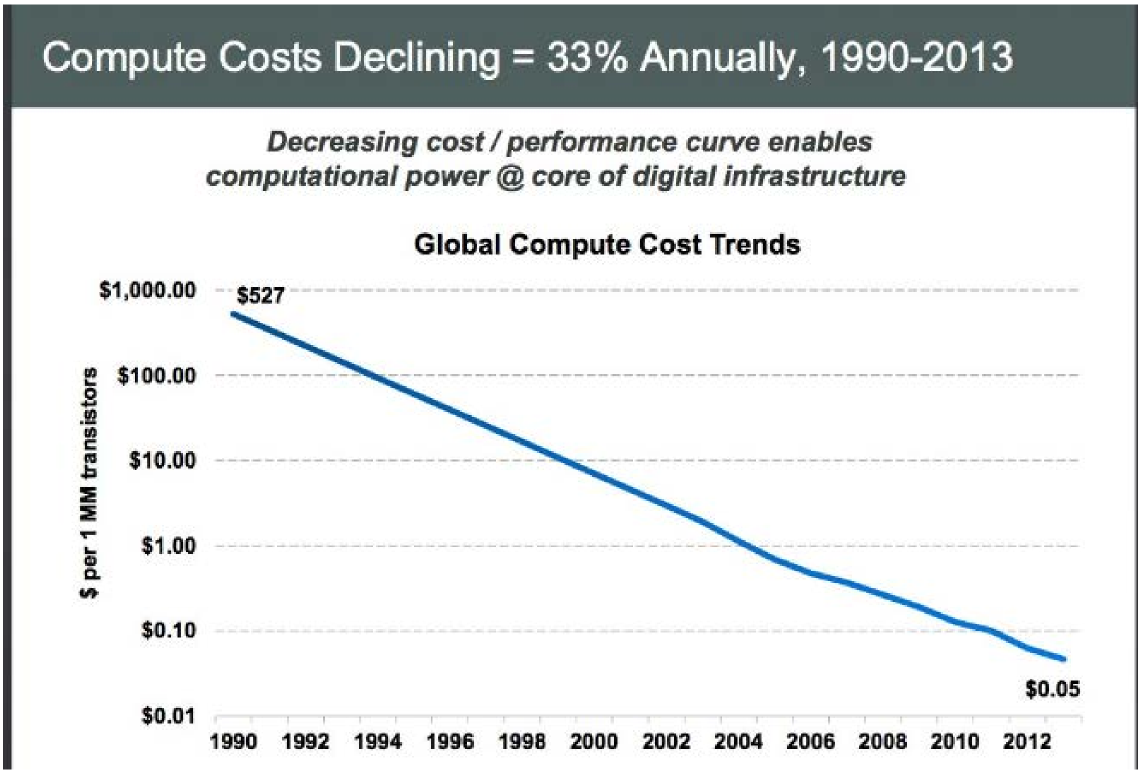

Figure 1. Compute cost decline (Business Insider 2014)

Figure 1 above shows the steady decline in the cost of computing power over the course of twelve years. This proves it is vastly beneficial to adopt cloud services in a Smart City project if cost is a major impediment than anything else. According to Smart Cities Council et al. (2015, 83), cloud computing framework is well suited for delivering efficiency and optimization in a Smart City. In their definition of cloud computing, IBM (2014) referred to the 'cloud' as "the delivery of on-demand computing resources- everything from applications to data centres- over the Internet on a pay-for-use service".

The important thing to note about the cloud computing concept is the fact that services are delivered over the Internet by a third party service provider. Some city stakeholders might not be confident of trusting data of residents of the city to a company that might be located offshore. However, cities can opt out to build their own cloud service utilizing the same architecture used by third party service providers. (Batty 2013, 275.)

Cloud-based Smart City solutions can offer cities several benefits such as secure identity service which provides workers in different department access to a consistent and secure single on. Cities can take advantage of virtualization features offered by most cloud providers. Virtualization is the process of accessing computer resources such as different operating system, servers and storage services virtually. Another important benefit is city management's visibility and control of all the services in real-time. The ability to scale up or down to the amount of data traffic in real-time is one of the major selling points of cloud computing. The cost of computing resources is drastically reduced as computing power can be bought on a need basis and be decommissioned when no longer needed- this is mostly accomplished as easy as clicking and dragging devices you need. (Batty 2013, 275-276.)

Cloud services offer small or cash-strapped cities the opportunity of using advanced features present in the big cities. It is difficult for small cities to afford the technical manpower to maintain data centers should they decide to shun cloud services.

Open Data is taking the Smart City concept in new directions. President Barack Obama (White House 2013), described Open Data as "the new default for government information". As the economy of most countries continue to experience a decline, causing governments to implement austerity measures. Citizens are beginning to demand more accountability from their government (Smart Cities Council et al*.* 2015b, 1). Cities collect massive amounts of data from any city activity under their authority such as data from business ownerships, tax payments, marriage licenses, building permits, pet ownerships, water and energy data, abandoned buildings to disease outbreaks (Smart Cities Council et al. 2015b, 3).

The digitisation of every aspect of our lives has even permeated into how cities are managed (Deloitte 2015, 3). City records which existed in paper form for decades have witnessed increased digitisation. The adoption of computers into every fabric of our existence made this transition easy to accomplish. Presently, cities are publicly releasing government data in a move to be more open and transparent. The open data movement will also spur innovation. It provides developers, architects, students and residents alike, the opportunity to develop solutions to societal problems affecting the city. Open data is a major enabler of the Smart City concept. (Deloitte 2015, 3-5.)

Another valuable computing resource which is beneficial to Smart City is a geographical information system (hereinafter GIS). GIS is the process of mapping spatial coordinates to reference city assets and location information (Smart Cities Council et al. 2015, 89). This is synonymous to a database specifically made to store maps to city assets. GIS is one of the technologies that makes a city smart. It combines massive amounts of data all linked by their latitude and longitude (geographical information) which helps to quickly see patterns and draw meaning from data. For instance data from air pollution sensors in the city can be easily used to check the health conditions of people living in areas with high rate of air pollution. This will help city administrators to take action on neighbourhoods with high records of pollution. (Al Nuaimi et al. 2015, 4.)

GIS has a lot of great application in a Smart city such as mapping city crime data, locate leakages in pumps, pipes and faulty power cables and enhance traffic flow to aid up to the minute traffic information.

3.3.7 Analytics

Analytics can be regarded as the most important ICT enabler for a Smart City. Analytics derive data from instrumentation devices. Analytics utilize data from different departments in the city and sieve through these data to find insights. This section will not go into details about big data and analytics but will discuss what can be achieved with analytics in a city.

Analytics allow city administrators gain full knowledge of what is happening in every sector of the city. Through advanced analytics technology, it is possible to have real-time knowledge of what is happening in different city services through a dashboard. This dashboard provides a visual representation of different services in the city through advanced analytics. For instance, the pollution metrics in every neighbourhood in the city can be represented in a graphical way on the dashboard in real-time. This can be referred to as situational awareness. Situational awareness has several benefits in that it helps city administrators know the situation on ground before taking action. This knowledge saves time, money and even lives. (Smart Cities Council et al. 2015, 91.)

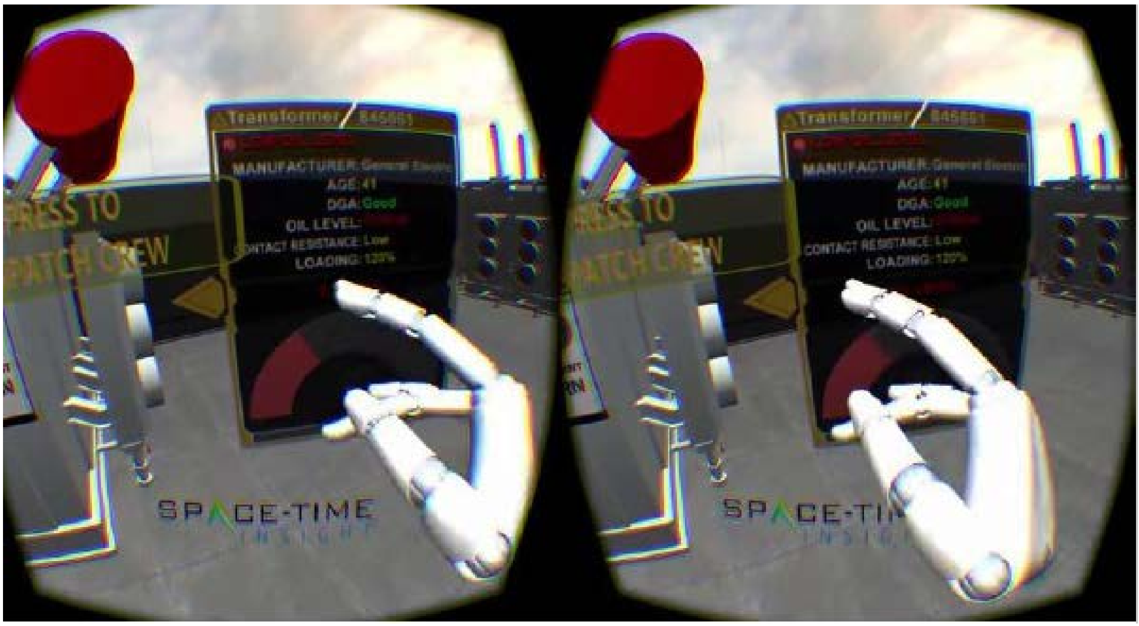

Image 1. Real-time visual analytics (Smart Cities Council et al. 2015, 91)

Image 1 above shows the utilization of real-time visual analytics and what transpires when the combination of virtual reality and big data is used to demonstrate situational awareness in a power substation. The demonstration was performed using an Oculus virtual reality headset to visualise a power station. The headset lets users access the power plant and check the status of power equipment ‘virtually’ and carry out corrective actions in real-time. (Space Time Insight 2016.)

