AMERICAN UNIVERSITY OF BEIRUT

REVAMPING THE MOBILE NETWORK INFRASTRUCTURE OF A DEVELOPING COUNTRY TO PREPARE FOR THE FOUNDATION OF SMART CITIES

by
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AN ABSTRACT OF THE PROJECT OF

Maria Nicolas Abou Arbid for Master of Business Administration
Major: Business Administration

Title: Revamping The Mobile Network Infrastructure Of A Developing Country To Prepare For The Foundation Of Smart Cities

In the context of developing environments, and based on the list of findings I came up with for the developed and rich developing countries, I proposed a smart city project to be implemented in Lebanon, along with its corresponding driving forces; provided that Touch mobile operator is the initiator of the idea and has to have a major role in its accomplishment. The driving forces include the motivators and objectives of the initiative, its scope, the stakeholders involved and their contribution to it, the value chain comprising the four pillars or activities required in relation to capitals, labor, ICT and city infrastructures' provision, and the business model used to achieve the goals of the initiative.

Bearing in mind that Touch, under the supervision of the MoT, is the leader of the initiative and responsible for the bulk of the ICT provision, I performed an in-depth technical analysis to benchmark the capabilities of Touch mobile network with the global ICT infrastructure requirements in smart cities, particularly regarding the network layer, as well as proposed plausible technical solutions for the shortfalls and evaluated the financial viability of some. For that reason, I conducted several interviews with people from Touch Technical, IT, Finance, and Commercial departments, and from Huawei Technologies which are the main providers of network equipment for Touch.

This step within my feasibility study was crucial to assess the likelihood that Touch will be able to meet the requirements and thus contribute to the project, as outlined in the business model adopted. I eventually used the technical analysis to translate the business need that Touch is intended to fulfill in this project.

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CHAPTER I

EXECUTIVE SUMMARY

Using the existing work on smart city achievements in developed & wealthy developing countries, the major driving forces of the smart ecosystem were identified and analyzed to prepare and build the grounds for the smart initiative that is to be instigated in Lebanon, a rather poor developing country, under the leadership of Touch mobile operator.

The driving forces are mainly about:

- The motives & objectives and scope of SC initiatives;
- The list of potential stakeholders;
- The stakeholders' categorization scheme based on their role & contribution to the initiative;
- The activities of the value chain process, i.e. the provision of capitals, labor, and ICT and city infrastructures, while emphasizing and describing the global ICT requirements for smart cities in relation to the sensor, network, analysis, and application layers; and
- The business models and the dynamics of the stakeholders' relationships.

Accordingly, the main takeaways from this report are as follows:

- Considering the context of Lebanon, the approach towards the deployment of smart cities is to go one step at a time by focusing on one industry sector, primarily due to the restricted financial resources, and the political instability in the country. The government will obviously be involved in the change initiative, because it remains to be the leading power in the developing countries, regardless of the true power it can bestow. Since Touch is the initiator of the idea, and particularly since it is a public entity so that the government intervention would be guaranteed at all times, Touch will be the leader of the initiative; however at this stage, we will not reveal the entire business model to be espoused. The agreed upon project is relevant to the transportation industry because of the instructive role Touch has played during the past years through launching many awareness campaigns to reduce the road accidents, given that the roads in Lebanon are not adequately managed and maintained, one of the key objectives of the smart transport initiative under consideration. So briefly said, the initiative aims at revolutionizing the transportation sector in Lebanon, with the assistance of several governmental entities, city services or transportation companies, utility providers such as Electricité du Liban and private ICT companies, private banks and academic institutions, NGOs such as YASA (Youth Association for Social Awareness), and ultimately the Lebanese citizens, in which case the role and contribution of each, as part of the business model adopted, will be detailed later in the report. The Ministry of Telecommunications managing the operations at Touch will be intuitively leading the project, and thus in charge of the responsibilities assigned to the leadership role in the urban transport change initiative. The leading public institution will be managing the interactions between the other major players, supervising the work, as well as measuring and benchmarking the levels of investments in ICT and other requirements so as to make sound decisions on how to proceed at each hindrance or resistance that the group of involved stakeholders might encounter. The business model, as designed, portrays in fact the exemplary and most suitable engagement pattern in Lebanon, provided the economic and political situation of the country, which is commonly the status quo in all other developing nations as well. The government in such countries, through one of its many entities, has to be the leader of the initiative or at least be an active stakeholder backing the initiative if not primarily contributing to its accomplishment, or else there will be no consent among the participating stakeholders and no approval from the civil community to implement the change.

- Now is about time to fix my consultancy hat, and summarize the essence of this project report; in other words, the major inferences which need to be communicated to Touch mobile operator concerning the provision of the necessary ICT resources, for the company to constructively contribute to the smart transportation project in hand. These were the culminations of the benchmarking exercise between the ICT requirements achieved universally in existing smart cities and the know-hows and abilities of Touch in this respect. In short, the global ICT requirements are represented by four fundamental layers: the sensory or physical layer responsible for the data collection; the network layer responsible for the connectivity between the sensors, systems, and end users; the analysis layer responsible for interpreting the data and giving back insights to the citizens; and finally the application layer which represents the interface with the end users who are connected to the network and enjoying the available smart community services. In fact, the network layer is considered to be the most critical part of the ICT infrastructure required in a smart city, as well as the most fundamental asset of an ICT service provider, demanding very large investments to be properly maintained and developed. Within the network layer, the two important criteria that have to be met are 1) having a wide-ranging LTE (Long Term Evolution) coverage with high user throughput, and 2) having a high capacity medium of connectivity on both Radio Access and Core networks to benefit from the enhanced performance of LTE. Hence, you will notice that the bulk of the analysis pertains to the network layer requirements, and the abilities of Touch on this subject. Here are the main conclusions we have reached in relation to the status of Touch mobile network and the needed future expansions for the sake of our smart transport project.

- The LTE coverage is only 2% of the Lebanese territory, and the corresponding network load capacity in this area of availability is 19% of the total potential LTE data customers, which lead to very low LTE penetration rates, bearing in mind that the LTE enabled smartphones are also not reachable by everybody due to their high prices. Obviously, the LTE coverage has to be nationwide or at least in the cities which are within the scope of our smart transport project, and the network capacity has to cater for at least 50% of all potential data customers.

- The current LTE user throughputs are reasonably acceptable compared with the average data rates that can be attained in the developed networks, but can be further enhanced. However, the microwave links currently being used at the air interface for the transmission of data have limited capacities, and need upgrades if higher throughputs are to be achieved.

- The connectivity from the Access to the Backbone network, known as the Aggregation layer, in addition to the connectivity within the Backbone network are a mixture of electrical and fiber links having high bandwidth; still the best alternative would be to substitute all copper cables by fiber optics due to their improved capacities at long distances.

- The connection from the Backbone network to the Internet Service Provider, which works on account of the Lebanese government, is through E1 lines having a very low throughput of 2 Mbit/s. The project of swapping the legacy links with fiber optics has been started by the publicly owned ISP few years ago; however, it remains unclear whether it was completed or when it will be commercially launched in Lebanon.

CHAPTER II

INTRODUCTION

The notion of smart city is, actually, a fuzzy concept that has been evolving and given multiple definitions throughout time, albeit superficially used in many instances. However, the interest in smart cities has always motives, and is normally driven by major complications, such as a climate change, an economic restructuring, the shift to online retail and entertainment, the ageing populations, and the pressure on public financial resources. Hence, the motivator for smart cities can either be social, economic, or ecological alone, or a combination of the formerly listed drivers. The economic motivator reflects the need to construct or create a new economic model, which ultimately leads to the generation of new revenues streams for the potential stakeholders involved in a given smart city initiative. Having a sustainable infrastructure is one such economic motivator, which is usually a trigger for almost all smart initiatives, albeit being implicitly indicated sometimes. Actually, building a sustainable infrastructure delivers a return on investment, through the creation of new services and accordingly new revenues for the providers, including the city and government authorities. According to the Streetline online blog, parking is the second to third highest revenue generator for cities; yet, cities are losing up to 40% of possible parking revenue through ineffectiveness (Source: Streetline, Connecting the Real World, The Smart City Just Got Smarter). With smart parking management, these inefficiencies are meaningfully reduced to provide an expected a 20 to 30% increase in parking revenue. The outcome from this transition into the world of smart cities has also a set of clear objectives and goals that the change initiative intends to achieve; and accordingly, with the reasons and objectives in mind, the scope of the smart city will be defined. The scope of the initiative will determine whether the transformation will span the entire city and enfold all business sectors in the industry, or encompass one or more of the available industry sectors. Still, the variety of challenges driving the world of smart cities increases the ambiguity of the means and outcomes of actually deploying a smart city, and the conflict of interests might hinder alternative opportunities to achieving urban development as well as undervalue its downsides and the possible negative effects it might have on the environment and the people living in it.

In reality, the stakeholders that can potentially contribute to a smart city project include the individuals, corporations, or entities which can belong to the private or public sector, and which have normally motivations to strive for the development of smart cities. Moreover, the goals and hopes of the citizens, which are also stakeholders in the smart ecosystem, are different from the goals of the city, namely the public and/or private sector(s) partnering in the realization of the project. Citizens are increasingly demanding higher quality services and more transparency from both governments and companies, which puts the cities at stake of not clenching the full potential of their investments if they fail to properly connect the added-value of their technologies to their residents (Source: Information Marketplaces, The New Economics of Cities, The Climate Group, Arup, Accenture, and Horizon, 2011). In order to engage the citizens to accept the behavioral change brought by the urban transformation, the value from the new technologies should be communicated in a language that has direct applicability to people’s lifestyle. A smart transport initiative, for instance, should be clearly linked to the improvements citizens will be able to achieve in terms of time saved in their daily commute as well as reduced air pollution and road accidents.

The stakeholders involved in a given project differ from one country to another, whether it is a developed or developing nation, also from one city to another, and from one application to the other. The mixture of stakeholders in fact is highly reliant on the economic status of the country where the smart city is to be created, since the context defining developing countries is different than that of developed countries, whereby we clearly notice that in the former case the government has to almost always intervene to supervise, if not to decide upon, any project affecting the country or city irrespective of its scale. The government's omnipresence in developing nations is not related to the abundance of power and resources it can provide, but indeed to their nonexistence. It is just a perspective upon which the developing countries have been ruled for so long, giving the utmost empowerment to the government authorities regardless of their real capabilities and potential. Whereas in developed countries, the government stakeholder, that is evidently more capable of providing the financial and human resources needed as well as introducing the required change to the ICT (Information and Communications Technologies) resources and self-existent city infrastructure, has a more business-like way of thinking and assesses the pros and cons before it decides to embark on any investment. This mentality is hardly found in the developing nations; in which case, the participation of stakeholders is contingent upon the prevalent politics in the country, which will clearly involve the government and affect the choice regarding the other stakeholders required to afford for all the requirements of the smart city initiative. Assuming now that the mixture of stakeholders in a given project is settled, the series of activities that are performed by these stakeholders and that add value to the process of deploying the smart city will define the “value chain” in this smart city (Source: Getting Smart about Smart Cities, Understanding the Market Opportunity in the Cities of Tomorrow, Alcatel-Lucent, February 2012). These activities include the provision of the necessary resources such as capitals, labor, and desired ICT infrastructure, as well as the transformation required at the city infrastructure level to accommodate the changes related to ICT. To be noted here that the “what resources are needed” is constant and does not vary from a smart initiative to another; but the “how to provide the resources” is the changing factor that describes the concept of value creation through the different activities pertaining to the smart city value chain. Moreover, these activities have to be clearly segregated among the participating stakeholders, whereby each has to know and abide by the role it is entitled to fulfill in the project, in order to avoid redundancy of efforts or misalignment and thus failure of the initiative. So the nature of the stakeholders’ relationships is also a very important variable in the process of preparing for the foundation of a smart city, and is known by the “business model” or “engagement model” representative of the change initiative (Source: Global Innovators, International Case Studies on Smart Cities, Arup, October 2013). A business model incorporates the dynamics of the relationships among the different participants, namely the project leadership, the availability of stakeholders, their individual and collective role and contribution, as well as their coordination and alignment towards a shared vision; while in fact setting up smart city services enfolds a variety of business models and approaches to provide, supply, operate and manage the smart city services.

At this point, it is worth to derive the causal relationships from among the smart ecosystem's various elements highlighted above, but which will be further explained gradually in the following sections:

- The motives and objectives behind the deployment of a smart city will determine the scope of the initiative.
- The scope of the initiative and the resources (financial, labor, ICT) that the stakeholders are able to provide will determine the stakeholders to be involved in the project.
- The scope of the initiative and the choice of stakeholders will affect the value chain of the smart city, i.e. the process of ensuring the readiness and availability of the required funds and labor, as well as the advanced ICT and city infrastructures sought-after.
- The scope of the initiative and the value chain will in turn affect the business model to be adopted for the deployment of a given smart city, i.e. who does what?

All the components of the smart ecosystem might vary from one initiative to the other, but the resources required are always the same: labor, money, and developed ICT and city infrastructures. Hence, whenever the strategy of the initiative is well articulated and clear to the potential contributors, all requirements to fulfill the envisioned objectives start to take shape. This is the time for change with technology being used as a driver of that change. All change initiatives, irrespective of the areas they will affect, are deemed failures if the ICT infrastructure underpinning those projects was not properly designed and tailored to cater for the desired changes. Consequently, throughout my project report, we will be focusing on the role of ICT in deploying the smart cities of tomorrow, considering the case of Lebanon, a developing country in the Middle East region where the ICT infrastructure is basically behind that of developed nations, so as to compare and contrast with the advanced ICT structures, and subsequently pinpoint the major challenges and the improvements that shall be done towards deploying sustainable smart cities in the referenced country. As a working member of Touch, the leading mobile operator in Lebanon, my intention is to involve the company in the initiative that aims at creating smart cities in our country, by clearly analyzing its role and contribution, as well as its capabilities in relation to the ICT provision, which is an inevitable requirement in every smart city. So, from within the vast umbrella surrounding the foundation of smart cities, the various constituents that build up a smart city, i.e. the driving forces, will be presented in order to tackle the key outcome of my report, which is about doing consultancy for Touch mobile operator to assess its standing point in relation to being the leader of a smart city initiative in Lebanon and the major provider of the ICT infrastructure required.

My motivations behind the feasibility analysis I performed is to evaluate the likelihood of deploying smart cities in Lebanon, in view of the political and economic settings of the country, as well as the condition of its existing ICT assets, in which case having an advanced ICT infrastructure represents a fundamental enabler for the change initiative to take place. Accordingly, my role in this project is to formulate and analyze all the building blocks needed ahead of the implementation phase of the initiative, and particularly in relation to the ICT provision that is to be delivered by Touch mobile operator. In other words, my job as a consultant for the smart city project that is intended to be performed in Lebanon entails that I analyze all the aspects and dynamics involved in similar executions, grounding my findings and recommendations on the achievements done in this respect in developed and rich developing countries. I would like to also point out to the fact that the technical analysis I did is not relevant to my field of expertise as an engineer, whereby I had to understand at first the nature of the ICT infrastructure required in smart cities and assimilate all the related technical and IT components, prior defining the framework based on which I will assess the capabilities of Touch mobile network in delivering the necessary requirements. The learning process was actually done in steps, depending on the time that the engineers and people at Touch were disposed to provide, which did not allow me in some instances to delve further through the data I got and dig deeper into the analysis to get accurate cost estimations for some of the suggested upgrades needed to better position Touch mobile operator as the major ICT provider for the smart city project under consideration.

CHAPTER III

METHODOLOGY

In view of the above, here is the approach followed throughout my report to discuss the building blocks and dynamics involved in the development of smart cities, while giving emphasis to the ICT requirements, and in particular the network layer, that are empirically proven to be needed in all change initiatives that intend to modernize the urban life in cities.