In the Smart City of tomorrow, through advanced data analytics, it will be possible to achieve both operational and asset optimization. This simply means taking steps to arrive at the best decisions to give the best results. Operational optimization is achieved when data analytics is used to analyse data from different sensors with the combination of computing power to arrive at the best result in real-time. The implication of this is zero unplanned downtime, reduction of operational budget, effective remote monitoring and better outcome to the city and people. Advanced analytics also help cities achieve full asset optimization. This is done by rigging city assets such as water pipes, electric transformers, poles, roads with sensors that report their condition. Utilizing asset management systems analyse the data from city assets in order to maximize their lifetime value. For instance, city-owned assets such as buses can undergo maintenance, not on a guess or fixed schedule but based on their actual condition. This will make cities move from the usual scheduled preventive maintenance on city assets to ‘predictive’ maintenance. (Smart Cities Council et al. 2015, 92-94.)

It is true that cities can make decisions based on data from different city assets but the value derived from the data can still be utilized further (Glaeser, Kominers, Luca & Naik 2015, 1). Using already available data to predict future outcomes or scenario is one of the powerful aspects of analytics. Through predictive analytics, cities can quickly predict what is likely to happen in the nearest future based on the data in their possession. Instances where a water pipe experience a leakage can be easily predicted even before it happens. The purchase of certain merchandise such as illegal arms can easily let cities predict that a crime is about to happen and quickly take actions against the would-be perpetrators. Cities are now forecasting what happens to city assets and services in future just the way the weather can be predicted with almost 99 percent accuracy. (Glaeser, Kominers, Luca & Naik 2015, 1-3.)

4 BIG DATA AND ANALYTICS

This research work aims to review the potential of big data technologies and its application in Smart Cities. To present the potentials of this technology, the concepts of big data and analytics are described in this chapter. A brief description of big data and its evolution are explained. Additionally, in-depth study of data-generating sensors which collect data from the physical environment is explored. Finally, the different city responsibilities that big data and analytics are making smart are discussed.

4.1 Big data

In recent years, there has been an increasing interest in non-traditional and less-structured data from sources such as social media, weblogs, sensors and photographs. Declining cost of cloud computing services has made it possible to collect this data and mine valuable information from it. Organizations that adopted big data technologies recorded two-fold profits than their competitors. (Oracle 2013, 2.)

The big data concept has several conflicting definitions which further explains its ambiguity. According to Mckinsey (2011, 1), big data can be described as a massive volume of data which exceeds the capabilities of the traditional database tools to collect, store and analyse the data. Mckinsey also acknowledges the subjective nature of the definition and it can vary by sector. Another important definition is given by IBM (2016), “Data, coming from everywhere; sensors used to gather climate information, posts to social media sites, digital pictures and videos, purchase transaction record, and cell phone GPS signal a few”. This definition is encompassing as it signifies that data can be collected from virtually both nature and human activities. However, businesses have leveraged on the troves of data generated every second to make faster data-driven decisions in real-time.

According to Forbes (2015), 300 hours of video content are uploaded to YouTube every minute. This massive growth in online video and photo data is proof that traditional ways of consuming services have changed rapidly. The main challenge of big data is not the size of the dataset but lies in its utilization. Data analytics is used to derive value from petabytes of data generated on a daily basis from several sources. This opens up new frontiers for businesses and city governments alike to leverage the opportunities provided by big data and analytics. The proliferation of smartphone devices has witnessed an increase in mobile applications designed for city services. This monumental shift is the foundation of the Smart City concept. (Minelli, Chambers & Dhiraj 2012, 5-6.)

4.2 Sensor Technology

A sensor is a device that receives an impulsive action and reacts to an electric signal (Fraden as cited by McGrath, Scanail & Nafus 2013, 15). This definition is a general perspective of what can be classified as a sensor. There is no standard definition of a sensor. It is mostly defined based on its functionality in an application. In a Smart City, data-generating sensors are utilized to retrieve data from the physical environment. Big data technologies such as Apache Hadoop and Apache Cassandra are used to derive meaning from these data. Sensors can be utilized in measuring or detecting a broad collection of physical, chemical, and biological quantities, such as chemicals, gases, light intensity, motion, position, sound and several others. (McGrath, Scanail & Nafus 2013, 15.)

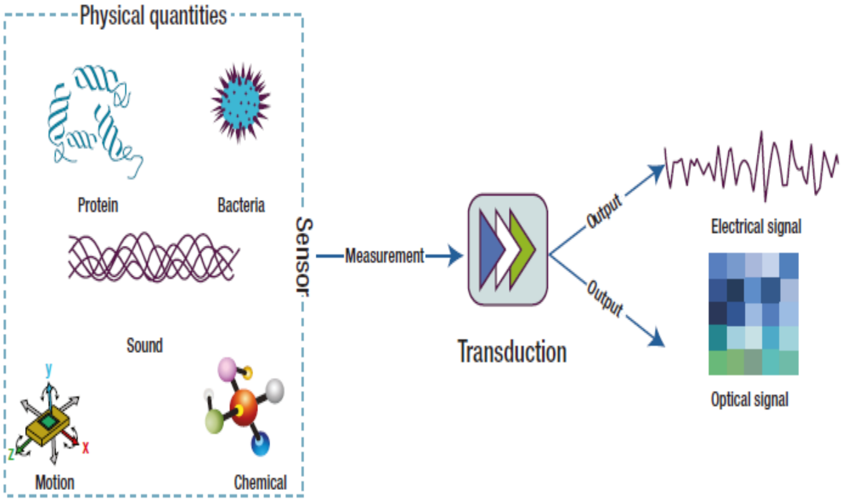

Figure 2. The sensing process (McGrath, Scanail & Nafus 2013, 15)

Figure 2 above illustrates the sensing process. Measurements from sensors go through conversion by a transducer which translates it to a quantity of interest understood by the physical environment or an observer. In this section, only sensing technologies for Smart Cities is reviewed.

4.2.1 Accelerometers

Motion sensing is comprised of five different modes which include acceleration, shock, tilt, rotation and vibration. The only mode of motion sensing not measured by an accelerometer is rotation. Without a doubt, the accelerometer is the most widely used sensor in capturing data from the physical environment. Accelerometers are made to be rugged especially when the goal is to achieve a high-frequency response. In Smart City applications, accelerometers can be used to collect data about the vibration of bridges in the city. Tornio municipality has bridges that connect different parts of the city together. Data from the accelerometer can be analysed using data analytics to determine car traffic on the bridge in real-time. The accelerometer can also be used to monitor the fleet of transportation buses in the city to determine their location in case of a mechanical fault. Apart from the location of buses, the accelerometer can also collect data on buses that are over speeding in areas where school children are crossing. (Engineers Garage 2012; McGrath, Scanail & Nafus 2013, 21)

4.2.2 Photodetectors

Photodetector sensors are implemented in applications that will require light to function. It is based on the principle of photoconductivity, where an element’s conductivity changes when exposed to light or when the light is not detected. Photodetector sensors work by detecting waves in the range of optical wavelengths from ultraviolet to infrared waves. The utilization of photodetector sensors can vary in different application. (McGrath, Scanail & Nafus 2013, 22.)

The notable use of photodetectors in Smart City application includes that used in active pixel sensors for webcams used in telepresence applications. In telemedicine, citizens use webcams to converse with doctors in real-time to give a feeling of being in a doctor’s office. This is also utilized in a situation where students are home schooled and does not require contact lectures. Photodetector sensors can also be found in room lighting, where the light automatically switches on when the presence is detected and automatically switches off when no presence is detected. Photodetector sensors are also used in the dimming of light in a room when the number of people in a room is scanty. Light dependent resistors which are used in street lighting use photodetectors to detect the presence of a target and switches on and off automatically. (McGrath, Scanail & Nafus 2013, 22.)

In Tornio municipality, the use of photodetector sensors are already implemented in schools such as those found in the toilets of Lapland University of Applied Sciences. Residential homes also utilize photodetectors for lights in staircases and perimeter fences.

4.2.3 Infrared sensors

Infrared sensors (hereinafter IR) sensors exist in both the active and inactive state. In the active state, the sensor utilizes a light-emitting diode (hereinafter LED), which beams light directly to a different detector such as phototransistors.

Anytime an element passes through the light beam it interrupts the receptor signals at the detector’s end. A beam of light projected from the IR source point is reflected from an element as it passes into the infrared sensor’s line of sight. The reflective nature of the element’s surface determines the amount of light received. IR sensors have several applications in a Smart City, common areas of application include people counting sensors, infrared CCTV and automatic doors. IR sensors functionality extends beyond daytime only but works perfectly at night too. (Engineers Garage 2012; McGrath, Scanail & Nafus 2013, 22.)

Unlike active sensors, inactive sensors do not rely on any form of energy to trigger detection. Inactive sensors depend on the heat radiating from an element, such as human bodies in its line of sight. Inactive or passive sensors are used to detect intruders in a highly secured urban space. (Fried, 2012 as cited by McGrath, Scanail & Nafus 2013, 22.)

Tornio municipality can benefit from IR sensors in a couple of ways. IR sensors can be used to automatically count people entering a public space and the data is stored in a database. Big data analytics can extract meaningful information from this data such as predicting the number of people that is expected to visit the local mall in a festive season. IR CCTV can see objects in the dark and this is most useful for surveillance in the city in areas where the streetlight is poor or not available. However, IR sensors can already be found in the automatic doors at Rajalla mall in the city centre.

4.2.4 Gas sensors

Gas-monitoring semiconductors can be used to detect several harmful gases. Carbon monoxide detection in homes is the most widely used application of gas monitoring sensors. A regular gas sensor has an enclosure housing the sensor base and also a sensor layer which includes a metal oxide semiconductor layer. The process of sensing occurs, when the metal oxide heats up to a maximum temperature of air. This produces an obstruction against the free flowing of electrons. This process triggers the sensing layer to detect gases in the atmosphere. (Engineers Garage 2012; McGrath, Scanail & Nafus 2013, 25.)

The gas sensors have several advantages which include long lifespan, relatively low cost and maintenance. However, gas monitoring sensors find it difficult to differentiate specific gas in an atmosphere filled with different gases. To solve this issue and increase the sensitivity of the gas sensors to a particular gas, chemical filters are used to filter the wanted gases away from the sensing layer. (Engineers Garage 2012; McGrath, Scanail & Nafus 2013, 25.)

Tornio municipality can install gas sensors in specific areas of the city to collect data on air pollution in the city. Data analytics software can find a correlation between gases high in the city and merge that information with airborne diseases in the municipality. Gas sensors also help the city to monitor greenhouse gas emission coming from the residence, companies, and automobiles.