In the Literature Review section, the different elements of a smart city are disclosed and explained, counting the scope, timeline, and constraints, the value chain, and the business model pertaining to a given smart city project. Initially, the smart city value chain is represented by the stakeholders involved and devoted to accomplish a smart city project through a variety of activities that aim at creating a value which will be perceived once the smart city is deployed. Starting with the potential stakeholders, I used the many readings I have gone through, concerning the nature and role of stakeholders in the foundation of different types of smart cities, to draw a customized list that classifies the various stakeholders based on their plausible contribution to a project. Now concerning the activities around which the process of developing a smart city is centered, these comprise the provision of the necessary resources from money to ICT to the labor force, as well as the city infrastructure which is also considered a resource in this context, since all new smart technologies to be created will be eventually implemented in and applied to the city compartments. The focus will be accorded to the activity of ICT resourcing, through explaining what the global requirements are in this regard, and how they can be achieved, i.e. which stakeholders are involved in the process of ICT provision and which one(s) to choose while maintaining that all requirements are fulfilled. The literature review section builds upon various successful implementations that have occurred mainly in developed countries in order to provide an overview of the components of a smart city, particularly the delivery of the four ICT layers including the sensory, application, network, and analysis layers, all of which are constant requirements in every smart city. Besides, this part prepares for the following section that takes the case in point of Lebanon, a developing country, to evaluate the possibility of introducing the change and shifting the urban life towards the smart technologies.

In the section “Application of the Global Smart City Standards in Lebanon”, which is based on the findings of and analysis done in the “Literature Review” section, I started to draft and analyze the various building blocks for establishing smart cities in Lebanon, considering the prevailing social, political, and economic environments of the country, and given that Touch mobile operator will primarily participate as the leader of the proposed initiative. The motivators, the scope, the stakeholders involved and related categorization model, the value chain and business model were all tailored to integrate the dynamics of Lebanon, and come up with a smart initiative to be led by Touch mobile operator. However, from among the various driving forces explored, the main target was to perform a gap analysis between the global standards applied to the four ICT layers in a smart city, as revealed in the literature review section, and the current ICT capabilities of Touch mobile operator. The contribution of Touch will be assessed against each and every layer, while concentrating on the network layer because it represents the nervous system connecting the other layers together and with the city. Accordingly, my job was that of a consultant evaluating the likeliness of Touch being a major stakeholder and contributor in this project, by laying out the role it is likely to assume, the challenges it might confront, as well as some recommendations for the company to better position itself where needed, and enforce its participation in the foundation of smart cities in Lebanon. Briefly said, it is agreed that Touch will be a major stakeholder in the smart ecosystem; but since Touch works for the benefit of the Lebanese government, this means that the local authorities will also take part in the project. Provided that Lebanon is a developing country, this would be eventually the optimal approach to consider anyway. With this in mind, we will analyze the motives and objectives that might stimulate the creation of smart cities in my country, and delimit the potential scope upon which the project can be pursued. Then, taking into account the context and circumstances of Lebanon, we will identify the list of stakeholders that can conceivably partake in the project and define the business model which will directly ensue. This is definitely while analyzing the elements of the value chain with respect to the activities of providing the needed financial and labor resources, and most importantly, the necessary ICT requirements and resources which will represent the bulk of my analysis in this report. At the end of the day, using this feasibility analysis, Touch will be able to know where it really stands in relation to the provision of the four ICT infrastructure layers stemming from the literature review and the working examples of smart cities deployed around the world, and to estimate the extent of investment needed for the company to compete in delivering the universal requirements pertaining to the four ICT layers, above all the network related partition.

For the reason above, and to be able to compare and contrast between the technologies that have to be adopted within each ICT layer and the capabilities of Touch mobile network in this respect, I started by analyzing one layer at a time to understand the requirements for each and then moved to describe the current status at Touch in relation to the four layers. The global requirements were mainly assimilated through the many readings and the exhaustive research I have conducted about the ICT standards adopted by the developed networks and ICT service providers worldwide. While concerning the situation of Touch broadband network, and the remaining analysis, sensory, and application layers, I met with engineers working in the Technical and IT Teams at Touch, as well as engineers working for the international vendors from which Touch acquires all the needed technology equipment, systems, and solutions. I also met with people working in the Finance and Commercial departments, which allowed to better understand the market positioning of Touch and to perform the feasibility analysis of a possible network expansion deemed compulsory for the operations of the company, if it were to meet the universal ICT standards desired in smart cities.

Depending on the ICT layer being examined, the data that I needed to plug in my report for the sake of the analysis was essentially gathered through either one-on-one interviews, whereby I asked several questions which I have derived from the requirements set globally, and which I will present a sample of as an appendix at the end of this report, or through presentations sent by the concerned people. The following divisions are the ones I relied on to collect the information that describes the capabilities of Touch with regard to the four ICT layers under deliberation:

- Technical Department
    - Packet Core
    - Radio Transmission
    - Service Quality
    - Radio Network Planning & Optimization
    - Research & Development
    - Site Management
    - Site Implementation & Maintenance
    - Huawei Technologies, Wireless Department
- IT Department
    - Enterprise Applications
    - System Database & Storage
    - Corporate & Internet Services
- Commercial Department
    - Business Planning
    - Corporate Communications & Relations
- Finance Department
    - Financial Planning & Reporting
    - Technology Procurement

This is basically the methodology I followed throughout my report, which makes use of the concept of smart cities and the general requirements of deploying smart cities, namely in the developed countries because they represent the majority of the living examples, and focuses on the activity of ICT resourcing, i.e. the requirement to have an advanced ICT infrastructure that is capable of implementing the needed change in the cities.

CHAPTER IV

LITERATURE REVIEW

A. The Smart City Motivators

According to Frost & Sullivan (2014), it is expected that 60% of the total population will move to urban cities by 2025, and the number of people over the age of 60 is expected to triple and outnumber that of children by 2050 (Source: ICT infrastructure as key enabler of Smart Cities, Alcatel-Lucent, May 2012) which marks the decision pertaining to “making smarter cities” a must. In fact, another publication by Alcatel-Lucent also published in May 2012, and entitled “Getting Smart about Smart Cities – Recommendations for Smart City Stakeholders”, states that there is a variety of drivers stirring every smart city project; those are mainly the economic, eco-sustainability and social motivators. The economic motivator drives a city to construct a new economic model likewise the case in Masdar city, Abu Dhabi (Sources: Crafting Smart Cities in the Gulf Region: a Comparison of Masdar and Lusail, Evren Tok, Fatemah Al Mohammad, and Maha El Merekhi, June 2014 & Getting Smart about Smart Cities, Understanding the Market Opportunity in the Cities of Tomorrow, Alcatel-Lucent, February 2012), where the oil-based business archetype was reformed into one based on renewable and alternate energy sources to cut down costs and achieve reputable financial performance. As highlighted above, the economic motivator is usually a driver for almost all smart city initiatives; whereby city administrations as well as contributors to the initiatives would definitely be investing their resources (time, people, money) expecting a return on their investments. The second motivator is illustrated by the need to reduce energy consumption – the case in point of Amsterdam smart city project. And the final stimulus is proven by the necessity to improve the quality of life in a city environment, which can be exemplified by the Suwon smart city project in Korea that aims to enhance the citizenship life through providing smarter means of transportation for the residents' daily commutes (Source: Getting Smart about Smart Cities, Understanding the Market Opportunity in the Cities of Tomorrow, Alcatel-Lucent, February 2012). In my opinion, it would be totally off beam not to notice that there is some interconnectedness between the three factors: the economic motivator, the social motivator, and the eco-sustainability motivator. In point of fact, the initial incentive for deploying a smart city might provoke transformations related to another motivator that was implicitly articulated in the mission statement of the original smart city project. And admittedly, this has been and will always be the case, especially when it comes to overlooking the social factor as a main driver to the project. Every project will ultimately be sustaining the residents in the city who are, even if subliminally stated, the reason behind all smart city initiatives.

B. The Smart City Driving Forces

The driving forces of every smart city project principally include the contributors to the project and the nature of the interactions among them, the available resources for execution (Financial, Human, ICT, and City Infrastructure), as well as the motives and the desired end goals of the project; all of which will decide whether the scope of the project is

Greenfield or Brownfield. So whenever we say a Greenfield project, it is meant that the entire city will be built from scratch without relying on the existing ICT infrastructure, and all business sectors in the industry will be subject to the reform with no exclusions. However, a Brownfield project implies that only one industry sector will be revolutionized, or part of it; and the existing ICT infrastructure will be either revamped or expanded to implement the needed change. Subsequently, the criteria of scope, timeline, and constraints – characteristics of every smart city initiative – will be explained in an attempt to clarify the city areas that will be potentially affected, the time needed to accomplish the objectives set, and the pitfalls which the project might stumble upon, in addition to possible ways of mitigating the risks so as to achieve a successful implementation.

1. Scope

The process of developing a smart city is based on two models, which are either to create the new city from scratch, not considering the incumbent city and ICT infrastructures in place, by following a Greenfield approach or to use the existing city and ICT infrastructures to bring change to the city following a Brownfield approach. Hence, the scope of a smart city project is defined by whether it is Greenfield or Brownfield (Source: New Smart Cities, a Focus on Some Ongoing Projects, Cristina C. Amitrano, Annunziata Alfano, and Francesco Bifulco, Conference of Informatics and Management Sciences, March 24 – 28, 2014). In general, Greenfield projects have economies of scale and scope, which means that they are wide-ranging in size and opportunities. Typically, they aim at introducing change at all the levels of a city, with the efforts being made simultaneously in order to attain the desired results and revamp the entire city in one shot. Such all-encompassing projects require very large investments in technology, and financial and human resources, and they usually entail the government because they span the entire city including all public and private constructions and areas. Greenfield projects are also referenced as turnkey projects since they deliver a complete solution to the customer instead of an incomplete product that ordinarily comes with the assumption that the buyer would need to complete it. In other words, a Greenfield project will revolutionize all industry sectors at once, from health, education, transportation… all the way to energy usage and utility management. We can take the examples of Masdar in Abu Dhabi and Skolkovo Innovation Center (2010-2020) which is a planned city for 20,000 residents to be built just outside of Moscow, Russia (Source: The Urban and Regional Innovation Research Unit, March 2015). On the contrary, Brownfield projects are smart interventions in existing contexts, whereby they are smaller in size and more concentrated on a limited number of implementation areas or business sectors. This process permits to progress by incremental steps instead of completely transforming the city at one time, by emphasizing on priority issues and either revamping or expanding the existing ICT and city infrastructures. Some cities might find it more critical to enhance mobility, while other cities might consider energy efficiency a top urgency. Thus, making the city smarter will be a gradual practice, in which case every industry sector is tackled aside, each often requiring more than one Brownfield project to be revolutionized. Examples of Brownfield initiatives are the smart transportation project in Lavasa, targeting to improve the city transport systems and create a consolidated parking management technology, as well as the smart street lighting to be deployed in the city of Los Angeles in the United States (Source: LA to Become the First City with Smart Street Lighting, Business Wire, April 9th, 2015). In the latter project, the connected lighting management system uses mobile chip technology implanted into each fixture so that street lights are able to recognize themselves and the surrounding network straightaway, and accordingly, city administrators will be able to better manage the city services through the newly developed web-based technology.

2. Timeline

Normally, Greenfield smart city projects take years to be executed and have a long-term plan, which implies that the return on investment and revenue realization from the project will have likewise a long-term sight. Brownfield projects on the other hand have a short-term implementation plan and can be executed much faster since their scope is smaller and they do not revamp the entire city but only parts of it. This, in turn, reveals that return on investment and revenues will be grasped faster, which is indeed a major source of attraction for investors.

3. Constraints

Due to the fact that Greenfield projects craft new cities and involve the founding of builds and infrastructure from scratch, decisions usually require fewer efforts and encounter less resistance than those made in Brownfield projects. However, the major constraint facing Greenfield cities is the level of empowerment provided by the city government, which is in such cases the initiator of the project. In fact, Greenfield projects necessitate a high contribution from the government because it is usually the most enabled body to introduce changes in a city, and thus the most likely to get the consent of citizens and other participants. Another challenge to Greenfield implementations is the large amount of investments required in terms of labor and funds. But whenever there is a decision-maker and resources are available, such large scale projects will frequently run smoother than Brownfield projects. This is due to the fact that Brownfield projects confront the very serious difficulty of having to either revamp the existing infrastructure of the city or expand it and build on top of it. As it was mentioned earlier, Brownfield initiatives target a single industry sector or sometimes only part of it with buildings, roads, and an ICT infrastructure already in place; all of which makes the decision to adopt either alternative more problematic. Brownfield projects are generally led by the private sector, which obviously does not have as much authority as the government body to access, mutate, and control the infrastructure of the city; accordingly the contribution of the government is often needed to provide the enablement to execute the initiative. An example with regard to the smart transportation sector would be the need to plant sensors all over the city to capture the movement of citizens in their cars whereby all roads, bridges, and city localities fully belong to the government, and which might represent a barrier to the project implementation unless the private sector project leader is able to get the consent of the city administration and involve the local authorities in the project. In addition, for the sensors to receive and aggregate all the data, this requires some changes to the ICT infrastructure such as putting down optical cables across the city, and these changes require access to public spaces and government properties to be accomplished. However, even if the Brownfield project is initiated by the city government, the choice to either transform or extend the incumbent infrastructure might be restricted by a conflict of interest with the landlords or the technology providers involved, and thus the project will be affected directly or indirectly by stakeholders other than the government leader. For instance, a project instigated by the municipality of a city and aiming to improve the urban mobility might not always get the buy-in of transportation companies which will have to invest more and probably a lot in their business in order to achieve convergence. Whenever the government has an active contribution, despite not having a prime role, its involvement will either soothe the decision-making in relation to the city setup or add to the funding required, depending upon whichever provision it can extend. Nevertheless, this does not eliminate the fact that Brownfield projects, especially those initiated in developing nations, impose that the government generally leads, or primarily intervenes to proffer the empowerment as well as the capitals necessary for the project. This is due the fact that the context of the developing nations differs from that of the more developed nations, whereby in the former countries the utmost power remains in the hands of the government, irrespective of whether the local or regional authorities have enough coherence and wisdom to rule their countries, or are even able to assist in financing the change initiatives that might emerge. The political instability in the developing countries as well as the poverty and the tightness of public finances make the situation even worse, and weaken the leaders while they constantly keep on trying to prove their credibility, or the lack of it, at every arising opportunity. Similarly to Greenfield projects, another strategic constraint to Brownfield developments is the financing model by which the essential funds for the completion of the project will be collected, and the return on investment and revenue generation will be ensured. It is worth mentioning here that it would require the execution of a handful of Brownfield projects, each with a specific timeline and implementation plan, in order to transfigure the whole city into a smarter metropolis and thus be able to deliver a better quality of life to the citizens in whatever they do during their daily commute. The city that is able to shift its fragmented use of technology projects into a more systematic approach, will improve the odds of becoming a smart city in a shorter period of time. However, for that purpose, the different stakeholders should agree on an all-inclusive vision for the city, but instead of going with one irreversible big Greenfield project, they create a bunch of individual Brownfield projects to move the city onward. This might be the case when the sources of capital – including municipal budgets and private funds – are limited, or the return on investment is difficult to measure. Nevertheless, similar step-by-step initiatives should either be led by one entity or be highly coordinated, if the leaders of the projects are diverse, so as to prevent redundancy and lost efforts as well as to guarantee having the same goal throughout every one implementation. In reality, the disjointed technology projects in cities will reap their benefits each in the place where it was first initiated and then applied. Yet, to attain a global transformation of the city and introduce the needed change, it might be sometimes sufficient to just emulate one of these projects then scale it up to cover other organizations/areas of the city. Consequently, additional barriers to Brownfield projects are the lack of coordination between the economic actors of the smart city value chain, and the blurred linkage to a global picture of a smart city, which will make the ability to remodel the entire city a hard-hitting endeavor. In fact, the lack of coordination among the stakeholders arises mainly when the country is seeking to modernize a city one step at time, by initiating multiple consecutive small-scale projects instead of following a Greenfield methodology to the reform. Since the contributors will not necessarily be the same throughout the multitude of projects, the different groups of stakeholders might not communicate and cooperate between each other to ensure that there will be no lost and redundant efforts, going from one project to another. What might further worsen the synchronization among the stakeholders and forbid the realization of smart cities is the fact that instigating a series of Brownfield projects is usually the approach pursued by developing countries where there is already enough chaos and lack of a clear top down communication from the leading authorities to the followers, namely the private sector and civil society. Thus far, it is not always better or feasible to go with a Greenfield project or a pack of Brownfield projects envisioned towards the same goal. It would be more adequate, at times, to launch small individual projects whenever the purpose is to convey change to only a specific area or industry sector, the accessibility of capital is circumscribed, or the agreement about an integrated vision of a smart city is difficult to be reached in the presence of multiple stakeholders. In my opinion, before a city decides to instigate any smart initiative, it must carefully determine its priorities based on metrics and plans developed in specific for the outcomes it aims to achieve. It is very rare, actually, that two cities go along the same smart path, because the goals and capabilities for one city are different from the other. After the city defines its objectives, it would have the knowledge to better evaluate which smart solutions will evoke the highest value and have a remarkable change impact on the city life. Should it start with electric grids, electric vehicles, and other transportation technologies, or should it focus on improving the health or education sector to enrich the value of services offered to citizens? Should it go for a directed initiative which outcomes can be achieved in the short-term, or should it pick out a long-term project to revamp the whole infrastructure of the city and target all business sectors at once? Personally, I recommend that the city follows a Greenfield approach if it has the required resources and enablement to completely revolutionize the city by setting up novel ICT and city infrastructures together. But in developing countries such as Lebanon, it would be more appropriate to launch small-scale initiatives to introduce the desired change one at a time, based on the priorities of the city and the availability of potential competent stakeholders, bearing in mind the necessity to ensure coordination and synchronization of efforts between the consecutive projects.