4.3 How Big Data is making Cities Smart

Big data has far-reaching opportunities to utilize data in the process of service creation and provision in a city. According to Deloitte (2015, 4), organisations that adopted big data to make decisions outperformed their competitors by a margin of up to 6%. Cities can also leverage big data technologies to stay competitive in the global economy. However, in developing cities, the acquisition of data is still a manual process. In more advanced cities, the use of data analytics to enhance service delivery and eliminate bottlenecks by extracting data from different unified sectors such as assets and workforce is recording massive economic benefits. This section examines the different responsibilities of the city of Tornio that big data and analytics can make smart.

4.3.1 Built Environment

Buildings are an indispensable component of a Smart City infrastructure. According to Smart Cities Council et al. (2015, 97), buildings are the major source of carbon emissions in a city- accounting for about 40% of greenhouse gases in the world. City administrators that are concerned with providing a sustainable, livable and workable environment for the residents are paying attention to contemporary innovations in the built environment.

The term built environment is concerned with buildings but also refers to public spaces, parks and sports centres such as stadiums. Buildings are an essential part of any city from schools to restaurants, offices, factories and private homes. The increasing use of ICT to control and monitor buildings is popularly being referred to as a smart building. Smart buildings utilize sensor technologies to monitor and control different aspects of the building such as lighting, water, power, surveillance, fire, motion and elevator monitoring. All integrated back into a building management system (hereinafter BMS). (Suzuki 2015, 1.)

According to Suzuki (2015, 1), advancement in IoT and digital technology has necessitated the need to collect information from the physical environment which ultimately leads to reliance on automated machine-to-machine (hereinafter M2M) interactions. However, data collected from buildings can sometimes be overwhelming, resulting in a disconnect between users' needs and the devices that generate these data. Suzuki (2015, 1) suggests that the major concern should be on interoperability of emerging technologies and data management tools. (Suzuki 2015, 1.)

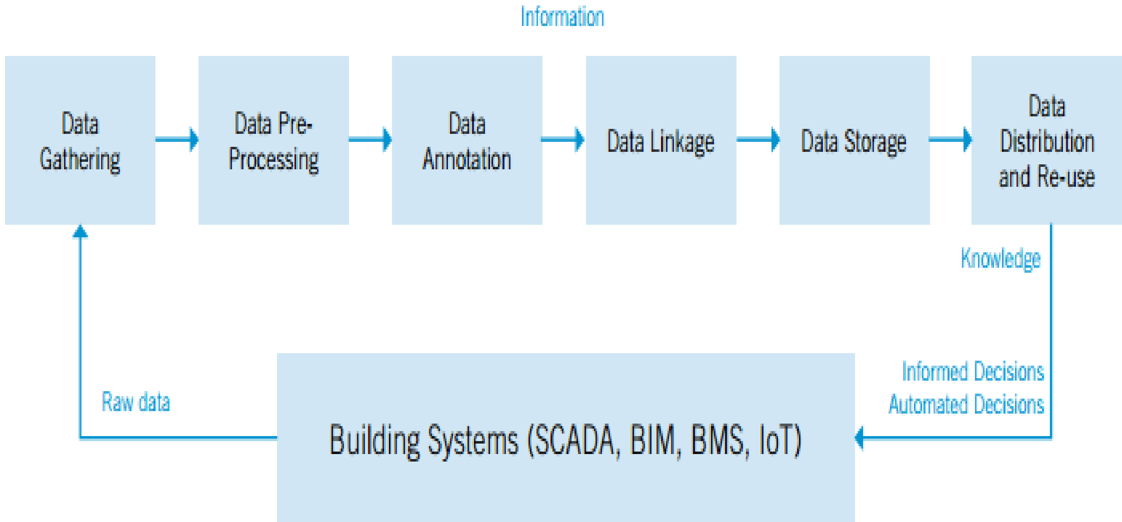

Figure 3. Data Integrations in Buildings (Suzuki 2015, 2)

Figure 3 highlights the process of data integrations in buildings. This figure starts with data gathering from sensors that collect data in buildings and facilitate interactions between systems. The next phase is pre-processing which analyses the quality of the data, history, origin and ownership. Annotation has to do with giving the data a description (metadata). For uniform access to the data, the metadata must be semantically annotated in a standard and established format. Once the data has been annotated, it is linked with previously collected data in the repository and this is the point where duplicate data are eliminated. The data is now set for reuse and the data is transformed into knowledge. The upheaval challenge exists in the effective ways to manage the entire process in a manner where the data is easily stored, processed and reused across different systems and injected back into the smart building system to produce informed and real-time decisions. (Suzuki 2015, 2.)

The most prominent challenge in implementing digital technologies in built environment is for stakeholders to establish a clear purpose and vision for the project aligned with the needs of the city. Building information modelling (hereinafter BIM) is gradually becoming a common practice in construction projects. BIM incorporates important product and asset data coupled with a three-dimensional computer model that can provide ways to effectively manage the information of buildings throughout a project lifecycle, from the conception phase through to operation. BIM goes beyond software and analytics but deals with processes, governance and interactions among key stakeholders. (Schwarzenbach & Tomkins, 2015, 2)

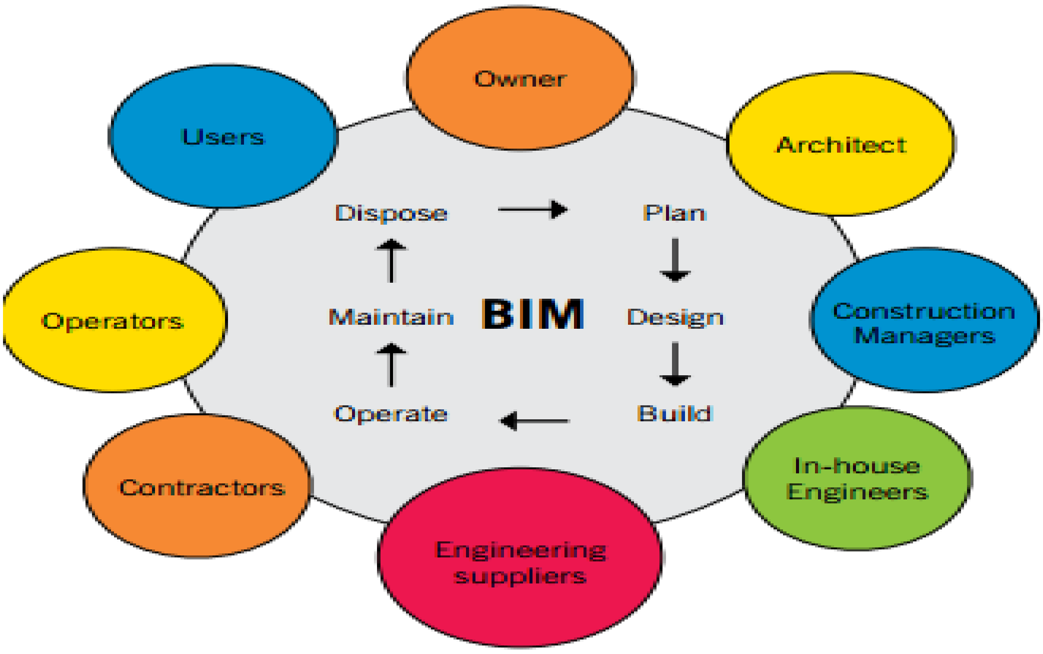

Figure 4. Illustration of BIM stages and key stakeholders (Schwarzenbach & Tomkins, 2015, 2)

Figure 4 above outlines the different stakeholders that need to be involved in order to satisfy the clients requirements in a building project. The plan of the building is first proposed to the different stakeholders. The design phase of the building includes architectural modelling of the building both on paper and on the computer. The following phases of build, operate, maintain and dispose all follow guidelines from the planning and design stage.

Smart buildings can improve occupant's comfort by using situational awareness to optimize the condition of the building. People spend a considerable amount of their time indoors, Smart buildings can tailor the condition of each room to occupant's desire. This means occupants can have different temperature conditions in the same room of the house. Smart buildings make use of sensors to collect data on people, adapting to occupants' needs and intentions in order to provide personalized services in real-time without the user physically controlling the system (Jarvinen 2015, 42).

The city of Tornio can implement a key policy framework for the construction of buildings in the city. This policy will address key technologies that every building erected in the city should possess. The city government can go a step further by implementing BIM in government-owned buildings so as to set precedence for future construction of buildings in the city.

4.3.2 Energy

Energy is an integral part of any city’s responsibilities and has a far-reaching effect on the quality of life of the citizens. An impressive measure of activities in the city depends on energy such as transportation, heating and business transactions. Energy accounts for the largest source of greenhouse gas emission. The increasing demand for the utilization of energy resources is at an all-time high because of increasing population and economic output. The importance of energy for the optimal functioning of a city has facilitated innovative ways of managing and distributing this scarce resource. (Airaksinen, Mäki, Peltonen & Pakkala 2015, 56.)

The adoption of data analytics in the energy sector has increased the possibilities of getting real-time information from instrumentation devices such as smart metres and sensors. The utilization of instrumentation devices permits service providers with the opportunity to identify issues in energy transmission and implement measures that would have ordinarily caused service disruption. This is accomplished by installing smart metres at the customer’s premises in order to transmit energy usage information to the utility of the service provider. (Airaksinen, Mäki, Peltonen & Pakkala 2015, 56; Smart Cities Council et al 2015, 130.)

Sensors and smart metres generate massive amounts of data when used in energy transmission in a city. Big data and analytics provide real-time energy consumption to residents which can be accessed through a web portal or through a smartphone application. This open and transparent approach enlightens energy users such as residents and business owners about their energy usage in real-time. This way, residents can make adjustments in energy consumption to reduce payment in utility bills. Additionally, this cost-saving measures also applies to service providers as it facilitates effective monitoring of their energy installation across the city. Fault detection can easily be detected and ageing systems that are approaching their lifespan can be quickly replaced without causing service disruption. (Smart Cities Council et al 2015, 132.)

However, it remains unclear if all the household in Tornio municipality has a smart metre installed in their premises but the benefits can never be underestimated. According to Al Nuaimi et al.(2015, 8), smart energy “allows forecasting in a near-real-time manner through efficient analysis of the big data collected”. Predictive analysis helps cities prepare for unexpected events that might have otherwise caused economic losses. Another benefit is the flexible pricing models in relation to energy supplies, demands and production models (Al Nuaimi et al. 2015, 8).

4.3.3 Transportation

Transportation is an important aspect of any Smart City plan. In major cities around the world, traffic congestion is, unfortunately, an unwavering malaise which cannot be wished away. The use of sensors to collect data from transport vehicles further increases the effectiveness of the transport system in the city. However, for transportation to be smart, reliable power and robust communication networks must be present.

The implementation of instrumentation devices such as roadway sensors and global positioning system (hereinafter GPS) trackers to capture data from vehicles and all other transport infrastructure. Data are gathered and analysed from the different mode of transportation in the city. Cities armed with this type of data have a better understanding of the multimodal traveller behaviour and seamlessly adapt to it using big data and analytics tools. (Smart Cities Council et al 2015, 177.)

Achieving full situational awareness is the major reason big data and analytics have a phenomenal impact in transforming industries. When data has been aggregated from different transportation modes, data analytics provide insights to transport managers with a holistic view of the transport situation in the city in real-time. This allows cities to avert congestions and quickly respond to incidents that might have a major impact on the free flow of traffic in the city. (Smart Cities Council et al 2015, 177.)

Data analytics let cities achieve full optimization of the different modes of transportation in the city. For instance, when a mode of transportation such as the train shuts down, commuters will naturally explore other means of transportation. In such situations, data analytics quickly equip commuters with information on the best mode of transportation and alternative route to their destination. Data analytics provide cities with proactive and actionable data that allows the city to save on man-hours otherwise wasted in traffic gridlock and invariably increase the city's economic gains. (Smart Cities Council et al 2015, 186.)

Predictive analysis can also be used to manage certain transportation assets of the city. A city that owns a fleet of buses can use predict analysis to perform maintenance on their buses. Predictive maintenance provides a city with data about the condition of their transportation assets and thereby prevents buses from breaking down during operation. Analytics can also be used to study the behaviour of commuters to influence pricing models based on times of the day when the transportation service is used most frequently. (Xerox 2012, 3;Smart Cities Council et al 2015, 186.)

In Finland, a new way to consume transport services is gaining traction. Mobility as a service (hereinafter MaaS) is a combination of different transport options from different transport providers including travelling plans and payments. It uses an intuitive application to help commuters pay for transport services on demand in the most convenient and smart way. MaaS has the potential of helping citizens spend less on transport needs by eliminating the use of personal cars and promoting a demand-based transport service. (MaaS 2016.)

The city of Tornio, like any other city, has compelling reasons to optimize its transport services. Tornio is a major transit point to the north of Finland and also a border town with Sweden. Having an effective transportation system is not only a goal to be achieved but a need to be fulfilled.

4.3.4 Water Services

The importance of water does not need to be reiterated. Water is essential for the sustenance of human life i.e. consumption, agriculture and generation of electricity. According to a UN report on water (UN 2015, 11), 40% of global water shortage is expected to happen in the year 2030. There are several factors responsible for the shortage of water to urban areas from droughts to declining water quality, aging infrastructure, agriculture and recreation. (UN 2015, 11; Smart Cities Council et al 2015, 193.)

When ICT is used to enhance water supply in a city, the resulting effect is a water system which is not only potable but efficient and sustainable. The smart water system is the future of how cities are combating the harsh reality of the issues facing water bodies. Water is scarce due to increasing flood and population. Global warming is causing water bodies such as lakes and rivers to dry up. Water is presently under-priced and the reality will only be apparent when water becomes scarce in the future. The water system used in most cities is inefficient and will only lead to wastage and mismanagement. (Smart Cities Council et al 2015, 194.)

There are different ways ICT can contribute to water management in a city. The physical infrastructure of the water system can be spread citywide. Efficient mapping provides city administrators with a holistic picture of the location of the pipes and valves in the city. Survey-quality GPS, electromagnetic groundpenetrating radar and acoustic technology can produce a three-dimensional map of water pipes laid underground and with high precision locate leakages in pipes. Smart water metres can also alert users of their daily or monthly usage of water in the household. (Smart Cities Council et al 2015, 194.)

Sensors placed in strategic points are used to detect water pollutants. The acidity, alkalinity, heavy metals, chlorine and biological contaminants can be monitored by sensors. The system immediately sends an alert to operators when any impurity is detected in order to quickly implement safety measures to prevent waterborne diseases in the city. Data analytics can help cities better manage floods and equipment failures through graphical dashboards which can enhance the knowledge of water infrastructures in the city. (Oracle 2015, 7.)

4.3.5 Health Services

The proliferation of mobile applications to monitor sleep, walking activities, weight, blood pressure and general health condition will not decline anytime soon. Cities spend a substantial amount of the city budget on the health of its residents. Sensors are installed citywide which monitors air quality, noise pollution, ultraviolet radiation and disease outbreaks. Residents can also share certain information about their health status through a mobile application. Data from residents can be analysed and used to make decisions in critical instances when there is a disease outbreak.

The data generated in health services of a city is massive. Residents through feedback, give data through devices which capture data from the patient’s body or the environment. Telemedicine is another technology which is poised to change the way healthcare services are delivered in a city. According to Microsoft (2016), Telemedicine or Telehealth is the “remote provision of clinical services via technology”. This technology affords residents access to health services from the comfort of their homes and saves both time and money. (Smart Cities Council et al 2015, 245.)

The prevalent use of monitoring devices in advanced societies help collect important information from the residents. The use of big data and analytics help cities achieve full situational awareness by matching different data from different sources to make important decisions based on the health of residents. Effective analytics has helped health providers to avoid human errors which have led to many deaths in the past. These inefficiencies are usually due to factors in human control such as collecting, sharing and utilization of data. (IBM 2012, 2-4.)

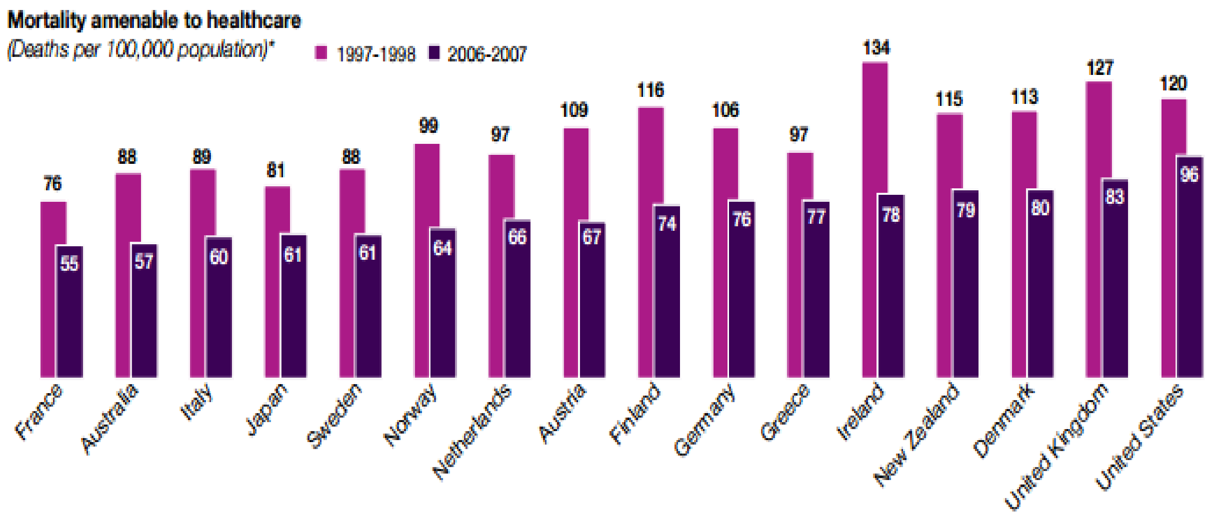

Figure 5. Clinical outcomes remain suboptimal in many nations (IBM 2012, 2)

Figure 5 above, shows deaths in different countries per 100,000 people which were attributed to errors from healthcare professionals. According to the figure, 74 people per 100,000 die annually in Finland from conditions liable to inefficiency by healthcare professionals.

Analytics provide better insights to city governments by highlighting areas where attention is needed most. For instance, a sharp increase in the number of lung cancer patients in a certain locality can help healthcare officials narrow down the cause to the massive air pollution experienced in that area. By using predictive analytics, health officials can always predict where in the city a disease outbreak will strike next by monitoring the path. Predictive analytics can also help residents understand and predict their own health and take active behavioural changes to achieve optimal health. (IBM 2012, 2-4; Smart Cities Council et al 2015, 252.)

The privacy of data of residents requires strict government policies to assure residents that information they share through different channels is safe and protected. City governments should publish privacy rules for the entire populace in order to let residents know they have measures in place to protect their privacy. A security framework to combat threats from cyber attacks which have risen in recent times against online public services is also required. (Smart Cities Council et al 2015, 247.)

The city of Tornio can benefit immensely from the implementation of big data analytics in healthcare service provision in the municipality. The ageing population in the city can benefit from telemedicine from the comfort of their home. Predictive analytics can help residents understand their health and how current risk behaviours will affect them in the nearest future. Proper education of the residents on health practices can be disseminated through intuitive mobile applications personalized to every resident.

4.3.6 Public Safety

Public safety is a major priority of every city government, to keep residents from harm and provide a safe environment for all that have come to work, live and connect with the city. Present realities show public safety is not confined to armed robbery or burglary alone it encompasses any occurrence that threatens the safety of the residents. It could be the likelihood of wildfire, storms, earthquakes or even a dangerous animal on the loose.

The use of ICT to enhance public safety makes use of data to arrive at better decisions. There are several ways a data-driven society helps to improve public safety. Generating public safety is not enough to create intelligence, it has to be merged with other sources of information. This requires data sharing among different city departments in order to build a wealth of city intelligence which aids the work of security agencies. (Smart Cities Council et al 2015, 264.)

In a city, data gathered for public safety is generally obtained from surveillance devices such as closed circuit television (hereinafter CCTV), facial recognition devices, audio and pressure sensors. Surveillance devices can also be combined with all other city infrastructures used for other services. Cloud computing resources are needed for storage capabilities which should be accessible in real-time by different departments. Another important resource for security agencies in the city is social media. Social media data holds a lot of information and if carefully mined can hold actionable data that can be used by security agencies.