To sum up, the choice of the project scope, i.e. the decision to go with a single broad Greenfield project, a stack of small Brownfield projects stretched to a common vision, or just individual small projects targeting one specific area or industry sector is inspired fundamentally by a series of driving forces that are usually prevalent when a smart city initiative is to be started. The subject driving forces are represented primarily by the motives and objectives underpinning the project, followed by the choice of stakeholders, the dynamics of the relationships among them (including the project leadership, besides the availability, contribution, and coordination of partners), and the available resources (financial, human, ICT, and city infrastructure) for execution. . The willingness and responsiveness of these driving forces, each alone and together, will influence the type of the developmental approach to be used, and ultimately the project sustainability.

C. The Smart City Value Chain: an Analysis on ICT Resourcing

As it was previously mentioned, the value chain in a smart city is represented by the stakeholders involved in the smart initiative as well as the activities pursued by the stakeholders to provide the required resources which are all capitalized to facilitate the smart city conception, and which include the capitals, the workforce, the ICT infrastructure, and the city infrastructure planned to be revolutionized. For the purpose of my report, I will explain next the ways and manners to perform the activity of ICT resourcing and the related requirements that need to be fulfilled in this regard, considering that ICT is a vital enabler to the value creation process featured by the concept of a smart city value chain. Then, I will expand on the nature of the stakeholders that can potentially partake and contribute to the accomplishment of any given smart city project.

It was documented in the paper "Getting Smart about Smart Cities – Understanding the Market Opportunity in the Cities of Tomorrow" published by Alcatel-Lucent in February 2012, that the key enabler of smart cities is its ICT "central nervous system". Indeed, what fortify the intelligence in these cities are the omnipresent and dense networks of sensors, actuators, smart grids and other devices, the M2M (machine-to-machine) connections among them, with the network, and with the end users, in addition to the data analytics that generate the necessary awareness and smartness to be delivered to the citizens. The whole represents the Internet of Things (IoT) appointed to improve the quality of both community services and community life (Source: Internet of Things for Smart Cities, Andrea Zanella, Nicola Bui, Angelo Castellani, Lorenzo Vangelista, and Michele Zorzi, IEEE Internet of Things Journal, Vol. 1, No. 1, February 2014). As a result, it was agreed that the infrastructure of all smart city technologies is planned around a multi-platform technology stack that comprises the sensory (physical), network, analysis (IT), and applications layers, as it is shown in the figure below (Source: Smart Cities in Southeast Asia: The opportunity for Telcos, PwC Consulting Services, 2015):

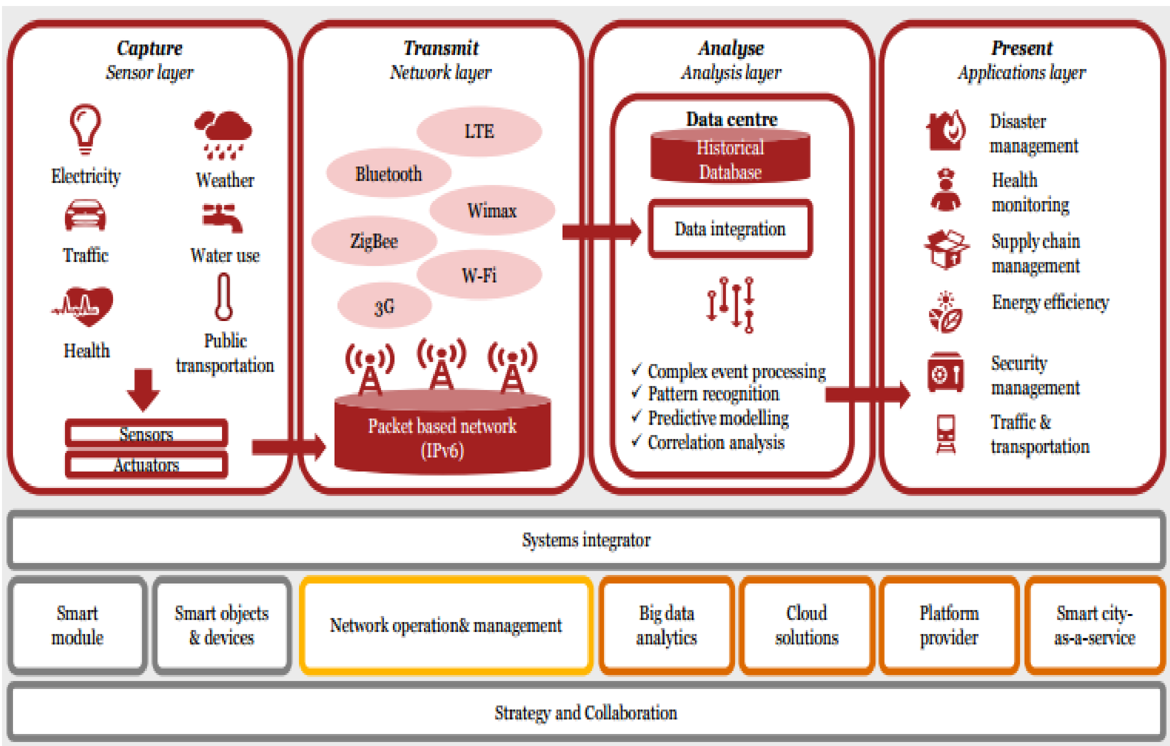

Figure 1 – ICT Layers

The four layers have to be integrated together and commonly shared across the whole city to facilitate the flow of information from the sensor layer to the analysis layer through the network infrastructure, which in turn transfers real-time insights to the customers (presence, location, usage) via a value-added application and service enablement suite having a citywide open access to sensors and actuators. In fact, the sensory layer is about planting sensors across the city in order to gather as much data as possible regarding the behavior of the residents and the activities that are happening in the city. The analysis or IT layer builds the required intelligence through data mining techniques and a set of sophisticated authentication and billing capabilities. This will allow founding a differentiated pricing strategy and accurately charging the customers according to their Internet consumption, in addition to giving them meaningful insights which will help them better understand and cope with the smartness of the city. As to the application layer, it represents the interface with the end user, and is established through open application programming interfaces (APIs) which authorize the citizens to download applications that run on mobiles and fixed ICT platforms (desktops, laptops, tablets, etc.), and to benefit accordingly from the e-services offered. The smart city will be able to monetize the investments it has made, and generate revenues from those applications, unless its intention was to deliver free community services to the population. There was, to be sure, an inflation of the number of Open APIs from 265 in 2005 to almost 6,700 in 2011, as denoted in the 2011 research partnership between the Climate Group, Arup, Accenture, and Horizon, titled Information Marketplaces – The New Economics of Cities. Whenever it is seized and accepted that the user interface is the easiest to design and implement, it becomes evident that the telecommunications network and platforms underpinning the application domains have the most important role in enabling incremental smartness in cities. Consequently, the network layer, which is in charge of providing seamless connectivity across the entire city, is considered to be the most critical ICT requirement.

In view of that, we will expand upon the network-related criteria that are essential for building an intelligent, responsive, and compliant ICT infrastructure in smart cities. Basically, they can be portrayed by the following:

- The readiness of 4G (Fourth Generation) LTE (Long Term Evolution) technologies on both Radio Access Network (RAN) and Core or Backbone Network, bearing in mind the necessity to have a wide-ranging LTE geographical coverage in smart cities, as well as to ensure high bandwidth, i.e. high data throughput (up to 300 Mbit/s), low latency at the user and control plane, efficiency, reliability, data security, and user privacy (Sources: Enabling Smart Cities with Mobile Broadband, Sponsored by Huawei, October 2014, IDC #CEMA21562 & 5G: A Technology Vision, Huawei Technologies Co., Ltd., 2013). In addition, the deployment of LTE networks in this manner prepares the road to other advanced technologies in smart cities, such as:
    - Voice over LTE (VoLTE) over IP Multimedia Subsystem (IMS);
    - Multiple-Input-Multiple-Output (MIMO) antenna schemes for improved microwave transmission capacities at the air interface with the end user, i.e. faster data speeds;
    - Wi-Fi Offloading to support the increasing data volume and user demand and deliver better quality of experience to indoor customers; and

- LTE-Advanced technologies that enable the Carrier Aggregation (CA) feature which also increases the bandwidth at air interface to 1 Gbit/s on average.

- The availability of a high capacity medium of connectivity on both access and core networks, in order to benefit from the advanced LTE performance and hence, enable the users to enjoy the fast-speed and real-time community e-services in smart cities (Sources: Smart Sustainable Cities: An Analysis of Definitions, ITU-T Focus Group on Smart Sustainable Cities, November 2014 & Large-Scale Mobile Sensing Enabled Internet-of-Things Test Bed for Smart City Services, International Journal of Distributed Sensor Networks, Hindawi Publishing Corporations, Volume 15, 2015). Globally, fiber optic communication within the access and backbone networks, and from the backbone to the external packet data networks (e.g. Internet) is deemed to provide a much higher bandwidth (up to 10 Gbit/s) and lower attenuation loss over long distances compared with electrical and coaxial cables; while the last connection at the air interface to the mobile end user continues to be through microwave wireless links.

The two basic characteristics pertaining to the ICT network layer in smart cities will be further detailed and analyzed when setting the grounds for the business case of Touch, the leading mobile operator in Lebanon in the following section. The latter will be an active primary stakeholder and the leader of the Brownfield smart transportation project that we intend to evaluate and build a business model for, considering the social, political, economic, and geographical circumstances of this developing country. The case in point will handle all the driving forces influencing the success of realizing a similar initiative in order to assess the feasibility of transforming the transport sector in Lebanon, and ultimately deploying the sought-after smart Lebanese interconnected territory. During the course of analyzing this project led by Touch, we will emphasize the role of the Telco in delivering the four ICT requirements stipulated previously and in particular with regard to the network provision, as the network layer ensures convergence among the sensory, analysis, and application layers. In addition, we will expound the network-related criteria implemented in developed networks and accordingly, benchmark the capabilities of Touch mobile network with the global network doctrines desired in smart cities. The gap analysis done, we will be able to assess the competences that Touch can provide in this respect, and determine the extra miles that need to be achieved by the Telco so as to guarantee the execution of the project in hand.

D. The Smart City Value Chain: Stakeholders' Selection, Role, and Contribution

Having disclosed the necessity of attaining interoperable and advanced ICT networks and operations (among other resources needed) as one of the pivotal activities of the smart city value chain, we will identify now the portfolio of potential economic actors, which are in fact responsible for providing the resources needed, and accordingly performing the activities pertaining to the value creation process underlined by the smart city value chain. In the simple diagram below, we will illustrate the value chain process, in which case the stakeholders are at the center of the process executing the different resourcing activities required for crafting smart cities:

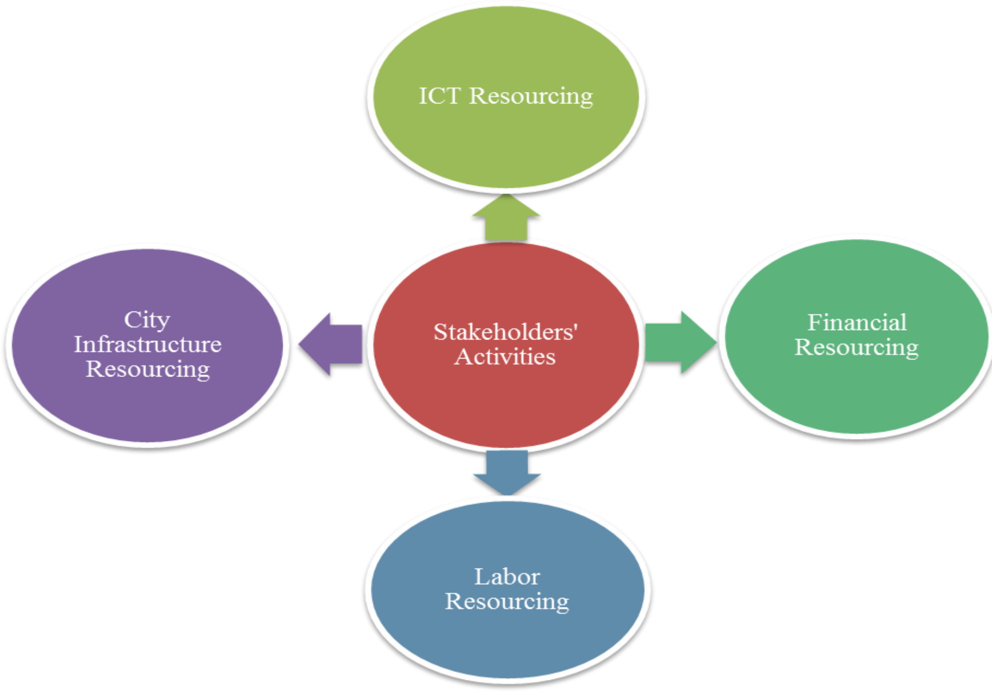

Figure 2 – Pillars of the Smart City Value Chain

Whilst the nuts and bolts of the value chain are being unveiled, we will interpret the dynamics of relationships and the types of interactions that might happen between the different stakeholders involved. That is, we will understand the roles and responsibilities they can assume in relation to the project leadership and the availability, influence, and coordination of partners, then divide them accordingly into categories as per their level of contribution and accountability to the project. The stakeholders' and relationships' mapping will help uncover the fundamental business models that were exploited to develop smart cities up until these days. The Telecommunication Standardization Sector of the International Telecommunication Union (ITU-T) used focus groups to confer about smart sustainable cities, and in this respect, produced a technical report “Setting the stage for stakeholders’ engagement in smart sustainable cities” in March 2015, which basically designated the smart cities founded in developed countries, and in some cases, the successful achievements that occurred in developing nations such as China, India, and the Gulf countries including Qatar and Dubai. On a side note, a country is considered developing if it scores low on some pre-defined general reference points such as the Human Development Index (including the income per capita, life expectancy, and education indicators) and the Gross Domestic Product (GDP) per capita relative to other countries. However nowadays, it would be wrong to solely rely on these measures since many countries are scoring high on them, but are still labeled as third world / developing countries. Other factors that should be included are the political stability, level of investment, trade policy, illness / disease, level of poverty, etc. In the instances where smart cities were deployed in developing nations, those are rather high income countries and score high on the GDP per capita index, but are still lagging in relation to the other indicators of life expectancy, education, poverty, etc. In fact, the availability of capitals to fund the smart city projects was mainly the reason for their accomplishment, although these countries still have vast underdeveloped areas and an imbalanced approach towards regional urban growth, all of which prohibits them from becoming fully industrialized and thus categorized as developed nations. In addition, as it was mentioned earlier, the wealthy government in developing countries is almost always actively engaged towards the realization of smart city initiatives, by leading, empowering, or financially backing the initiative. We will build on the findings of this report and the publications of Alcatel-Lucent mentioned previously, in addition to the research paper by Arup “Global

Innovators: International Case Studies on Smart Cities, October 2013", in an attempt to generate a custom-made stakeholder categorization scheme and corresponding business models that are as generic and all-inclusive as possible, and that can be tailored and slightly adjusted to suit any smart city project that is to transpire in developed countries. So the one drawback from the analysis to follow is that it plainly covers the well-off states, in which case the stakeholders' potential and readiness are high to provide the necessary resources required to develop the ICT infrastructure and modernize the city infrastructure according to the smart city standards. In fact, none of the readings discussed the case in point of a developing country where usually the capabilities and willingness of the prospective stakeholders are constricted, which in turn, restrains the motives as well as the envisioned objectives. Hopefully, the business case and role of Touch mobile operator in leading a Brownfield smart transportation project in Lebanon, a developing republic by origin, will allow us to shed light on the convergence and peculiarity of the smart city building blocks between the developed and developing world.