Big data analytics equips city governments with information that can be used to make data-driven decisions. Cities can make use of command centres in order to achieve full situational awareness of what is happening in every part of the city. In the event of a crime or disaster, command centres can effectively be used to deploy incident response team around the city without fail. This will not only let cities achieve situational awareness but will help to reduce response time drastically. Predictive analytics can give cities actionable data which can be used to forestall a crime right before it is committed. The Department of Special Investigation in Thailand commissioned a Microsoft big data solution using Microsoft SQL Server 2012 and Apache Hadoop to automate data collection in crime scenes and easy access to information from the city’s database. (IBM 2016; Smart Cities Council et al 2015, 270-275.)

In summary, the city of Tornio can leverage big data analytics to reduce capital expenses on security by preventing and resolving crime before they happen. Data analytics also helps the city in minimizing expenses spent on the prosecution of offenders. The competitiveness of the city as a place to do business will increase as most investors consider public safety for its workers and infrastructures as an important factor. The real estate sector of the city will experience incremental growth annually as families prefer a city with low crime rate and safe to raise kids.

4.3.7 Waste Management

Solid waste generated in cities around the world is already exceeding the rate of urbanization. City governments are constantly searching for innovative and sustainable methods in tackling waste managements in their municipality. According to the World Bank (2012, 9), 1.3 billion tonnes of solid waste is generated annually in the world and it is projected to increase to 2.2 billion tonnes by 2025. Solid waste if left unattended to can cause serious implications to the city, least of which are diarrhoea, flooding, air pollution and respiratory disorders. (World Bank 2012, 9-11.)

Advancement in waste recycling technology is compelling municipalities to start viewing waste as an asset. Innovative ways of recovering materials and energy from waste are being popularized by advancement in ICT. This shift of viewing solid waste as a problem but as an asset to be reorganized and returned to the marketplace is welcomed by city governments. City governments now view solid waste as a revenue source by selling waste materials to companies that process garbage into marketable products. (Smart Cities Council et al 2015, 218.)

Smart waste collection is the process of implementing ICT in collecting waste materials in a city. The use of trash cans embedded with sensors enables the waste management authority in a city to effectively track trash cans. The level of waste in a trash can be monitored from a central location. Garbage trucks are easily dispatched to households or establishments with filled garbage cans. This enables the city to cut down on the number of trips by garbage trucks. Sensor fitted trash cans also make the job of the truck drivers efficient while cutting down on green gas emission.

Radio Frequency Identifier (hereinafter RFID) tags have also been implemented in garbage collection. The RFID tags are placed on bins and the garbage trucks are also fitted with a mechanism to read information from these tags.

Information about the weight and composition of the garbage is sent to a central database which is later analyzed to establish correlations and trends about garbage from different parts of the city. This type of information lets waste managers anticipate the level of waste to be collected in an area and plans can be made on the size of trucks to be dispatched. This enables the city to utilize fewer trucks, reducing cost and cutting down emissions coming from too many garbage trucks. (Shahrokni; van der Heijde; Lazarevic; Brandt 2014, 2 & Smart Cities Council et al 2015, 220.)

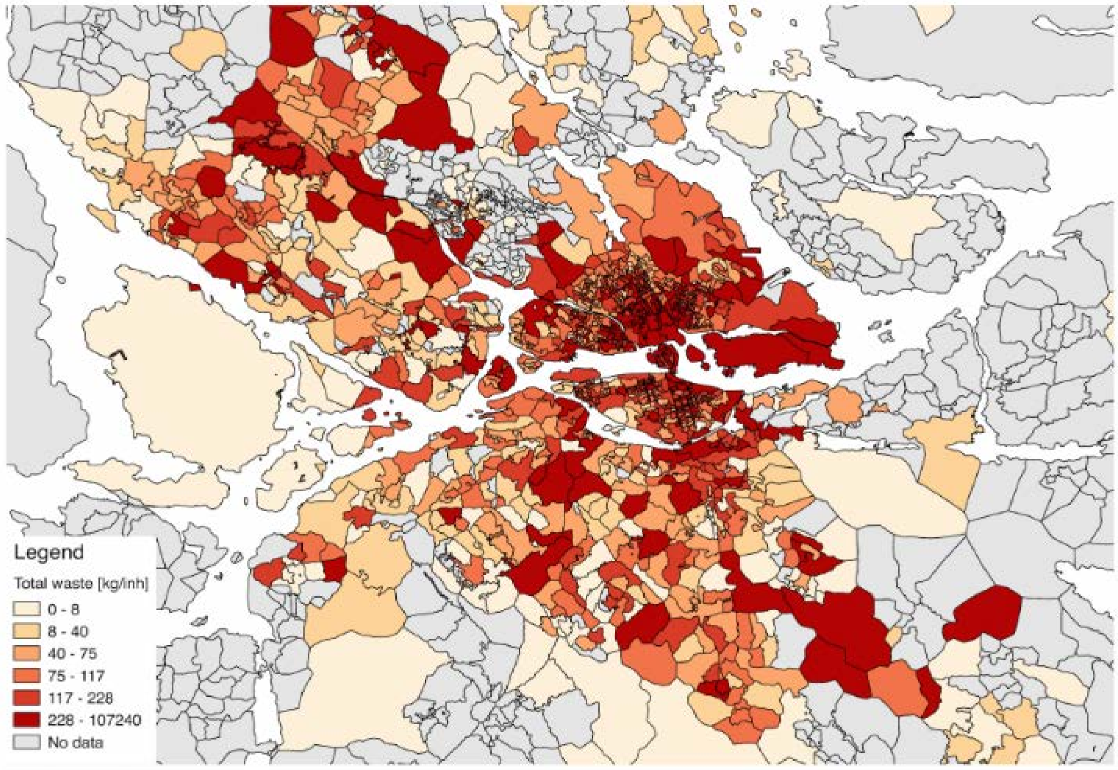

Figure 6. Dataset aggregated per zip code (Shahrokni; van der Heijde; Lazarevic & Brandt 2014, 2)

As shown in Figure 6 above, waste data visualisation from every zip code in Stockholm. The waste per capita in every zip code is meticulously illustrated in the map. This map clearly shows that massive amount of waste per citizen comes from cities in the centre and considerably large amounts are also found in the southern part of the map. (Shahrokni; van der Heijde; Lazarevic & Brandt 2014, 2)

Another essential technology in waste management is the utilization of GPS in tracking of garbage trucks. This enables waste management authority in the municipality to monitor drivers' behaviour to determine if drivers are adhering to designated routes, garbage pick-up schedules and driving within the speed limit instituted by the waste management authority. For instance, the ancient city of Porvoo in southern Finland had waste management issues which were tackled using ICT. The city of Porvoo is usually filled with tourists during summer which accounts for the sudden increase in refuse in the city. The city embarked on a Smart City solution to tackle the problem by installing wireless fill-level sensors at recycling plants. The system enables forecasting of when waste bins are filled. Traffic and vehicular information are also analysed to suggest best routes to truck drivers in order to curb emission in the city. (Smart Cities Council et al 2015, 221.)

Tornio municipality already has an effective waste management system. Trucks have scheduled times to pick up waste from different neighbourhoods in the city. However, this system can be enhanced a step further by implementing sensor, RFID and GIS to the city waste management process. Garbage cans fitted with fill-level sensors communicates its fill status to the waste management authority. Advanced GIS enables the waste management authority to plan the best routes for garbage truck drivers. Predictive analytics facilitates accurate forecasting of waste collection periods. Implementation of this will reduce collection times by almost 50%, minimize multiple trips by truck drivers and help the city save on operating expenses.

5 ANALYSIS OF EMPIRICAL DATA

The empirical part of the research work was based on qualitative research method employing the questionnaire survey approach. The chapter is divided into two sections; the first section will analyse data from the interview and the second section will present analyses to the data collected from the questionnaire survey.

The questionnaire technique is employed to reach the residents of the city of Tornio. The respondents were given the questionnaire in paper form. The main reason for using the paper form was due to the fact that it was impossible to get hold of the email addresses of residents of the city. Another reason was to get the opportunity to meet the residents of the city and ask for their consent in answering the survey questions. The paper questionnaire technique might seem archaic in the age of digital technology but it was the only opportunity of meeting the people who the Smart City concept is intended for. The major challenge of using the paper form of questionnaire survey was to get the attention of people. The questionnaire targeted people living in the city of Tornio but opened to people living in surrounding cities such as Haparanda who make use of citywide services in Tornio. The respondents had basic knowledge of the English language and, therefore, the questions in the survey were designed with the respondents in mind. The survey includes a total of 10 questions; 7 multiple choice questions, 2 yes or no question and an open-ended question.

The survey was given to random people in the city centre of Tornio. The survey was also given to respondents in a unisex hair salon in the city centre which afforded respondents the opportunity to answer the questions from the comfort of a swivelling chair at the salon. A total number of 51 respondents answered the paper based survey questions. The data was inputted manually into an Excel workbook to analyse and visualise the results of the survey.

The questionnaire survey is divided into two sections. The first section is to get personal information to determine the respondents' demographics. The second section is to get respondents' knowledge about the Smart City concept.

5.1.1 Respondents’ Demographics

It is essential to understand the demography of respondents in the city in order to see how people from different gender or age perceive digital technology in an urban space. This will help the city to know which demography of the population uses citywide digital services. The respondents’ genders, ages, and nationalities are illustrated in the charts below

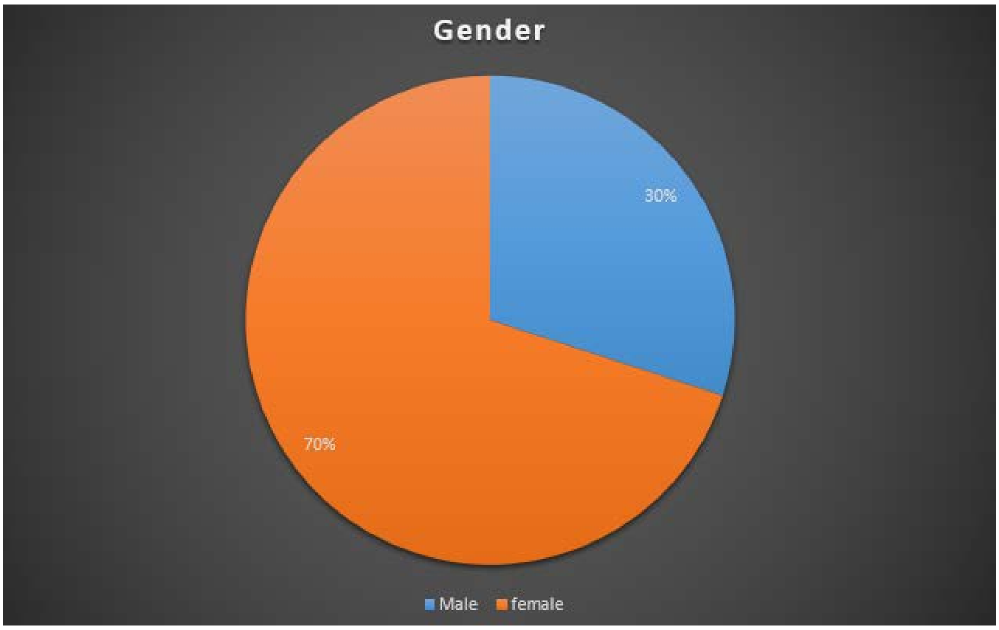

Figure 7. Respondents’ gender

Figure 7 above shows the respondents of the survey were largely female which accounted for 70% while males accounted for the remaining 30%. However, the age of the respondents showed that females were very well represented in all categories. This is due to the vicinity where the data was collected since it was usually frequented by females.

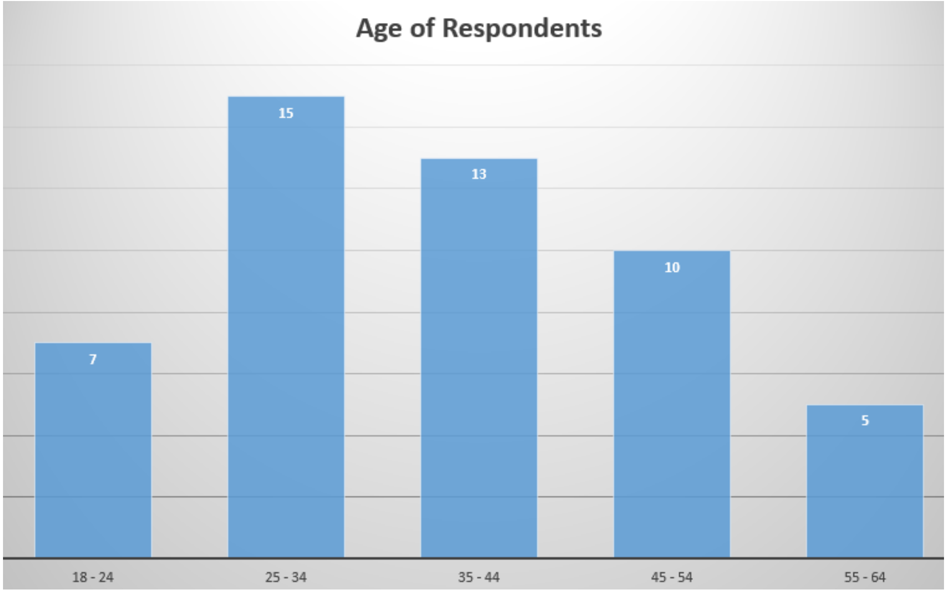

Figure 8. Respondents' ages

In Figure 8 above, the highest number of respondents came from the age brackets of 25 – 34 years old and it was closely followed by respondents in the age bracket of 35 – 44 years old. The age distribution, however, is not enough to prove anything but it could signify that residents' in these age brackets are more open to innovations in the urban space.

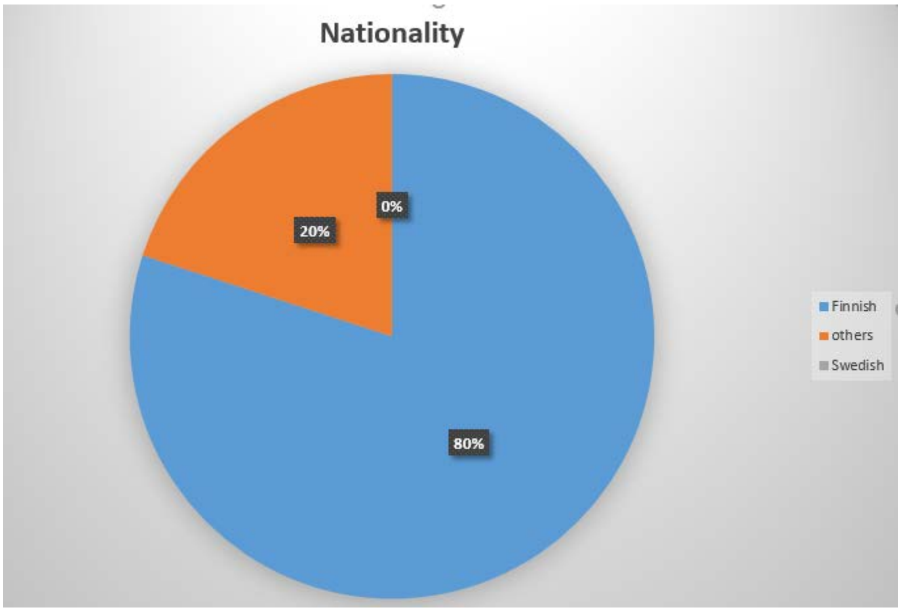

Figure 9. Respondents' Nationality

In Figure 9 above, 80% of respondents are Finnish but the 20% accounted for people of other nationalities which signify that the city of Tornio is gradually becoming multicultural. For any city to be competitive in the current global economy, it is important to consider visitors and foreigners when citywide services are being created.

5.1.2 Smart City awareness and scenarios

Smart City is a relatively new concept and yet to go mainstream. It is important to get the views of residents about Smart City applications before they are deployed in a city. There were 2 questions related to Smart City awareness and 4 questions related to Smart City applications and scenarios. The results are illustrated in the charts that follow.

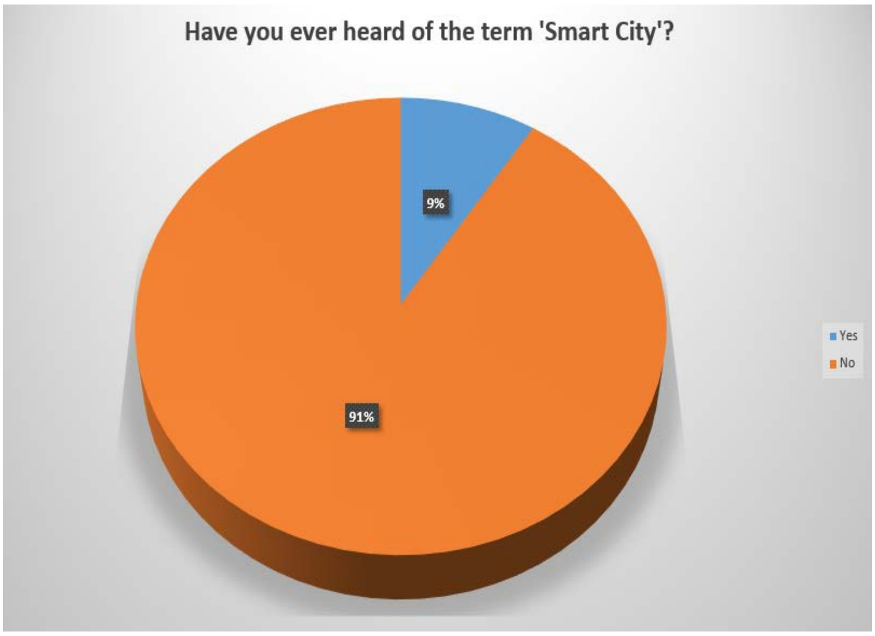

Figure 10. Respondents’ Smart City awareness

In Figure 10 above, a wide gap between those who are aware of the Smart City concept among respondents in the survey. A large proportion of the respondents stated that they had never heard of the Smart City term. Only 9% of the respondents are aware of Smart City which is quite low. The majority of respondents below the age of 55 accounted for 91% of respondents who were unaware of the Smart City concept. The younger population who are widely suggested to be Internet savvy surprisingly accounted for a larger percentage of the respondents who were unaware.

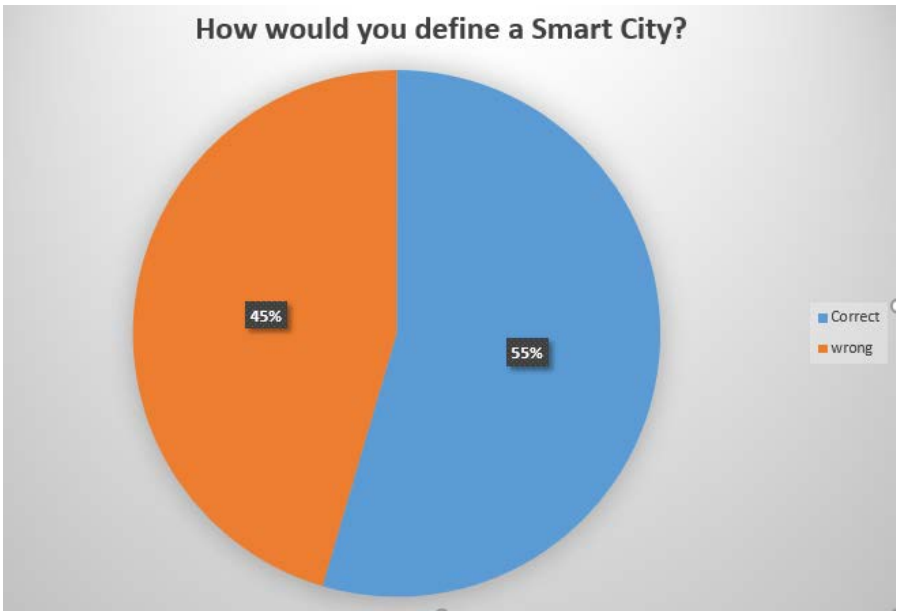

Figure 11. Respondents' definition of Smart City

However, in Figure 11, when asked to choose from a list of options the definition of a Smart City, 55% of the respondents got it right while 45% chose a wrong option. Again, the younger population accounted for the 45% who got the definition of Smart City wrong. Some of the respondents believe a Smart City is a city that has a strict cleaning routine for its buildings, roads and public places.