The stakeholder, by definition, is an entity, institution, or individual that can meaningfully control or be controlled by the creation of a smart city. Not all potential stakeholders might consider the city welfare as a priority and work towards achieving it; and even if they do, they might not have the abilities to do so. For that reason, we will divide them into categories according to the role of each in transforming the idea from a mere concept to a concrete application, whereby the first-level engagement categories are "active" vs. "passive", having the subcategories "primary" vs. "secondary" and "supporter" vs. "opponent" respectively (Source: Setting the Stage for Stakeholders' Engagement in

Smart Sustainable Cities, Telecommunication Standardization Sector of the International Telecommunication Union (ITU-T), March 2015). The following table will help visually understand the stakeholders' categorization and contribution to a given smart city project:

Table 1 – Stakeholders' Categorization and Contribution

<table>
<tr><th colspan="3">Active (Influencing)</th><th colspan="2">Passive (Influenced)</th></tr>
<tr><td rowspan="2">Primary (Power & Capital)</td><td colspan="2">Secondary (Benefactor)</td><td colspan="2">Beneficiary</td></tr>
<tr><td>Power/Enablement</td><td>Capital/Funding</td><td>Supporter</td><td>Opponent</td></tr>
</table>

To be more precise in defining the role of each category, the "active primary" stakeholder acts as an influencer and has the financial resources, will, and power, combined altogether to manage the change; the "active secondary" stakeholder supports and influence the initiative by providing either the means or the authority; and lastly the "passive supporter" or "passive opponent" group refers to a stakeholder not actively contributing to the project implementation but which is relatively affected by the smart city deployment.

An active primary role enfolds all the major partners that are giving at the same time the empowerment and the funding necessary for the project execution, regardless of the chain of command in place i.e. which is the leader initiating the project and which are the team members. By providing empowerment, the primary stakeholders are ensuring the needed governance for institutional improvement and citizen engagement through either promoting and emphasizing the usefulness and importance of the initiative to people and other potential stakeholders, or authorizing and enabling its implementation in places where it is difficult to be carried out and deterring incipient obstacles as they arise to ensure a smooth implementation throughout the way. Funding, on the other hand, is about affording the necessary capitals to execute the project. The financial resources are not always secured in the form of cash; and even when they are, the cash will be used to execute the milestones required for the initiative to succeed. In point of fact, when the primary partakers invest their money in the project, this money will be eventually converted into assets such as the network, the systems, and the sensory devices, or will be used to pay the labor force remunerations and revamp the city infrastructure to accommodate the smart technologies. Basically, whenever the primary involved stakeholders are not capable of providing the needed power/enablement and capitals to carry out the plan, they will be assisted by secondary stakeholders entitled to deliver whichever necessity they can give. The common point between the two categories is that they are committed to the smart city initiative by the same token, and have both influence over the strategy and implementation of the project. However, their impact on the decision-making process will follow the hierarchy and distribution of roles assigned to each entity. In other words, the leader and other primary active stakeholders, having more responsibilities compared with the secondary stakeholders, will have evidently higher influence regarding the decisions to be made and wield greater control to guide the progress of the project in the desired direction.

The leader is by default the prime originator of the initiative, and has to have an active primary role by giving in a large proportion of the empowerment and resources needed for the initiative to succeed. Accordingly, depending on the reasons/motives, scope, and objectives of the initiative, any governmental body or private organization meeting these two requirements has the opportunity to lead a smart city project. The role of the leader is to define the strategy and business plan which consists of developing the scope of the project, the timeline for execution, and the implementation plan, and then conscientiously support their fulfillment. Normally, the leader has an irrevocable share in the decision-making; however, the final decisions are always the culmination of the negotiations among all actively engaged stakeholders. Decisions mostly pertain to the volume of investment that has to be done with regard to the ICT and city infrastructures. The leader has to ensure that sound and constructive communication among the stakeholders is always maintained, as well as to coordinate their efforts, segregate their duties and keep them lined up towards the same end goals. Due to the fact that smart city projects entail multi-stakeholder relationships, in which case the interest of some might not happen to be the concern of others, coordination and motivation towards the same goal are therefore crucial. In other words, the vision or purpose has to be clear, common, and shared among the stakeholders of the project before any practical exertion is launched. Once all opportunities of synergy among the stakeholders are grasped, decisions will be more easily made and obstacles discharged one at a time. Consequently, the key driver of any smart city achievement is a well-structured plan devised by the leader of the initiative, comprising what is to be covered throughout the implementation phase, and upon which all stakeholders have reached consent. The partnerships among the stakeholders have to be strongly mapped and highly coordinated, whereby the role of each entity towards of the realization of the smart city project has to be well-defined, tracked, reported, and assessed. Despite the shared responsibility among the different associates, there has to be one party leading the project.

This would guarantee that all partners are continuously communicating with each other, providing constructive feedback whenever necessary, as well as being held accountable for every action point on their agendas. The project manager can be the city itself (municipality of the city or any local governmental entity inside the city) or a local private organization, preferably in the technology domain, such as IT vendors or Telcos.

On the other hand, the last category comprises the stakeholders which do not stimulate or vigorously contribute to the smart city initiatives, but are rather affected by them. They are labeled "passive" because they do not actively participate in the decision-making and the project planning and execution, nor are tied up to its vision and goals in any way. In fact, before the project is inaugurated or throughout its execution, passive stakeholders decide whether they want to benefit from and support the initiative or become rivals to it, depending on how the change is going to affect their well-being and on the forthcoming impact of the initiative. Although they are part of the value chain and are called stakeholders, they cannot be considered partners or partakers in the project because they do not participate nor have an active role in transforming the city, or part of it, into a smart conurbation. The mere fact that they are recipients of the change and beneficiaries of the to-be-deployed smart ecosystem makes them become either followers or challengers. Whenever the initiative appears to be promising of a better quality of life or of a sustainable source of revenues in the future, passive stakeholders will support it and embolden others to promote its usefulness as well. But whenever the purpose or impact of deploying a smart city is not aligned with their interests, they'd better be against the idea and disprove it.

On a side note, adversaries to smart cities might emerge even before the first-level categorization occurs, i.e. even before the potential stakeholders are considered active or passive. All the potential stakeholders assess the initiative in relation to the resources and empowerment they can afford, and accordingly the classification happens. However, some might try to become active partakers even though they lack the requirements needed to be able to effectively contribute to the smart city initiative. This is, in point of fact, when rivals to smart city projects can be formed early before launching the project, i.e. during the initial negotiations about the nature of the stakeholders and the level of their involvement. Moreover, it might happen that conflict arises after the project is instigated and the roles are assigned. The players might argue about the distribution of roles and responsibilities or the scope of the initiative itself. Considering the former argument when the project is not launched yet, if the choice of stakeholders involved fails to incorporate all interested parties, then the likelihood of resistance to the initiative will be higher. Individuals, institutions, or entities which will not get the chance to actively add value to the project, like in the event of conflict on ICT delivery between IT companies and Telco service providers, might become passive opponents of the smart city initiative and thus be assimilated with the last category of stakeholders. The paradigm of ICT provision demonstrates an early clash of interests between two potential stakeholders, validating therefore the need to make a selective decision about which ICT service provider to choose, ahead of starting the project. Conversely, any disagreement emerging among the consigned stakeholders throughout execution, regardless of their engagement level, does not make of them antagonists to the initiative since they are already engaged and assigned to execute the framed plan. Those will be practically considered discordant partners that are urged to solve the issue in order not to beget any detriment which might slacken off both their collective and individual efforts and ultimately hinder carrying out the project.

The smart city value chain comprises fundamentally the project stakeholders and the activities assigned to them so as to ensure that the needed resources from capital to workforce to ICT and city infrastructure are available and ready to be used or transformed during the project implementation. Normally, the financial, human, and ICT resources are provided by the contributing stakeholders, whereas the city infrastructure is an existing resource by itself such that the integration of infrastructures and technology-mediated services is an indispensable building block for deploying smart cities. The identification of the different components of the value chain process is not sufficient to successfully complete a smart city project, but it is quite about recognizing the business model in use. The business model embraces the participating stakeholders and the dynamics of the relationships among them. It is not about enumerating the stakeholders and describing their roles as solo players, whereby the stakeholders' choice in a given project might be the optimal selection; still the project ends up by being a failure. It is good to know what every participant is giving, but what is mostly important is to be able to discern what all of them are giving cooperatively. Consequently, the nature of the relationships among the participants anticipates and defines essentially the outcome of the project. Basically, the interactions convene the project leadership, the availability of the stakeholders, their individual and collective contribution, as well as their coordination as partners in this project. Above all, the role of the leader is to supervise and coordinate the activities and relationships of the various stakeholders taking part in the project, as well as to evaluate and assess the investments being made in relation to ICT and other requirements so that the right decisions are eventually pursued. Normally, leadership of projects being executed in developing countries is in need of more perseverance from the leader's side due to the not-very-stable political, social, and economic circumstances in the referenced nations. Accordingly, maintaining the order within the group of participating stakeholders requires a strong leader that is capable of taking sound decisions for the welfare of the initiative, even if no consent is reached among the stakeholders, in addition to managing the work done by others and following up on all pending issues. This is obviously required as well in the developed countries; however, the point here is to highlight that the leadership responsibilities will take much more efforts to be implemented and sustained in the developing countries, likewise Lebanon, especially that leadership in these countries is usually assigned to the government or one of the public organizations associated with it, which are generally the reason for the disarray in these countries. It is necessary to have a leader for every project in order to maintain sound relationships between the stakeholders involved and ensure that coordination and negotiations are being conducted constructively before any decision is made. However, the leader is never a dictator and cannot impose its preferences on the rest of the participants which might also be giving as much to the project. Generally, the stakeholders involved in the decision-making are the leader, and the other primary or secondary stakeholders which are actively engaged and investing their time and/or money to complete the assignment. The passive stakeholders, by not adding a value to the project, shouldn't have evidently the right to influence any decision. On the other hand, all major players are qualified to legitimately partake in the decision-making process so as to get justifications for every dollar or every second they are spending on this project. The leading stakeholder has generally the utmost power regarding the decisions to be made, followed by the active primary and secondary stakeholders congruently. In fact, what reinforces the significance of the stakeholders is the nature of the value they are adding to the project. This value is begotten through giving in empowerment and/or funding which will basically affect the ICT infrastructure or the city infrastructure

Subsequently, we will reveal the exhaustive list that compiles and reels off the prospective stakeholders all in all, whereby the conceivable classification or categorization, and the likely participation levels of each are explained so as to understand the various determinants that might affect the role of a given stakeholder in any smart city project to be assumed. The stakeholders' register below is customized and not taken from any book or research paper; it was assimilated based on a personal effort that involved a lot of readings, in particular the ones done by Alcatel-Lucent, Arup, and ITU-T cited previously. The role that an economic actor in the smart ecosystem can play will, in line, contribute to the collective efforts and relationships within the group of stakeholders involved. Again, the dynamics of the interactions among the major players in a smart city project allude to the project leadership, and the availability, impact, and coordination of the different partners. Stakeholders can contribute differently, based on the scope of the project, its motives and end goals, as well as the availability of resources that are to be provided by the stakeholders, if chosen to participate; all of which reinforces the variety of business models that can emerge, and results in the fact that every smart city initiative is unique with regard to the planning and execution of its scope of work. Moreover, throughout this section, we will underline the provisions that ICT stakeholders can add to a smart city project in order to emphasize the importance of the ICT driving force and the possible conflict that might befall between the ICT service providers.

1. Municipalities, City Council, City Administration, Ministries, Governmental Departments, and National and Regional (or Local) Governments

They usually play an active primary role in the smart city project, or else nurture the development of the initiative by offering either the enablement or the means. Also in some rare instances, they might just be receptors of the change that is made available in the city through the smart solutions created. For simplification, we will be using the term "Government" to designate each of the above subcategories. Whenever the government has an active role in the project, the resources and/or power it retains will determine the position it will embrace with regard to the initiative. By way of explanation, whenever the government has both credentials of money and power, and given that it has initiated the idea of the so-called smart city project, then leadership will be assigned to it. This is actually the ubiquitous best practice for Greenfield projects, which require very large capitals, but most importantly the control, direction, and empowerment of the government to be successfully tracked and done. Brownfield projects, despite their restricted scope of work, can also be started and managed by the government, specifically by ministries, governmental departments, or publicly owned companies working in ICT, transportation, health, education, safety, water, or energy; but the probability of being initiated by a private organization is much higher in this case. Yet, although being led by the private sector, Brownfield initiatives in most of the cases require the government intervention to enable and empower the initiative, or back the funding associated with it, or to provide assistance in both. The government will still have an influential role, but will be considered a major player within a team that is led by a different entity. Yet, if the government abstains to provide the resources and the authority simultaneously, it will be supporting the initiative by giving away whichever necessity it can afford. This means that despite having minimal public finances and/or power, the government can still actively contribute to the project. Its membership remains a vital requisite for the mission to run flawlessly and ultimately be completed within the pre-defined timeline, scope, and constraints. Alternatively, government and city organizations can be passive agents if they lack both requirements, whereby their role is restricted to basically promote awareness about the significance and inevitability of implementing smart initiatives in the city. After all they will be definitely affected by and benefit from similar arrangements at the time they will take place, so their pertinent support will boost the engagement level of other stakeholders in order to actually deploy the initiative. Almost all stakeholders partaking in smart city initiatives practically claim the importance of the government contribution, despite being partial in some instances. No matter how capable the actively engaged private sector is in inducing the change, the decision-making process might require the government intervention at some point, provided that the initiative could infringe public properties, in which case getting the government consent to make the initiative operative becomes mandatory.