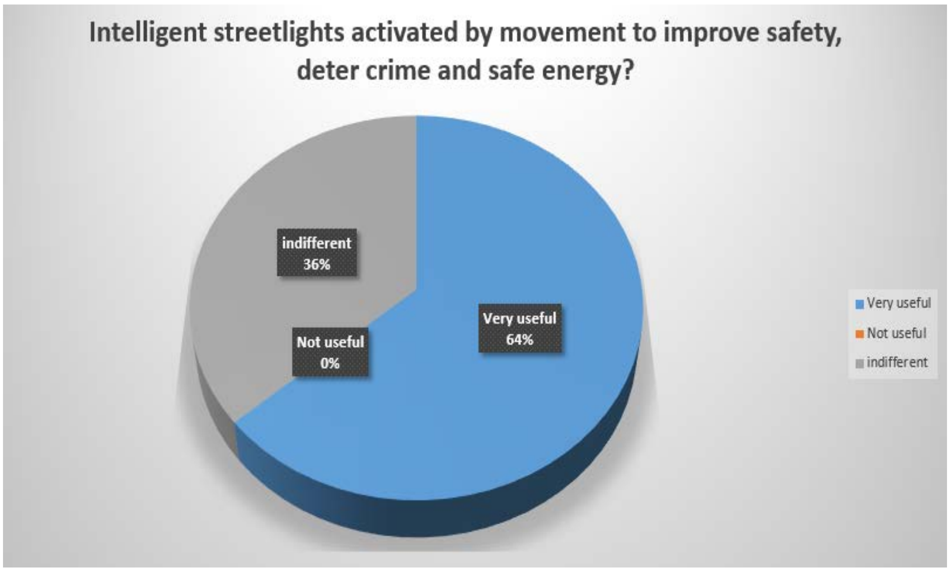

Figure 12. Respondents' view on Intelligent streetlights

In Figure 12 above, 64% of respondents believe intelligent streetlights activated by motion to improve safety and save energy is very useful while 36% were indifferent about it. The response to this question indicated that most of the respondents welcome the idea of utilizing technology to improve safety and save energy. This could be a major indicator that the digitisation of services is already gaining traction among the residents of Tornio municipality.

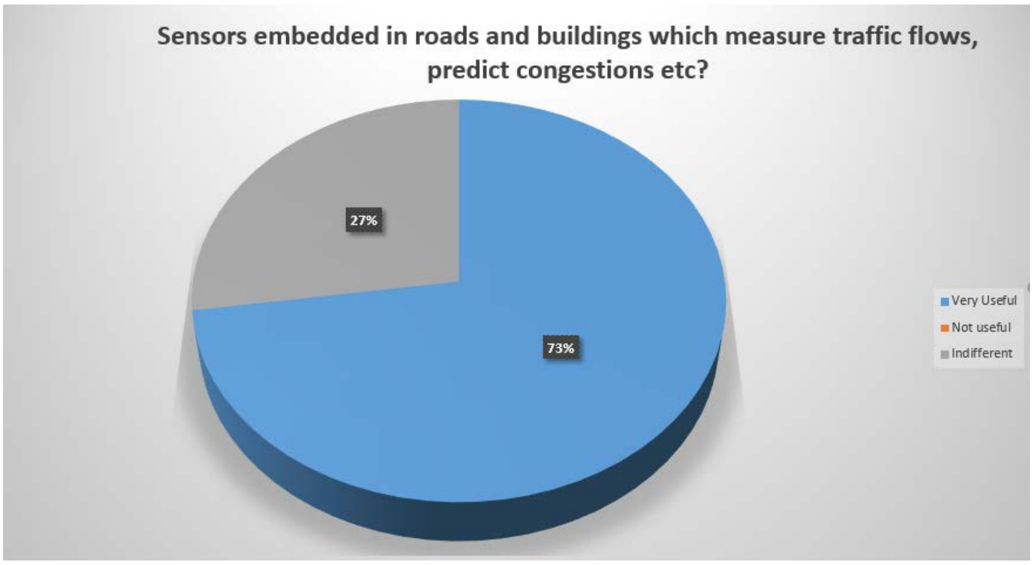

Figure 13. Respondents' view on Sensors embedded in roads and buildings

In Figure 13, When asked for their views on sensors embedded in roads and buildings which measure traffic flows, predict congestions and adjust traffic lights and signals, 73% think it would be very useful. The remaining 23% were indifferent about it. Interestingly, the 23% of respondents with indifferent views were all below the age of 35 years old.

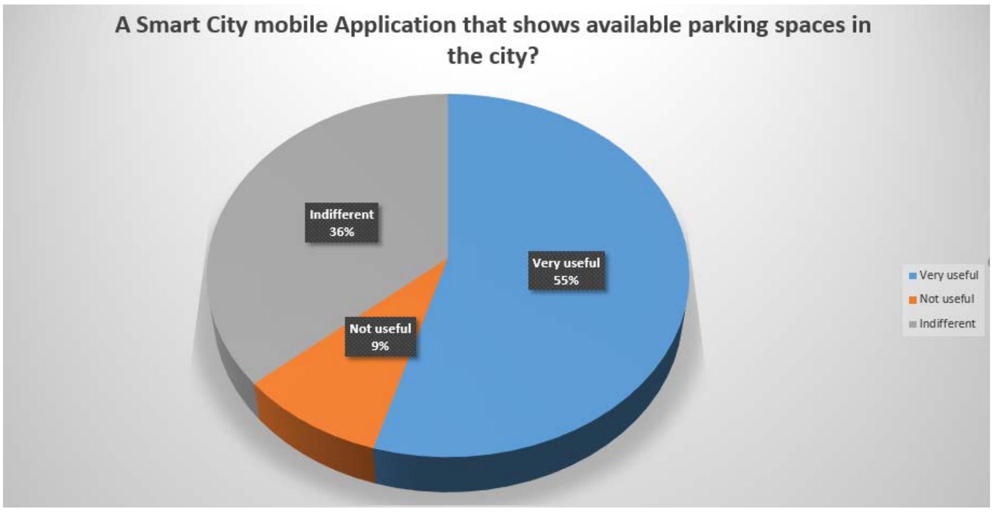

Figure 14. Mobile Application for finding available parking space in the city

Another Smart City application which helps city dwellers and visitors alike look for available parking spaces in the city generated diverse views from respondents. In Figure 14 above, more than half (55%) of respondents indicated that the application would be very useful, 9% indicated it would not be useful while 36% were indifferent about the technology. Motorists searching for where to park accounts for massive amounts of greenhouse gas emission in cities.

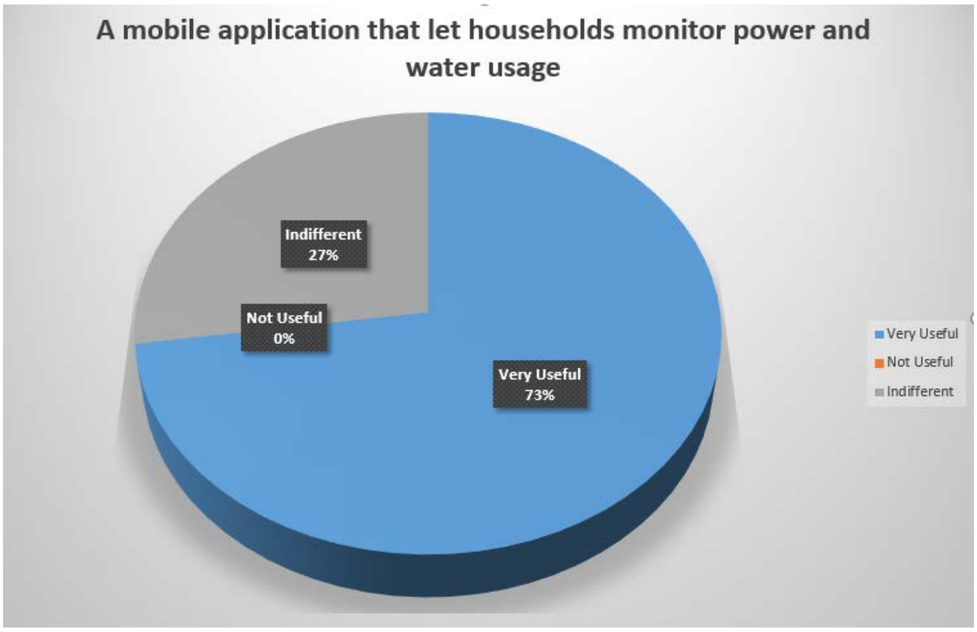

Figure 15. Mobile Application for power and water usage in a household

Power and water usage is an essential city responsibility to every household. The response to this question were quite similar to the response to the question on sensors embedded in roads. In Figure 15 above, a total of 73% expressed the opinion that the Smart City application would be very useful while 27% of the respondents were indifferent about it.

5.2 Summarization of results

The creation of services in cities generally requires no consultation from residents of the city. The report shows that an increasing proportion of the residents welcomed the idea of digital technology improving various aspects of their daily lives while a few proportion of the residents were indifferent about it.

However, the government of cities around the world spends a substantial amount of their budget on improving the lives of their citizens by deploying different ICT infrastructure in urban spaces. The majority of residents do not perceive how Smart City technologies is going to improve the quality of their living by enhancing traffic, infrastructure, health, power and water services.

The survey indicates that the younger generation in Tornio municipality needs to be educated the most about opportunities that digital technology has to offer. The younger generations were mostly indifferent to or oblivious of the technological changes taking place in urban spaces.

However, city administrators, stakeholders, businesses and service providers should focus increasingly on the residents of Tornio municipality before they embark on the creation of services. A human-centric approach should be utilized when it comes to service provision in a city. This will make city stakeholders to fully understand the technological innovations the residents would like to have in the city of Tornio. The human-centric approach enables residents to have an input regarding the future of a city that promises to improve their livability, workability and sustainability. The moment residents are left out of the service creation process, the risk of developing a city with digital services that the people neither recognise or value is inevitable.

6 SMART CITY SCENARIOS FOR THE CITY OF TORNIO

The preceding chapters in this study discussed the Smart City concept and the enabling technologies behind Smart City. The Smart City scenarios presented here is a combination of Smart City technologies to enhance citizen's experience in Tornio municipality. The Smart City scenario helps to showcase the issues, solutions, opportunities and benefits of adopting the Smart City concept in the city of Tornio. Additionally, based on the Smart City scenario, the recommendations are proposed for the city of Tornio.