2. *City Services Companies*

They refer to the private or public businesses which will be implementing the smart solutions once available. Generally, those are active secondary stakeholders because they will be investing their time and money to renovate their devices, tools, and equipment and revolutionize their services according to the criteria and practices implemented in a smart city. In a smart transportation project for example, city services companies entail all those providing conveyance and delivery facilities by means of taxis, minibuses, buses, trains, etc. While city services companies in a smart education project include universities, schools, research labs, and academic institutions; all of which will apply the smart innovations to enhance the efficiency of their learning services. It is worth indicating that this category of stakeholders might have an active primary contribution, if it were to provide the empowerment as well as the support in financing the project. Let us consider the example of a Brownfield smart health initiative that aims to revolutionize the hospitals' equipment and services, and create e-health solutions for the patients to connect with their doctors. The city services companies are the private and public hospitals, the medical laboratories, the private clinics, the health centers, etc. All of those have the possibility to be primary stakeholders by promoting the initiative to other potential stakeholders such as people and other city services corporations, enabling and empowering the project by authorizing the implementation of the necessary ICT changes at their premises, and finally investing to upgrade their own equipment and tools to be able to improve their services and amenities. Moreover, one of the city services companies with a primary participation, a hospital for instance, can be the initiator and the leader of the project as well. Whenever similar initiatives are started by either a public or a private city services company, they will normally follow a Brownfield approach based on the specialty of the leader company.

3. Utility Providers

Those can also be privately or publicly held institutions, responsible for deploying the major features of a smart city such as the networks and connectivity, the software required for the ICT infrastructure management and the interface with end users, and the compulsory hardware and equipment from smart grids to smart meters to water management tools to internet hotspot machines, etc. By and large, utility providers consist of ICT companies and vendors working in oil and gas, water and sewage treatment, electricity or any other form of energy. Given that this category of stakeholders plays a key role in the achievement of any smart city project, irrespective of its scope of work, we will assume that utility providers need to be always actively involved. Yet, their classification as prime investors or backers is contingent upon the enablement and/or resources they can bestow. If a utility provider that is willing to give the empowerment and the money comes up with the initiative, then it will be also handed over the leadership of the initiative. Ordinarily, smart city projects led by a utility provider are Brownfield and contracted in scope; however, it is possible for a publicly owned utility provider working in the domain of ICT or energy to lead a Greenfield project. This is due to the fact that these two fields of expertise are usually needed for all smart city initiatives irrespective of the targeted industry sector, and that the leading utility provider belongs to the government which will ensure the empowerment and maybe part of the large investments required for building Greenfield cities. Seeing that ICT will always remain a principal enabler in every smart city initiative, we will disclose in details the various roles and associated impact of ICT companies on the course of action and success of any smart project under consideration. In other words, we will take the various activities performed by these firms in their daily operations, and associate them with the four ICT layers we have been discussing, in order to evaluate which company is better positioned to provide the requirements inflicted by every layer.

In essence, ICT companies make hardware devices and software tools, as well as offer a variety of services required for the accomplishment of the project. Hardware denotes the computer hardware, satellites, telephone handsets, consumer electronics, transmission cables, antennae, switching and routing equipment, remote wireless sensors, and smart grids; whereas software includes mobile and website applications developed for end users to be able to connect to the network, as well as transmit to and receive data from the network entities. Moreover, software ensures management of and harmony within all network elements and IT systems, from sending and receiving emails to running the telephone switching equipment to transmitting data from sensors, satellites, and devices to other devices (Source: WETFEET, Industry Overview: Telecommunications, posted by the editors on December 3, 2012). Services, on the other hand, cover local and long-distance communications services for fixed networks (landlines), mobile (cellular or wireless) networks and wireless sensors, in addition to Internet access, configuration of private networks for businesses. They also take account of IT services such as backup and storage, security, accounts and access, business intelligence and reporting, consulting and development, servers and databases, and web development (Source: Stanford University webpage). Rarely does an ICT company incorporate all of the above goods and services into the core of its business, whereby what we commonly notice is that the Information and Communications Technology Industry is divided in two major businesses:

- The Telecommunications Companies, also known as Telcos, concentrate specifically on the communications services by giving access to Telephone services (whereby Telcos are called Mobile Network Operators or Mobile Network Carriers or Wireless Service Providers), Internet services (whereby Telcos are called Internet Service Providers), and other related communications services; but they frequently outsource the needed IT services. The main responsibility of Telcos is to plan, monitor, operate, and improve the active network plus to manage all the corresponding equipment and hardware installed through robust software and systems, in order for the consumers to seamlessly connect to the network. The software used to control the network as well as the probing tools are usually subcontracted, but managed internally; the same applies for the online and web applications which constitute the crossing point between the end users and the network. As to the hardware and equipment manufacturing and sales, the activity is hardly being pursued by Telcos which mostly put emphasis on supplying the communications and connectivity medium. Nevertheless, some corporations like AT&T encompass all of the previous businesses in their portfolio. In the past, most of the Telcos were owned and managed by the government because of the very large capital overheads involved. However, the number of Telcos being administered by the private sector is exponentially increasing nowadays, particularly in the developed nations, besides the fact that many of the government owned Telcos are also being denationalized. This Government-Telco affiliation infers that the government leader of a smart city project, regardless of the project scope, will presumably entrust the Telco, rather than an IT company, to provide all the ICT requirements or at least most of them, which might not be the suitable option to aim for. The ICT related costs of the project might massively increase if the capabilities of the chosen Telco are not developed enough. Indeed, ICT, and communications in particular, represent an indispensable enabler to deploy any kind of smart city. No matter whether one or many industry sectors are being revamped, i.e. no matter the scope of the project, ICT remains a major driving force, whereby it is impossible to deploy the smart city unless the ICT infrastructure is available and ready. For that reason, a public utility provider of ICT, i.e. Telco, that is leading a smart city initiative, has the opportunity to go Greenfield and cover several business sectors all at once, if enough support is being provided by the government. This is, in fact, a privilege to the leading utility providers owned by the government and working in ICT and energy, because all cities make use of ICT and energy to be upturned into smart conglomerates.

- The Information Technology Companies, i.e. IT Companies, are private organizations centralizing their core business activities on delivering the hardware and software necessary for the deployment of the network, and maintenance and support for both if needed, in addition to the IT service management for the diverse IT services listed above. The rest of the communications services are not a specialty of IT companies; yet, there are occurrences when the IT companies provide the communications medium or network. In general, there is a higher probability to choose IT companies for the network provision whenever a Greenfield project is initiated by the government, except for two conditions. The first being that the government owns a Telco so it will most probably choose to adopt the mobile network managed by this Telco even though it might be below the desired standards; and the second being that the existing mobile network is provided by a private Telco but is not advanced enough and requires large capitals to reach the necessary maturity level. Greenfield cities are, by definition, created from scratch and the deployment of a new network might cost less than the upgrades and expansions that need to be done on the legacy network of an existing mobile operator for it to become up to the standards desired in a smart city. However, it is assumed to be more cost-effective to capitalize and upgrade the quality and performance of the existing mobile network, when the approach touches upon a Brownfield assignment initiated by the government, not considering whether the latter owns a Telco or not. Basically, there are no specific determinants of ICT choice in relation to the network layer. It might occur that an IT company provides the network connectivity in a Brownfield project that is led by the government, likewise IBM via its Smart Cities Program introduced in 2009 (Source: Visionary Innovation Leadership Award, Best-in-Class Smart City Integrator, Frost & Sullivan's Global Research Platform, 2014). In April 2013, IBM worked along with the government of Gran Valparaiso, Chile, to bring about an efficient transportation solution that is able to bear the increase in the population density, and ultimately connect people and communities more effectively. IBM offered to oversee the transportation infrastructure by collecting and analyzing incongruent data from all over the city, and coming up with insights to better manage the city resources. Apparently, the network of the incumbent mobile operator in Gran Valparaiso would have called for more time and more money to be modernized; therefore, laying new fiber cables to deliver the needed connectivity represented a more feasible alternative. Contrariwise, whenever the private IT company is the leader of a smart city initiative, it will always go for a Brownfield project that targets a specific industry sector. The leading IT company will seemingly follow a Brownfield practice since Greenfield projects need very high levels of empowerment from the government, which might not be straightforwardly granted by the local authorities in a certain country. Even in Brownfield initiatives, the IT company might find itself urged to involve the government, as a primary or secondary stakeholder, and get its consent and empowerment to be able to implement the necessary changes to the city infrastructure. In addition, the IT company might choose to deliver all four ICT requirements, in relation to the sensory, network, analysis, and application layers. However, its choice possibly will be affected by the capabilities of an available local Telco, whereby the IT company might resolve to delegate some of the ICT provisions to the existing Telco, provided that it will guarantee fewer ICT costs.

All ICT building blocks, and specifically the network-related part, infer that smart cities propose an important market opportunity that can be straightforwardly seized by many performers in the smart ecosystem, whether those are telecommunications companies or their telecom equipment cohorts, i.e. the IT companies. Though, capitalizing on this window of opportunity and getting the most out of it are not as easy and obvious as they appear. As a matter of fact, a well-crafted and clear strategy plan needs to be developed by the players in order to be able to benefit from this golden chance in the best way. Bearing in mind the crucial must of having advanced ICT resources as an integral component of the smart city value chain, it is compulsory to shed light on the likely conflict regarding ICT provision that might occur between Telcos and IT companies which are both capable of delivering the ICT infrastructure looked for in a smart city. In an attempt to overcome this challenge recurring in many smart city initiatives, it is preferable to highlight the key strengths and weaknesses of both prospective stakeholders in supplying the necessary ICT layers, with the purpose of optimizing the decision-making process in relation to ICT delivery, and hence the choice of either ICT provider or both for the execution of a specific project.

At the sensory layer, IT companies are usually the prime providers of telecom equipment including sensors, actuators, routers, and switches; but large and forward-looking mobile operators have also the chance to supply telecom equipment to the market if they wish to integrate this side business within their portfolio.

Though at the network layer, it is normally easier for Telcos to provide the network infrastructure because mobile operators have already a nationwide network in place, which expedites the deployment of the smart city. The mobile network's main role is to connect all the devices together, and connect them with application programming interfaces, data centers, and ultimately connect all the previous elements with the citizens' mobiles and laptops in order to supply them with valuable insights about the city life which, in turn, will help them improve their lives. However, an IT service provider has also the opportunity to lay fiber cables in the city and install all necessary related equipment according to the proportions required by the project, whenever the available network technologies used by the local mobile operators are not advanced enough and require large capitals to become capable of delivering the exceptional quality of experience desired in smart cities. Keep in mind that the network provided by IT companies is a totally novel network that will be exclusively established for the urban development purposes, and has nothing to do with the incumbent mobile network of Telcos. How to decide whichever option is the most cost-effective, yet most value-added, is relative to the size/scope of the project and its far-reaching objectives, the choice of stakeholders, the maturity of the existing mobile network infrastructure of Telcos and the related operational, technical and privacy dynamics, in addition to the availability of funds to be spent in relation to network provisioning and service mediation. If the Telcos are to run the connectivity through their existing mobile network, they will most probably have to expand it to accommodate the big flow of data across the city, which is sometimes not feasible and very costly. But, then again, it would be much easier to leverage the existing mobile network since it already ties all the residents of the city and has the required information about each one of them. Few mobile operators have, in fact, an advanced network that will permit a smooth implementation of smart city projects without any additional expansion. Consequently, using the mobile connectivity in smart city initiatives will require a partnership with an IT company to provide the network equipment that will ensure reliable transfer of data across the city. We can take the example of Istanbul in Motion, a project initiated in 2011 by a partnership between Vodafone Global Enterprise and IBM (Source: Guide to Smart Cities, The Opportunity for Mobile Operators, GSMA, February 2013). The project intends to better match the delivery of public transport with the habits of the people in Istanbul. Vodafone, with the assistance of IBM, gathers information on the start and end points of the inhabitants' journeys to support the Istanbul Municipality in optimizing public transport routes. Usually, for small Brownfield assignments that are initiated by an IT company, using the mobile network, especially if it has limited capabilities, and having to pay service fees for Telcos might not be the right decision. Hence, laying new fiber optic cables dedicated for the realization of this specific project would be a better and cheaper option. But in Brownfield initiatives run by the government or by a Telco, the better and less costly alternative is to leverage the existing mobile network to supply the desired connectivity in the smart city. Out of the 150 Brownfield smart cities the GSMA trails globally, more than 100 cities have arrayed services – beyond smartphone applications – that make use of mobile networks, with half of these cities located in Europe. While for large scale projects spanning the entire city, it would be less costly to deploy an out-and-out new broadband network on top of the infrastructure in place, provided that the mobile network is not competent enough to fully grip the opportunities ahead.

Similarly to the network layer, Telcos are at a higher advantage with respect to the analysis layer that comprises the IT platforms and solutions mounted onto the network for the purpose of dissecting, aggregating, evaluating, and interpreting the data gathered from all the users accessing the network. This is due to the fact that Telcos have already access to the user information of their customers such as gender, age, location, occupation, etc. The data collected will be analyzed to better understand the behavior of the citizens, and accordingly provide them with services that will improve their quality of life. However, it is worth to mention that a robust and mature mobile network infrastructure is requisite before the Telcos can compete with IT companies on the analysis layer. Additionally, assuming that a Telco has the necessary network capabilities, but does not have the resources to acquire the intelligent platforms and systems, the analysis part will be therefore delegated to and managed by a separate IT company. This alternative puts the project success at a higher risk considering the security restrictions and user privacy conditions that have to be always maintained by the contributing stakeholders throughout the implementation of all upcoming smart community services and solutions that the project intends to offer to the citizens living in the to-be-deployed smart city.

Finally, when it comes to the application layer, Telcos are increasingly entering the world of mobile and web development; still the common approach is to purchase the business software applications needed from an IT company and manage them internally. Citizens will be able to benefit from the available community e-services for free or by paying a certain tariff, as agreed upon with the stakeholders of the project. Nowadays, Telcos are heavily investing in this side business, since the conventional revenue streams from Voice, SMS, and Data services are not being capable alone of sustaining the profitability of the Telco industry.

4. Non-Governmental Organizations (NGOs) and Multinational Organizations such as United Nations (UN)

NGOs and industry associations are neither public nor private, but considered as civil society organizations. They are not-for-profit and have very limited revenue earning opportunities; so instead of giving in money, they can devote their people and form pressure groups to invest their time and influence the community and enlighten the citizens about the importance and expediency of the initiative. Basically, they are considered in this case as active primary stakeholders, providing not only the enablement needed, but also the human resources committed to further empower the initiative. NGOs are advocates of innovation and technology transfer, and strive to promote smart city initiatives that aim to enhance the quality of the services offered to people, and ultimately their quality of life. Multinational organizations like UN agencies, on the other hand, can contribute to sponsoring the smart city initiatives, whilst promoting their usefulness as well. Accordingly, if they are to provide both, they will be dual-hatted and active primary stakeholders; still they are hardly ever the initiators of the project. But if they are to either empower the initiative or take part in the funding needed for its accomplishment, then they will play an active secondary role. In all cases, NGOs, industry associations, and international bodies can be simply passive supporters to smart cities initiatives, as long as they don't get the right opportunity to partake in the value chain.

5. Academia, Research Organizations, and Specialized Bodies

This category comprises private as well as public academic institutions and research organizations, with the main purpose of studying smart cities and their accompanying trends, including their effects and influences on sustainable growth. Generally, they are considered passive supporters because they are somehow affected by the deployment of smart cities, which thrusts them to research the ensuing benefits and repercussions from such assignments. However, they can have an active secondary role by promoting the usefulness of the initiative to other potential stakeholders, including the citizens, and its importance in enhancing the manners in which knowledge is conveyed from and to the community. They can also have an active primary role by empowering as well as providing their infrastructure resources, i.e. campuses for instance, as test beds on top of which the smart technologies can be implemented.

6. Government Development Banks and Private Financial Institutions

Private financial institutions include private banks, trust companies, insurance companies, investment dealers, or community development finance institutions. Both public and private financial institutions are essentially active secondary stakeholders providing the additional funds needed for deploying smart city initiatives. However, they might not always contribute to community development, and rather be affected by the smart implementations taking place, which makes them at long last passive supporters.

7. Citizens and Citizen Organizations

One of the three main incentives for building smart cities is the social and communal welfare of the citizens, and ultimately, the other two motivations of economic viability and ecological sustainability also enhance the quality of services accessible to people, and thus assist in improving the community life. Additionally, by being residents of the cities, citizens will have to eventually swallow the actualized smart innovations and use them in their daily activities; which implies that citizens are passive followers of the smart initiatives being achieved. Nevertheless, some citizens have the chance to become active partakers in the value chain by providing the means that will facilitate their interaction with the smartness of the city. In other words, they can have an active secondary role by investing their time to develop mobile and web applications that will permit them to connect to the intelligent network, to other devices, and between each other, so as to benefit from the various community services available in the city, and ultimately promote their usefulness to others. Moreover, citizens can be active secondary contributors by only encouraging other stakeholders to promote and adopt the smart city initiatives, without necessarily customizing their own interface with the smart technologies available. Whenever the inhabitants of the city are providing enablement for the smart city initiatives to be implemented, they will have definitely a positive impact on the outcome of the project; but through the course of reading I have pursued, I realized that none of the standing smart cities were started by the citizens themselves.

Going back to the underlying relationship that we established formerly between the project scope, motives, and objectives, as well as the readiness of resources that are to be provided by the participants, we were able to recognize that the combination of these drivers describes the foundation upon which the selection and classification of stakeholders are based. In particular, we will use this correlation to depict the instances when the stakeholders are considered passive mediators that are affected by the smart city initiative, rather than affecting its implementation. In relation to Greenfield initiatives, the government usually leads the initiative or is at least an active primary player in a team that is led by a governmental organization such as a public Telco, but not a passive stakeholder. While in Brownfield initiatives, all potential stakeholders are equally likely to be passive agents. In point of fact, the project's motives and objectives, and the type and value of the resources that the stakeholders can supply the initiative with will ultimately determine the extent of their participation. For example, in a given smart health project instigated by a private city services company, i.e. hospital, the government might have a passive role considering that neither empowerment for upgrading the city infrastructure nor help in funding are needed to complete the assignment. Alternatively, the latter can play an instrumental role by contributing either to the enablement or to the funding of the initiative, or both. The government's active commitment to the initiative relies on what it can offer in this respect, not counting the reasons and aims underpinning the project. Provided that the undertaken Brownfield project intends to reform the entire health industry, including public health centers and laboratories, then it will definitely need to involve the government and gets its approval to revolutionize the infrastructure of those public constructions. Briefly, the stakeholders in the smart city value chain can be picked and combined together in manifold ways, and their roles can differ from one initiative to another. Yet, the main pillars that will support in choosing the optimal combination and defining the contribution of each economic actor in the smart ecosystem are the scope, the motives, and the purposes of the project, plus the abundance, worth, and significance of the resources that are to be donated by the stakeholders.

E. The Smart City Business Model: Stakeholders' Mixture and Relationship Dynamics of Leadership, Availability, Influence, and Coordination

Clearly, there exists a diversity of ecosystem players tangled at the inception and then in the realization of any smart city project. As tallied above, those are the government and its affiliated administrations, the privately or publicly owned organizations including the city services companies, the utility providers of ICT, and energy and water management, the academic and research bodies, and the financial institutions and development banks, and finally the NGOs and the citizens residing in the smart cities to be deployed. The would-be stakeholders are not exclusive of each other, whereby a single project might not involve all kinds of players, but is rather a combination of one or more of the available entities. The potential contribution and classification of each player, as an individual stakeholder and as a productive member of the team of stakeholders, begets the various business models described previously. A business model is, in some measure, determined by the project leadership which can be held by the public or private sector, largely contingent upon the scope of the smart city project. In addition, the availability of partakers, their degree of involvement in providing the required empowerment and resources, and the collaboration and teamwork spirit that they reveal at the outset and throughout the implementation phases of the project, denote altogether the dynamics of the stakeholders' relationships which ultimately shape the business model to be adopted for the execution of the smart city initiative in hand. We will disclose next the possible scenarios and the different degrees of contribution associated with each.

- The government is the prime initiator and sole executor of the smart project aiming at restructuring the existing or to-be-deployed infrastructure. We can cite for example Masdar City in Dubai, Cape Town in South Africa, Suwon City in Korea, and Gdansk city in Poland. All instances were undertaken only by the government of the city which had all the power and resources to plan and implement the smart solutions without requiring additional funds or empowerment from any secondary participant. The Office of Urban Revitalization embarked on the project in Gdansk, while the Ministry of Information and Communication and the Ministry of Construction and Transportation in Korea merged their efforts to manage the omnipresent urban issues that will be improved in newly formed communities. In the case of Suwon City, the government has most probably contracted technology vendors for a period of time to help execute the project; yet it did not enter into formal ventures with any. Hence, these private institutions cannot be thought of as shareholders since they are hired by the government to do the job without interfering in the decision science embraced by the government. To be noted that the government in this case includes all public administrative bodies and organizations, namely ministries, Telcos, city councils, etc.

- The government is the initiator of the project but enters into strategic partnerships with private companies or other partners, such as telecommunications service providers, technology vendors, application developers, universities or Research & Development (R&D) institutes, etc. throughout the operational phase. Those are active stakeholders with either a primary or a secondary role based on how they will be contributing to the realization of the project. Assuming that the primary stakeholders did not have the means to purchase the sensors that are to be spread across the city for example, the additional capitals required can be provided by active secondary stakeholders. These might include IT companies that would invest in the project through the supply of sensors, or financial institutions that would give money to the government in order to buy the needed sensory devices. The groupings between the governmental head and the other corporations are usually maintained for a contractual term until the project is accomplished because the government has clearly no interest or benefit in forming sustained connections and definitive agreements with any private company. It is worth noting that contractors and sub-contractors, which might be major players in the smart ecosystem, might enter into long-term agreements with each other. Still, it remains unclear how any formal long-lasting alliance between the involved private companies can provide competitive advantage for either company after the project completion. Moreover, the planning of the project is managed by the government in this case, but the active stakeholders have also a share in the decision-making related to the investments to be done on the ICT and city infrastructures. The money that is spent on the project is essentially provided by the active primary and secondary contributors, whenever the second category of stakeholders is backing the project rather than empowering its completion. The government takes on leadership to manage the relationships among the different entities including itself, to ensure proper assignment of tasks and distribution of roles, as well as to assess the efforts being applied with the aim of improving the individual performance of stakeholders, and accordingly the project performance overall. As an example, the city government of Amsterdam, namely Amsterdam Innovative Motor, cooperated with an electric grid operator called Liander and instigated a project to reduce energy consumption and mitigate related environmental challenges.

- A private company takes the initiative and is backed by the government and possibly other private companies. The participants will promote the initiative or provide the enablement needed for its accomplishment and/or contribute to its funding. Supposedly, smart city projects are set off in this case by an IT service provider such as IBM, Alcatel-Lucent, Cisco, Hitachi, etc. or by Telcos, and executed with the assistance of the government and other private firms. The strategic partnerships between stakeholders can be contractually based or can be formed through joint ventures that might continue until after the project is realized. Whenever this business model is implemented, the mergers and acquisitions among corporations increase so as to provide all necessities required for the project deployment. With the technology advancements hopping by leaps and bounds, the strategic and premeditated mergers would generally cut on costs, ensure faster lead or response time and higher revenues, as well as allow the two companies entering into an everlasting commitment to relish a sustainable competitive advantage. On the other hand, the fact a partnership between two companies is maintained through contracts gives each party a resilience to choose among the available technology suppliers and to cease the relationship if the other party isn't abiding by the terms of the contracts. Likewise other business models, relationships among stakeholders have to be carefully selected and managed by the leader of the initiative, as well as aligned with the business strategy at all times in order to drive the project accomplishment forward. The contribution of the actively engaged government depends on the nature of the project and the resources that the government is able to provide, whereby initiatives that require smartening up the city infrastructure for instance will definitely need the government authorities' permission. We will use the example of a Brownfield smart transportation project that is initiated by a private ICT company to further illustrate the support that can be brought by the government as a secondary player in this smart ecosystem. The government contribution is contingent upon the abundance of the public finances and the degree of empowerment it has. Given that the government is not able to provide both, it will be considered a backer to the project by holding out whichever is less subtle. In this case in point, provided that the government does not have the resources to invest in the project, it will be conveying the empowerment to implement the compulsory changes to the infrastructure of the city, namely the public constructions, and streets and highways, which have to be overhauled to enable implementing the ICT requirements looked-for in a smart city.

- The private sector, comprising city services companies and utility providers, originates the change initiative and carries out its deployment without the government involvement. Basically, similar initiatives do not require the government empowerment and/or funds to be executed because they are small scale and target a specific industry sector, and sometimes only parts of it. Similarly to the previous engagement models, the privately held companies establish strategic partnerships among them to cater for all the requirements of the smart city project in hand. Provided that the strategy is founded on a deeper understanding of the smart city landscape, the leading private company and its technology partners will be empowered to tailor their products and services to the specific needs of each project, and accordingly to make the transition from facilitators and providers of basic M2M (machine-to-machine) and M2M2H (machine-to-machine-to-home) services to key influencers in the smart city ecosystem. This can be valuable to overcome the situation when the government is not an active stakeholder, yet its involvement could have expedited the smart city deployment.

Noticeably, the government and local authorities of a city play a key role in enabling smart cities' development, in which case the majority of the available business models involves the government, no matter the scope, motives, and end of goals of the project. However, the government pervasiveness does not infer in any way that the government always puts the needed efforts, or that it is capable, at all times, of making the change occur. In this era of tight governmental budgets, the majority of the efficient smart solutions are being delivered by the mutual efforts exerted by the public and the private sectors combined, whereby partnerships between the government authorities and private companies are likely to be the prevalent business model that is winning favor in most of the smart cities deployed in developed countries. In fact, the situation will hardly be any different in developing countries where the public finances are even scarcer and the unripe governments are not sufficiently expert at driving the change in cities on their own. Additionally, the lack of cooperation among the involved stakeholders is not the only barrier to robust business models and successful smart cities, in which case incoherent and disjointed technology projects represent an additional impediment that might threaten the smart city development. In fact, the fragmented technology projects that can be initiated by the private or public sector will earn their paybacks each in the area where it was first introduced and then executed. As specified in the paper issued by The Climate Group, Arup, Accenture, and Horizon in 2013, those cannot be called smart city projects, but rather organizational change projects because they emerge from the need to incorporate a transformative technology into the operations of the organizational structure. We can see that many city governments have formed a bunch of departments and agencies working in silos and rarely communicating with one another or with the private sector to ensure an integrated, aligned, and all-inclusive planning and goal accomplishment. This also applies to change initiatives managed by private firms without any coordination with the government or even between each other in order to avoid the execution of redundant technology projects and lost capital in ICT investments that could have been just replicated within an industry segment or across other areas of the city. The narrow-minded approach to value creation through ICT epitomizes a core barrier to smart city development, because when ICT is used on a project-by-project basis, the collaboration opportunities are rarely pursued or realized and hence, the undertaken project will only drive results within its delimited scope, and the transformation to smart technologies will hardly affect the city as a whole. It is only when all the uneven projects are materialized into a more systematic and efficient manner that the city will have a higher chance to become smart in a short period of time.

CHAPTER V

APPLICATION OF THE GLOBAL SMART CITY STANDARDS IN LEBANON

At this point, the fundamental driving forces of every smart city initiative were explained, and both the value chain and the variety of business models attainable in the developed countries and wealthy developing countries were detailed. Having set the global strategies in building smart cities, we aim to translate and apply these guiding principles so as to assess the feasibility of initiating a smart project in Lebanon. Therefore, the scope, motives, and objectives of the project, the resources available for execution, the stakeholders' selection, role, and potential contribution, as well as the dynamics of the relationships among them will have to be analyzed in order to agree on the source of the value chain components and formulate the optimal business model to be used. Considering that Lebanon is a developing nation, the scope of the initiative will be constricted, covering most likely a single industry sector, and the government will need to have an active primary role, if not leading the project as well. So how was the link between smart cities and the company I work for, Touch mobile operator, established?

When I started to think about my project, I was so eager to work on something that will serve the community and my company at the same time. Accordingly, I scheduled an appointment with our previous General Manager and Vice President-Chairman, in the presence of my second reader Professor Victor Araman. Given the importance of having an advanced ICT infrastructure in smart cities, and the fact that Touch by being the leading mobile operator in Lebanon can contribute to the provision of the needed ICT requirements, we agreed to study the possibility of transforming the major Lebanese cities to smart metropolises that favor a better quality of life for the citizens, in alignment with the vision and strategy of Touch for 2015 which will be revealed in a moment. However, for the former two conditions of limited scope and government prime contribution to be satisfied, the project has to be led by Touch mobile operator which works in the best interests of the ministry of telecommunications, and has to be certainly narrowed down, more focused, feasible, and within reach, considering the circumstances of Lebanon and the surrounding neighborhoods. Still, the capabilities of Touch in providing the necessary ICT requirements needs to be appraised in order to detect any possible loop holes and pinpoint the future work required to meet the expectations of smart cities.

A. The Mission, Vision and Strategy of Touch Mobile Operator

Touch, managed by Zain and formerly known as MTC Group, is the leading Telecommunications Mobile Operator in Lebanon, the Middle East and Africa. Zain was tendered continuous agreements by the Lebanese government across the past ten years to manage and commercialize one of the country's two existing mobile networks (Mobile Interim Company 2 – MIC2, also identified as Touch). In collaboration with the Lebanese Ministry of Telecommunications (MoT), Touch continuously works on expanding MIC2's network and enhancing its capacity in order to consistently provide its customers with a variety of high quality and cutting-edge products and services, the whole without compromising on cost-effective pricing modules.

Although Touch has dropped in market share during the 2nd quarter of 2015 to reach 52.73%, due to the scarcity of numbers that can be sold to and used by customers, the company is still the market leader, whereby it has achieved the highest market share in November 2014 at 52.90% which is a 30-month record. The operator aims at preserving its leadership by diversifying its product portfolio and enhancing customer experience to spread its market share beyond 55% in the coming 3 to 5 years (given the availability of numbers). Currently, it serves more than 2.24 million customers, 62% of which are data subscribers. The Mobile Penetration rate at the end of Q2 2015 was 92.34%, while the smartphone penetration rate on Touch network recorded 81.26%.

Touch is committed to excellence and constant improvement through embracing every opportunity of growth, and always ensuring high levels of professionalism, internal coordination, business performance, as well as customer engagement and satisfaction. Touch pillar objectives for the year 2015 and the upcoming 3 years are to:

- Enhance people’s lifestyle;
- Contribute actively to the community;
- Deliver value to stakeholders; and
- Provide a special place to work for its workforce.

Considering the strategic intent of Touch, we notice that a major share of it revolves around boosting people’s way and quality of living, which will in turn have positive repercussions on the community as a whole. According to the Corporate Communications & Relations Manager at Touch, the company envisions putting in place a differentiated communication and Corporate Social Responsibility (CSR) program of initiatives in 2015 to further position itself as the leader in this field paired with its position as the leading mobile operator in the Lebanese market. On top of that, there is unquestionably the objective of achieving a remarkable financial performance for the company to continue on growing and rewarding all the stakeholders involved in the strategy execution, which constitutes a driving force for Touch to benefit from every opportunity ahead.