6.1 Smart Elderly Care System

According to a report from Nordregio (2013), Finland and Sweden account for a large proportion of the ageing population in Nordic countries. The report also mentioned that the young population are moving to urban areas while the ageing population are found in the peripheral and rural areas. Tornio municipality, like most cities, have a considerable high proportion of the ageing population. This invariably has an impact on the welfare system of the municipality. However, ICT services can be utilized to support elderly care in Tornio municipality.

A social worker who is employed for home care in Tornio Municipality can benefit from the Smart City concept. The social worker drives to the same route every day to provide home care for the elderly. Tornio municipal Health and Care Department has just inaugurated a Smart Elderly Care System. This new system affords the social worker the opportunity to make decisions on which elderly home to visit based on the need of the elderly. The elderly homes in the municipality have been fitted with sensors that monitor light switches and water tap. The Health and Care Department is able to monitor the activity level of every elderly person. For instance, if an elderly person has used the toilet several times during the night or if no light has been switched on in the house for 24 hours. The first example signifies that the elderly person has bladder related issues and that can be acted on immediately. While the last example could mean something serious is wrong with the elderly person. The social worker visits the elderly person based on data received from the smart elderly care system. Implementing this system will save the city of Tornio on operating expenses paid out to social workers while still providing better elderly care and support. The system will also give the relatives of the elderly peace of mind knowing the conditions of the elderly family member is being monitored.

6.2 Public Parking Monitoring

According to a study by Shoup (2007), A considerable amount of traffic congestion is caused by drivers who are driving around a city looking for where to park. The city of Tornio hardly experiences traffic congestion but locating a good parking spot at peak hours can sometimes prove abortive.

Tornio Municipality just released a smartphone mobile application for the residents. The mobile application is available on Google’s Android operating system, Apple’s iOS operating system and windows mobile. The mobile application allows users to locate available parking spots in the city of Tornio. Sensors are embedded in the asphalt of parking areas in the city and users of the application can view available parking spots. The user can also interact with the system by indicating how long the car will stay parked in that location. Once a driver exceeds the time allowed to park in that zone, the driver is billed automatically and a bill sent to his mailing address or billed on the application.

This parking system will help Tornio municipality save on operating cost of the manual billing process. The system will help the city curb greenhouse gas emission from drivers circling the town searching for a suitable parking space.

6.3 Report Bad Restaurants

Food poisoning from restaurants is an issue taken seriously by all city governments. Local health officers pay regular visits to restaurants in order to ensure the safety procedures are being adhered to by restaurant owners.
Tornio municipality released a mobile application on the three most popular mobile platforms in the country. The mobile application enables the residents to report bad restaurants in the municipality. The restaurant with the lowest rating is visible on the city's website as well as on the mobile application.

The mobile application and website provide local health authorities information on which restaurant to visit and possibly sanctioned if found guilty. The mobile application saves the city money on operating expenses that would have otherwise been spent on an additional personnel. This system delivers information right to the city departments that need it.

6.4 Snow Plows

Tornio Municipality is situated in the Northern part of Finland and records very high amount of snow yearly. The city of Tornio can implement a snow plow application for desktop and mobile devices. The application tracks snow plows as snow is packed in different regions of the city. Snow plows are fitted with sensors or RFID tags that report their location. Sensors fitted in asphalts and sidewalks collect information on the level of snow on the streets. This information is visually represented on colour coded maps which indicate what neighbourhood of the city is cleared off snow.

The application enables city administrators to remotely monitor the status of snow plows in the city. This enables effective distribution of snow plows to neighbourhoods with considerably large amount of snow. Residents can check the estimated time of arrival of snow plows to every neighbourhood in the city. With the aid of the application, residents can also view a colour coded map of the status of snow clearing in the city. The snow plow application enables the city to effectively monitor the pace at which the snow plow operators are working. Through predictive analytics, the number of snow plows needed in the city can easily be determined.

6.5 Recommendations

The Smart City scenarios outlines several innovative applications of sensor technologies and big data analytics in enhancing city services. The Smart City scenario objective is to help Tornio municipality achieve significant savings by digitising some already existing services. However, certain Smart City interventions will disrupt service provision in different sectors of the city.

Technology is the underlying factor for a successful Smart City implementation. Acquiring the Smart City technological components might be too expensive for a city such as Tornio. Tornio municipality can utilize a cross-cutting approach to share infrastructure and share costs. Tornio and Haparanda have over the years enjoyed cross-border co-operation in providing services in the twin city. The two cities can share Smart City infrastructures to provide citywide services in both cities and thereby reducing the cost of acquiring technologies necessary for Smart City interventions.

The creation of services in a city requires new laws to be created or existing laws to be upgraded. Unleashing economic development in the city of Tornio should include necessary changes to antiquated laws to protect citizens. A policy framework for new service offerings in the city should be created. This promotes transparency and inspires trust from the residents of the city.

Financing the Smart City concept goes beyond sharing of infrastructures. The city of Tornio can explore other innovative ways of financing Smart City service provisions in the city. One prominent way of financing projects in a city is the public-private partnership strategy. Tornio municipality and private companies or investors can pull resources together to achieve set objectives for the greater good of the city.

The implementation of the Smart City concept in the city of Tornio means the governing body of the city has to re-organize different functions in the city. New roles and responsibilities in relation to city administration will be created to accommodate for the new Smart City concept. Increased inter-departmental collaboration should be enforced by the city administrators. The residents of Tornio municipality should be engaged in the creation and provision of services right from the inception of the service creation.

7 CONCLUSIONS

The impact of technology on the daily lives of humans can never be underestimated. The emergence of ubiquitous technology has introduced a whole new dimension into how cities are built. Tornio municipality can take advantage of data-generating sensors to enhance the various city responsibilities. However, before this can be done, several technology enablers have to be in place for a successful implementation of the Smart City concept. Instrumentation and control devices are the foundations of the Smart City concept. Instrumentation are those devices that collect data from the physical environment. Connectivity of different devices in the Smart City ecosystem needs to be robust. The city of Tornio can decide to build a new network for Smart City or just utilize the already available network. Interoperability of devices is essential for Smart City devices to work. Interoperability is the assurance that disparate devices from different vendors or on a different platform will communicate with each other seamlessly. However, Tornio city administrators have to handle the security and privacy of data of its residents carefully. Cyber attacks on public infrastructures are increasing daily, Tornio city administrators need to publish privacy rules if the city wants to run a transparent government. Additionally, massive amounts of data are generated from different sources in Tornio municipality. Therefore, an effective data management system needs to be in place and must be accessible by other departments of the city.

The thesis work explored the concepts of Smart City and big data. The different definitions of the Smart City concept are analysed. The constituents of a Smart City were also thoroughly investigated and the reasons why Smart Cities are built were discussed. The section “how big data is making cities smart” examined the different Smart City applications which are currently being utilized to create unique experiences in urban areas.

Investments in big data and analytics could propel the city of Tornio ten years ahead of its competitors. Big data analytics derives value from the prodigious amount of data. Data collected from sensors can be used to improve the current responsibilities of Tornio municipality. Sensors which capture different data help city administrators make decisions on important issues in real-time. The implementation of big data analytics ensures that Tornio city stakeholders have full situational awareness of citywide services. Predictive analytics enables the city to detect issues right before they occur and therefore eliminating avoidable downtimes. Tornio municipality can get insights from the different digitized city responsibilities found in this research work.

The results gleaned from the questionnaire were quite revealing. They showed that the younger generations were less concerned about the opportunities that Smart City technologies will provide to the city. The charts provided an in-depth knowledge of the Smart City technologies that residents want in their city. It also raises the question of why it is necessary for consultation with the city populace is essential before city services are created. Proper education of the citizens on digital services that are available in the city should be instituted by the city administrators.

Nevertheless, there are several benefits of the Smart City concept that will enable Tornio municipality to attract new residents and businesses to the city. The first conspicuous advantage is that Smart City and big data analytics provide cities with actionable data to improve service provision in the city. Having a full situational awareness of citywide responsibilities enables the city to immediately respond to issues in real-time. Tornio municipality will enjoy cost-saving benefits by implementing Smart City interventions to new and already existing city responsibilities. However, the result of this research is still largely based on the findings of the residents perception of a Smart City. Further research into the issues currently been faced at the governance level in relation to city administration should be explored.

In conclusion, the Smart City concept is constantly evolving and new technologies are taking the concept in new directions. However, there are still issues to be addressed. A standardized framework for the Smart City concept is still lacking and largely characterized by different implementations by industry vendors. Also, the issue of privacy should be taken seriously. Security and privacy of citizens should be treated with the utmost respect. The privacy laws should be a holistic detailed account of what data can be shared by the government with third party companies. The creation of services in the city of Tornio should not exclude the residents in order to create services that would be useful to the people.

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APPENDIX

Appendix 1. Smart City Survey – Tornio Municipality

APPENDIX 1 1(4)

QUESTIONNAIRE DOCUMENT

Smart City Survey

Personal Information

1. What is your gender?

- Female
- Male

2. What is your age?

- 18 to 24
- 25 to 34
- 35 to 44
- 45 to 54
- 55 to 64
- 65 to 74
- 75 or older

3. What is your nationality?

- ◯ Finnish
- ◯ Swedish
- ◯ Others

4. In what city do you live?

5. Have you ever heard of the phrase 'Smart City'?

- ◯ Yes
- ◯ No

3(4)

6. How would you describe a Smart City?

- ◯ A city that has a higher than average proportion of universities and colleges
- ◯ A city that has a strict cleaning routine for its buildings, roads and public places
- ◯ A smart community is a community that has made a conscious effort to use information technology to transform life and work within its region

SMART CITY SCENARIOS AND TECHNOLOGY (Please choose the option which best represent your opinion)

7. 'intelligent' streetlights activated by movement to improve safety, deter crime and save energy

- ◯ Very useful
- ◯ Not useful
- ◯ I don't know

8. sensors embedded in roads and buildings which measure traffic flows, predict congestion, and adjust traffic lights and signals

- ◯ Very useful
- ◯ Not useful
- ◯ I don't know

9. A mobile application that shows available parking spaces in the city

- ◯ Very useful
- ◯ Not useful
- ◯ I don't know

10. A mobile application that let households monitor power and water usage

- ◯ Very useful
- ◯ Not useful
- ◯ I don't know