To better describe the current situation of the company with regard to pursuing its growth plans in 2015 and benefiting from the existing revenue drivers, mainly local Data, we can confirm that the company is, in reality, generating extra revenues from additional subscribers following the increase of data caps offered in June 2014. Additionally, the brackets of the different corporate offers were reduced in order to cater for additional companies including SOHOs (Small Office Home Office) and SMEs (Small to Medium Enterprise). Bundles and packages combining Voice, SMS, and Data are also being offered for all customer profiles at attractive and affordable prices. Furthermore, the company began to conquer the world of mobile applications by acquiring its own application store where the end user has access to a multitude of apps from international and local developers, but exclusively displayed on Touch app store. This move Touch has undertaken to build a unique and authentic interface with its customers resulted as well in outsourcing a development company to design three of the most renowned mobile apps in the Lebanese market: Touch Self-Care, LebKeys (the first application for communicating in Latin Arabic that won the Global Telecoms Business innovation awards in London in May 2015), and Mobile TV. And finally, Touch started to get into the business of selling mobile handsets through launching several promotions on the Samsung S6 now and previously on iPhones 5 and 6, whereby the customer buys the handset from Touch and instantly gets free Data subscription for a certain period. But despite all the efforts to grow and flourish, how would Touch be able to attain the desired goals set for the year 2015 onward, if it keeps on solely delivering a cluster of diversified products and services? Here comes the need to innovate and get out of the box, so as to both enhance the lifestyle of all the Lebanese citizens and generate additional revenue streams.

Even so, cautiousness in getting creative and coming up with new ideas that might actually be a turning point for the company and the Telecom sector is without doubt a necessity, taking into consideration the impact of the Syrian crisis and the regional bleak outlook. In fact, despite the crisis distressing the people and stability of our country, Lebanon's economic conditions moderately improved in the first six months of 2015, with a real growth slightly exceeding 2% (Source: Lebanon Economic Report, 2nd Quarter 2015, Bank Audi S.A.L., Group Research Department). Moreover, the decline in international oil prices and calm weather contributed positively to the economic activity in Q2 of this year, reaching almost all industry segments, including the communications sector. Going forward, this reduction in oil prices will reduce the electricity bill, decrease public deficit, and raise consumers' purchasing power, all of which will hopefully have a positive impact on mobile ARPU (Average Revenue per User). However, despite a better and promising growth rate of around 2%, it is still deemed insufficient to have a substantial positive impact on the overall situation which remains very risky to enter into any large irreversible investments.

B. The Motives of Touch Mobile Operator for Smart City Deployment in Lebanon

Going back to the smart city project in Lebanon that Touch aims to initiate, manage, and provide the ICT requirements for, we need to understand what the motives are for instigating a change initiative in the country, likewise all smart city initiatives undertaken around the world. As it was denoted formerly, these motives are either economic, or social, or related to eco-sustainability reasons. So what are the motives for Touch to start a similar project in Lebanon? And assuming the motives are defined, what will be the scope of the project? Will it span the whole Lebanese territory and all industry sectors, or will it have a small scale and tackle a single business sector in the industry? For the purpose of answering these questions, we have to first determine the motives behind the inauguration of a smart initiative that is led by Touch mobile operator in Lebanon. As a matter of fact, the motives of the company were diverse and enfolded actually all three plausible reasons for deploying smart cities until today. Those are essentially the economic, social, and ecological drivers, whereby Touch intends to embrace in its endeavor the three of them combined since they are perfectly aligned with and representative of the pillar objectives of its strategy stated previously. In point of fact, the vision and mission of the company aim at improving the lifestyle of people, feeling socially responsible for the civil life by contributing efficiently to its affluence, and on top of all making the business more sustainably profitable. The role of Touch in such an initiative would introduce the business to the digital world of smart and advanced services, which obviously would significantly increase the data revenues that Touch is generating from users' subscriptions, application downloads, or media streaming. Hence, what is this one project that would combine all three motives and be within the grasp of Touch to achieve in the near future? Looking back at Touch initiatives – and not the products and services it created – in relation to its articulated strategy, one cannot not think about the “Don’t Text and Drive” awareness campaign organized in two phases.

Smoking kills.

Don’t drink and drive.

Don’t drive without a seatbelt.

Don’t text and drive is no exception.

These are messages that have been communicated for years in most of the awareness campaigns. Yet people still smoke, forget to wear their seatbelt and text; simply because communicating the negative consequences no longer makes a difference. So if we really want to make a difference, we need to change the way we talk to people. Accordingly Touch decided to tackle texting and driving in a completely new way, and rather highlight the positive consequences through telling people to “Whistle and Drive” instead of texting. The first phase of the campaign was incited jointly with YASA in November 2013 and centered on a song in both Arabic and English, which invites drivers to ignore their phones while driving.

Next, came the "Text if You Can" campaign invading all social media platforms, TV channels, magazines, Radio, and outdoor panels, and going viral through word of mouth within couple of days from its commercial launching in December 2014. The concept behind it was very simple and spun around proving one simple scientific fact that our brain can focus only on one thing at a time, which only means the following: when we text and drive, we are really only texting, and our foot just happens to be on the pedal. Consequently, when one is sending a text message, he/she can never ever do anything else. The second phase of the "Don't text and drive" movement was also in collaboration with YASA and was promoted in an entertaining manner through a 3-minute TV Breaker entitled "Text if you can", broadcasted during prime time on all local TV stations, whereby eight Lebanese celebrities were challenged to text while they are doing what they do best, namely their profession (dancer, singer, cooking chef, actor, music performer, hairdresser, TV anchor, and gym coach). The objective was clear and straightforward, and aimed to spread awareness and thus change the behavior of drivers who text while behind the wheel since no text message is worth risking a life. The advertisement of this social cause was an achievement, likewise the campaign itself which was capable of actively immersing Touch into the CSR world, leaving alertness in the minds of people and contributing to make all Lebanese families and communities safer.

C. The Project Scope, Timeline, and Challenges

As a result, after recapping with the General Manager, during the meetings we have held, the indisputable impact of this campaign on the communal life, we became almost certain that the project, by having exactly the same motives as the campaign, could be as well a state-of-the-art success if taken one step at a time. The decision was therefore to focus on the transportation side of the community life so as to preserve congruence across all initiatives undertaken by Touch. Our project would be a Brownfield rather than a Greenfield, with the target of conveying change only to the transportation industry sector at this moment, since the accessibility of capital is circumscribed and the maturity level of both our ICT infrastructure and city infrastructure calls for large investments if we are to build a city from scratch. In fact, given that the scope of the project is delimited, it would be more cost-effective to only revamp or expand the existing infrastructure pertaining to roads, buildings, and ICT (namely the mobile network infrastructure pertaining to Touch). Additionally, the choice of a Brownfield methodology would give more emphasis to the project in hand, so that all requirements are met without excluding any due to the lack of time or heavy loads of activities to be accomplished all at once. One crucial downside to brownfield projects that is worth mentioning is the necessity to have a clear vision for subsequent brownfield projects and for the global all-encompassing smart city. This might occur throughout or after executing the first Brownfield project, or maybe before it even starts, given that all the major players in the smart city ecosystem are highly coordinated and aligned towards the same aspiration. If Brownfield projects are ad hoc and randomly selected, especially if they are pursued each by a different group of stakeholders, then the reasons for their initiation as well as the outcomes from their deployment will be divergent, and the community will hardly be able to reap the benefits.

The timeline for planning and implementation of the Brownfield smart transportation project is estimated at four years with the completion occurring by the end of 2020, on condition that work on the ground starts as early as Q4 of 2015. As to the project coverage in Lebanon, it will essentially embrace the main and largest cities of the country, divided as follows:

- Beirut Governorate or Beirut City including Achrafieh, Dar El Mreisse, Bachoura, Mazraa, Medawar, Minet El Hosn, Moussaitbeh, Port, Ras Beirut, Rmeil, Saifi, and Zuqaq al-Blat;
- Mount Lebanon Governorate including the largest cities of the districts of Baabda, Maatn (Antelias, Dbayeh, Mtayleb…), Aley, Keserwan (Jounieh, Jeita, Kfardebian…), Chouf, and Jbeil;
- Beqaa Governorate including the largest cities of the districts of Baalbek, Hermel, Rashaya, Western Beqaa, and Zahle;
- Nabatieh Governorate including the largest cities of the districts of Bint Jbeil, Hasbaya, Marjeyoun, and Nabatieh;
- North Governorate including the largest cities of the districts of Akkar, Batroun, Bsharri, Koura, Miniyeh-Danniyeh, Tripoli, and Zgharta; and
- South Governorate including the largest cities of the districts of Jezzine, Sidon, and Tyre.

After having briefly discussed the reasons for Touch to opt for a Brownfield project to transform the way Lebanese citizens feel about their daily commutes, one can recognize that the motives that led to this choice might be, conversely, concealing challenges in the way of Touch and the remaining stakeholders throughout the deployment of the smart transportation project in Lebanon. These hindrances ranging from technical to sustainability to accessibility (Source: SMART CITY, From Dream to Reality, by Yasser Alobaidan, Business Growth Manager at Zain, Intelligent Cities Conference 2009) are summarized in the below table:

Table 2 – Potential Challenges in Smart City Deployment

Technical	Sustainability	Accessibility
The necessity of continuous upgrade, migration, and integration which requires the infrastructure to be extremely flexible	Power Management: - Active equipment requiring backup and heavy use of energy - Global warming and depletion of natural resources becoming more serious issues and leading to the definition of new regulations - Renewable energy resources not being developed enough yet to meet the demand of a large active network	Financial Accessibility: - The need to price the equipment and devices required in a way accessible to all citizens - The need to have all products and services in the smart city financially accessible to all citizens

Privacy and Security issues arising as networks evolve and expand	Waste Management or Recycling: - Production of a substantial amount of waste consisting mostly of faulty equipment - Production of large amounts of solid and liquid waste during the manufacturing phase of technological equipment - A large percentage of this waste not being recyclable	Awareness: - The need to conduct awareness and training sessions on the use of new technologies for all citizens - The necessity of continuing coaching and training efforts as products and services evolve in terms of technology and complexity
Smart cities incurring heavy capital and operating costs		
The products and services to be offered by smart cities demanding a very high bandwidth in the backhaul and access networks		

D. Overview of Smart Transportation Requirements and Applications

Now, why is it inescapable and mandatory to start taking action and planning for smart cities in every country, even in developing nations? And what is Smart Transportation to begin with?

According to the latest researches done by the United Nations, 54 % of the world's population currently lives in urban areas, and this rate is expected to grow to 66 % by 2050. Therefore, the realization of urban growth is a must so as to ensure for the citizens a convenient, intelligent, self-sufficient, and sustainable place to live. Transportation is, in reality, one of the most important sectors in rising smart cities; and particularly in Lebanon, which is by no means close from having the characteristics of a smart city, but which has all the criteria revealing how basic the transportation means and services are in this country. In fact, transportation is one of the most critical and hot topics being incessantly debated in the Lebanese market, bearing in mind the many awareness campaigns launched by NGOs and institutions promoting CSR work such as Touch mobile operator, that tackled the necessity for safety on the roads and sharing of real-time insights about traffic and incidents to drivers. However, not all problems have been raised through these campaigns and not all implications of performing a smart transportation project have been recognized. The reason might be that they seemed and still look as if they are less urgent and risky to mitigate. Lebanese people are by nature reactive instead of proactive creatures living for the moment and rarely planning for the future.

So the obvious upshot from making the transportation sector smarter is to develop a service platform that connects the providers and controllers of transport with the citizens, in a way that information flows are optimized while respecting and supporting the individual freedom, safety, and security. The latter imposes additional requirements in relation to advanced technologies and equipment which are compulsory to be mounted on the cities' roads, infrastructure, traffic lights, parking spaces, etc. Once the smart transport project is realized, cities will have thus an integrated platform to provide citizens with demand-adaptive transportation services, given that the Economy, People, Governance, Mobility, Environment, and Living, are all characteristics to be taken into consideration during the planning and implementation phases of a project (Source: Smart Cities: The Opportunities for Fuel Cells and Hydrogen, Contribution to IPHE Workshop– 4 December 2014 by Cristina Castillo, Stephen J. McPhail, & Angelo Moreno). On the other hand, the implied, yet most important advantage of smart transportation in cities is to leverage the consumption of energy and power in order to potentially reduce the pollution generated by those cities. But how is smart transportation linked to energy usage? In fact, smart transportation technologies most importantly rely on the technology of sensors, smart grids, networks, and analytical and applications ICT layers. Subsequently, we will explain first the sensors and smart grids' manners of usage, benefits, and applications in smart cities, as well as their interconnectedness with smart transportation, and then move to give direct examples of smart transport applications / solutions which are the ultimate end results of smart initiatives in the real world. One should note here that the smart transport technologies created are community services that the citizens will benefit from after the project is realized. These services are mostly e-services accessible to the end users through a mobile or website application, and thus are developed using the ICT application layer, which is a fundamental requirement among the ICT requirements in smart cities. Yet, some of them might be perceived by the users through direct contact such as the intelligent traffic lights on the roads, or the parking management sensing devices used to enlighten citizens about available parking spots. Sensory devices are basically used in every smart city, irrespective of the industry field being revamped; while smart grid systems are usually built-in and integrated within the city infrastructure whenever the urban change has eco-sustainability purposes and aims to cut on the energy usage inside the city. The use of sensors in smart urban transportation seems an evident approach to collect the data traveling all over the cities, but the need for smart grids is not very obvious indeed. In fact, smart grids are needed in a smart transport initiative, when the latter involves the advanced technologies of Electric Vehicles (EVs) functioning essentially on electricity instead of gasoline. Still, not all transportation initiatives will reach the level of introducing EVs into the urban applications from which the citizens and cities actually benefit. For a smart transportation project in Lebanon, it will definitely be a far-reaching goal to implement EVs, considering that the underlying infrastructure in most of the regions is very primitively constructed and maintained; and hence, incorporating smart grids within the city infrastructure would be an impossible mission at this stage.

To begin with, the low-power wireless sensor network platform is considered a revolution in improving smart city technology because it provides a variety of hyper-spectral data and pictures of whatever physical processes are occurring in the city. It also monitors myriad processes and parameters happening all over a city in real time. This includes anything that impacts city residents, such as air pressure, temperature, greenhouse gas emissions or microbial content of wastewater streams (Source: Hyperspectral Remote Sensing Technology and Applications in China, Qingxi TONG, Bing ZHANG, & Lanfen ZHENG, The Institute of Remote Sensing Applications, Chinese Academy of Sciences). The platform has the same low-power circuit board and real-time processing speeds found inside smartphones, and comes with various sensors; the whole being controlled by an operating system that will allow the project manager (Telcos, IT vendors, municipality of the city or any other entity) to determine the process by which every sector in the city is regulated. Fundamentally, the process of collecting data from streets requires that smart transportation technologies and infrastructure are structured through a multiplatform technology stack including sensors, analytics, network, and applications layers. In this stack comprising the four ICT layers, the large amount of sensors represent the sensory or physical ICT layer; they are connected to the network, and might be hidden inside boxes attached to the street infrastructure such as street lamps, buildings and utility poles, or buried into the actual roadways. The sensors used are not always fixed ones; some are placed on the public transport network such as buses, taxis and police cars. Even the citizens can become moving sensors in their own right if they download certain applications on their smartphones. All these kinds of sensors collect, detect, and send information data about traffic congestion for instance to the converged network throughout the city for real-time analysis, which in turn will transfer real-time data to a service platform or to end users.

Moreover, another pillar of smart cities is the formation of smart energy grids which main functions are energy or power adjustment, automation, and remote monitoring and control so as to distribute power efficiently throughout the city and reduce CO2 emissions (Source: Smart Cities and Communities, Key to Innovation Integrated Solution, Smart Grid Systems, prepared by Filippo Gasparin (Enel), combined by ECN and REC, November 2013). In theory, smart grids are responsible for the management and operation of energy networks in cities, through shifting between thermal and electrical loads (Source: Smart Cities: The Opportunities for Fuel Cells and Hydrogen, Contribution to IPHE Workshop– 4 December 2014 by Cristina Castillo, Stephen J. McPhail, & Angelo Moreno). The integration of reorganized renewable energy sources into existing energy grids brings up some major technical issues that have to be handled. The interface between engineering, science and technology (i.e. advanced communications infrastructure, mathematical modeling techniques and numerical simulation environments) makes this research area a powerful deed to pursue. The potential storage capacity for both electrical and thermal types of energy within energy networks is enhanced and better managed based on demand. Because of the difference in energy consumption between consumers and producers, the major requirement in smart cities is to control that energy in order to actually decrease the pollution caused by cities and emerging mega-cities. The successful combination of smart processes (real-time consumption management) and smart technologies (smart meters and intelligent energy management devices) will enable the energy distribution to be optimized, controlled, and secured, which will result in savings in both the residential and business markets. As a matter of fact, the interaction between the city and its energy management systems is complex and not easy to understand neither to manage. Consequently, in order to better understand this process with all the components involved at each urban scale (grids, buildings, technology suppliers, and consumers); it is crucial to be able to reveal the full potential of smart grids.

The smart grid has been the initial focus of smart cities and has accumulated the largest pool of investments. Soon afterwards, smart transportation started to gain importance because it is more explicitly linked to the improvement of the citizens' well-being. Smart transportation and smart grids are interrelated since almost all achievements in the smart transport domain require the use of smart grids. The intelligent grid receives power from all sources, and distributes reliable power to all kinds of consumers. In other words, it provides the city with residential charging, public charging, and most importantly, a charging facility for Electric Vehicles (EVs) which are a direct application to smart transportation. Hence, according to the discussion paper “Smart Grids and Electric Vehicles: Made for Each Other?” published in the International Transport Forum in February 2012 by Trevor Morgan, the interdependence between smart grids and smart transportation is demonstrated through the functioning of EVs, whereby smart grids enable the EV’s charging (Grid-to-Vehicle, G2V) while the EVs can, in parallel, act as storage devices to feed the grid with electricity (Vehicle-to-Grid, V2G) or for use within the home or office when needed. Besides, smart meters integrated in smart grids, allow the flow of data information in a two-way cycle in order to provide the consumers and utilities with real-time data. Both smart grids and embedded smart meters must be physically secured in a way to protect data from infiltrators, hackers and viruses because insecurity will threaten energy consumption, billing, and invoicing while secured and well-managed data helps prevent any manipulation or power theft. The smart meters schedule the charging of EVs intelligently, decreasing thus the load during peak hours and minimizing costs for the consumers. They allow remote connection and disconnection of EVs when being recharged during oversaturation of the grid capacity. Technically speaking, smart meters like sensors collect, store, and report consumer’s consumption data at any time, but also come with the additional ability to create the billing charges of consumers. In addition to dynamic pricing, smart metering delivers other more general benefits such as power outage detection, switching between the users consuming power, and a home area network interface placed at the customer premise for the consumer to track the energy consumption of all the smart appliances at home

(Source: Smart Energy Solutions for Home Area Networks and Grid-End Applications, by Meera Balakrishnan).

In the presence of these smart technologies, equipment, and devices, it is evidently the time to relate them to real-life manifestations in the field of smart transportation. All the direct applications derived from the combination of the factors elaborated above, will positively affect the quality of life of citizens in Lebanon and elsewhere around the world, reduce energy use and carbon emissions, and shift to sustainable transport services. The necessity for smart cities is to combine city governments with Telcos, technology vendors, and city services providers, whereby all of them collectively will benefit from the investments in the smart transport solutions. Below are some of the smart transport technologies implemented in the real world of smart cities, including direct applications that citizens can openly benefit from, and e-services founded on the ICT application layer, that citizens can have access to through their smartphones and smart devices:

- Traffic Management which will reduce traffic congestion, optimize public transport, develop systems for traffic control covering air, sea and land, as well as enlighten customers about their various transportation choices;
- Parking Management which will guarantee time management for the drivers, better mobility, less fuel consumption, and improvement of living conditions;
- Electric Vehicles which will diminish carbon emissions and pollution, as well as allow citizens to better manage their energy usage and related billing charges; and lastly
- Intelligent transport features counting:

- Dynamic traffic information acquisition, integration, processing, forecast and distribution;
- Electronic toll collection and speeding ticket collection;
- Intelligent parking guidance system;
- Vehicle license plate automatic identification;
- Traffic event automatic detection;
- Smart car technology solution that will allow customers to switch on their car air conditioning using their smartphone, at any time and any distance;
- GPS monitoring/dispatching and information service; and
- Video image based security and video image management.

In order to efficiently and effectively apply those applications, efforts should be mostly centered around a better management of resources by using data from incidents and service disruptions, analyzing traffic and parking data to make traffic flow smoother in case of an emergency, and integrating data discarded from social networking to track how residents and visitors to cities comment about the infrastructure and significant traffic conditions, and automatically serve that information into real-time planning. Certainly, not all the applications will be simultaneously available for citizens to use, especially in Lebanon. Accordingly, for the smart transportation project to be achieved in Lebanon, all stakeholders have to plan wisely and fulfill the easier-to-implement modifications first such as the traffic management and parking management solutions, then shift their focus to energy consumption management through electric vehicles and smart metering, which is estimated to implore higher capitals and irrevocable alterations to the city infrastructure.

Nevertheless, putting the community welfare at the heart of the situation, commitment, and civilized and regular communication and follow up by all the stakeholders of the project, will obviously soothe all probable deterrents and lead ultimately to success and a feeling of accomplishment.

E. The Project Stakeholders' Selection, Categorization, and Potential Role

Recall the driving forces in every smart city, which mainly include the stakeholders of the project and the dynamics of their relationships, the available resources for execution (Financial, Human, Information and Communication Technologies "ICT", and City Infrastructure), in addition to the motives underpinning the project and the end goals that it intends to achieve. Generally, all financial resources needed are spent on improving either the ICT or the city infrastructure. The value chain of a smart city comprises the stakeholders and the resources they use to accomplish any smart assignment. The motives and objectives defined, we will now determine the stakeholders of the value chain pertaining to our smart transportation project.

Stakeholders, as thoroughly elaborated in the literature review section, are the economic actors influencing and influenced by the deployment of a smart city. In support of the smart transportation project Touch intends to take part of, we will identify the exhaustive list of stakeholders to be involved in this smart ecosystem, along with their role and categorization as active primary, active secondary or passive players. Through the role and contribution level of each stakeholder, on top of the dynamics of their relationships, we will be able to subtly synthesize the business model to be adopted in Lebanon for this project and for further Brownfield smart city projects.

Table 3 – Identification and Categorization of Stakeholders Involved

Active			**Passive**	
Primary	Secondary (Benefactor)		Beneficiary	
Enablement & Resources	Enablement	Resources	Supporter	Opponent
The Lebanese Republic or National Government including: - The Municipality of Beirut and the other main cities in Lebanon, as local/regional governmental entities - The Ministry of Telecommunications, which belongs to the Lebanese Republic and is directly allied to MIC2 (Touch) in leading the second mobile operator in Lebanon - The Ministry of Public Works and Transport, which is also a governmental institution responsible for operating and managing the civil work in relation to infrastructure and transportation				
Public Utility Provider: Touch, Telecommunications Company		Public Utility Provider: EDL (Electricité du Liban)		

		Government Development Bank: Central Bank of Lebanon		
		Public City Services Providers: Public Transportation Companies		
		Private Utility Providers: IT Companies		
		Private City Services Providers: Private Transportation Companies		Private City Services Providers: Private Transportation Companies
	Research institutions and Academic Organizations such as AUB			
		Private Financial Institutions or Development Finance Institutions, if any		
NGOs such as YASA and Multinational Organizations such as the United Nations				
	Citizens		Citizens	

F. The Stakeholders' Contribution and Optimal Business Model for the Smart Transportation Project in Lebanon

Considering the political situation in Lebanon and the surrounding regions, discerning the role of the Lebanese government in this project might get somehow equivocal and confusing, particularly for the civil society which is actually the central goal of the project. It is true that we have been a year without a president for the country, and it is also undeniable that we have very large budget deficits and public debts. However, this is only the outcome of numerous deceitful actions and cannot be the reason for the economic stagnation Lebanon is enduring. The real cause is not that we don't have money or a president, but the fact that everyone is working solo, putting their personal interest about the welfare of the country and community. Money can be brought in easily whenever the people elected to represent the civilians put their hands together, and think only of Lebanon. I have no doubt that most of the Lebanese are already fed up with the situation of their country and the behavior of its officials; yet, I say that there will never be a republic and there will never be a home for the Lebanese people to happily and prosperously live in, without an omnipresent government. Even though the government might be weak at present because of the prevalent corruptive conduct of its administrators and the many intruder nations that have personal interests in our country, we cannot and we shouldn't be ignoring the leading authoritative role it can extend in terms of empowerment and enablement to all potential plans, investments, and endeavors to be inaugurated in Lebanon. As is the case for most of the developing countries, especially Arabic countries, the utmost power remains in the custody of the government irrespective of all the disappointments it has undergone and made the people bear – one reasonable cause for the project to be headed by the government. Another reason for this project to be held and led by government entities is the fact that seven major active players in the smart network we built in the table above are owned and managed by the Lebanese government. First there is Touch, assisted by the Ministry of Telecommunications in leading the number one mobile operator in Lebanon, and which will be both active primary stakeholders responsible for the bulk of ICT provisions and endorsed to enable and fund the project all at once. Secondly, the Ministry of Public Works and Transport and the largest Municipalities of Lebanon, will be actively funding the project as well as heavily engaged in the planning and real-life execution of the project, largely in relation to the groundwork of the city infrastructure. Thirdly, the Central Bank of Lebanon, as an active secondary investor, will be principally sponsoring the project and backing all budgetary demands. And then, the EDL is a public utility provider that is managed by the government in the same manner as Touch and liable to guarantee electricity 24/7 in the city for the converged network of systems, platforms, and devices to function reliably with no interruption. EDL, as an active secondary player, will have actually to heavily invest so as to secure the needed power in the city, considering the mediocre circumstances at present. And to finish, the public city services providers represented by the bus and minibus transportation companies, designate the seventh and last government related stakeholder. Those public transportation companies will be implementing the new technologies and solutions shaped for the smart city, in order to deliver higher quality delivery services to the citizens. By doing so, they will be mainly originating another interface with the end users – the first being the mobile applications, websites, and portals to be supplied by the participating ICT companies (Touch or any IT company specialized in the field of software development), and hence their contribution to the project cannot be optional but will be rather enforced by the government to ensure a smooth urbanite transition at all levels. The public city services companies have therefore an active secondary role because they will be investing their resources to renovate their buses and modernize and update their delivery services in keeping with the transportation standards of a smart city.

Given that all government affiliated stakeholders mentioned above are actively involved in the project, regardless of their classification as providers of authority and money, or one or the other, each one of them will have its share in the decision-making process, which will accelerate the actions to be undertaken, and ultimately drive the project to success. Additionally, smart cities will make the entire city seamlessly interconnected and the huge amount of data transferred between sensory devices, systems, platforms, and end users will put the security of both government and people at stake, in particular since privacy of data in Lebanon has been and is still a top priority to fulfill. So this reason alone leaves us with no option but to let the government take over the network and thus the leadership of the project, or else the smart city dream in Lebanon will never see the light. Fortunately, in our case, Touch which is the property of the government has already a mobile network spread across all the Lebanese regions, and is in a position to lead all network connectivity and data analytics, ensuring that all data flows, loading, analysis, and backup are accordingly controlled by the government. Through using the existing mobile network of Touch, the government will not only be keeping an eye on all the data being exchanged, but will also be incurring fewer costs in relation to ICT overheads because laying fiber optics only dedicated to realize a Brownfield small scale project costs in reality a lot more than leveraging or expanding the current network. This security issue in favor of the government leader, and the lower network related expenditures, are in fact, the primary cause for not allowing any IT company to deliver the network layer among the four ICT layers required in a smart city.

The above combined will result in granting the leadership of the project to the Lebanese government, and specifically to Touch which is the initiator and the first to bring about the subject of deploying a smart city in Lebanon to all potential stakeholders and the Lebanese community overall, on top of being the one controlling and owning the network infrastructure of the city, the most indispensable pillar of a smart city and the topmost priority for the Lebanese government to safeguard security and privacy of its citizens. Touch will be assisted by the Ministry of Telecommunications in leading the project since under normal conditions, both governmental organizations work together to operate and manage MIC2 mobile operator. Generally speaking, the leader of a smart city project is usually the originator of the project idea and matching plan, a stakeholder that is dual-hatted and actively engaged to that project plan by providing both the funds and the power, and a coordinator that brings together all stakeholders on one table to follow up on all finished and unfinished tasks, as well as to keep them all aligned towards the same end goals. Consequently, the Lebanese government as the leader of the Brownfield smart transportation project in Lebanon will have an undisputable share of the decision-making with regard to this project. It will be, indeed, in charge of the strategy definition and execution, i.e. devising the project scope and timeline, and the planning and implementation phases that will take account of optimizing the efficiency of the smart city infrastructure, in addition to subsidizing the project execution through paying for a large part of the capital investment required. At first glance, it sounds absolutely illogical to assume that the Lebanese Republic will be able to afford the largest amount of capitals, in view of the unstable and rundown economic situation in Lebanon with all the unsettled public debt. However, on second thought, the Lebanese government, as we revealed, is not a standalone entity, whereby seven of the major active players in the smart network designed for this project, happen to be ministries, departments, or organizations owned by the government, out of which four will be financially backing this assignment.

It is worth highlighting that if the project was initiated by a stakeholder other than Touch or the government, namely the Ministry of Telecommunications (MoT), there would have been a sort of competition between Touch and Alfa, the other mobile operator in Lebanon. However, the competition wouldn't have been as real as it is thought to be since both Telcos are managed by the same governmental entity (MoT) and have exactly the same ICT capabilities, so the MoT / government will be the winner in both cases. In our smart transportation project, Touch is the leader of the initiative and accordingly Alfa is out of the circle of potential stakeholders anyway, since the added value of both operators in a similar project is actually the same. Additionally, we cannot assume that Alfa will be an opponent of the initiative led by Touch, because they both belong to the MoT and whatever applies to either company is replicated and applied to the other. In fact, what will really happen is that after presenting the outcomes of my consultancy work to Touch Management, they will have to inform the MoT about the findings, in order to seek approval prior proceeding. Once the MoT is aware of this project, it will directly request from Alfa mobile operator to assess its own standing point regarding the ICT provision for smart cities in Lebanon, and benchmark its findings with Touch. This will help the MoT better validate the viability of carrying out a similar project in our country, and the amounts of ICT investments required for either Telco to outperform in this role.

Moving to the private sector, it is entitled to also contribute to the decision-making in relation to planning, investment, and implementation, as well as to utilize the city and ICT infrastructure to thrive the forthcoming services to be offered to the citizens. The privately held organizations that will influence the dynamics of the relationships among the participating stakeholders, as well as the outcome of the project in our business model, will have an active secondary role because they will be, each in its area of expertise, affording the costs needed to carry out the project, rather than facilitating its accomplishment.

To start with, the first nominated close corporation involved in this project comprises the private utility providers or the private IT companies which are qualified to arrange for the ICT requirements that Touch is not able to supply. The second nominee is represented by the private city services providers which will implement the new smart solutions in the field of transportation once available, likewise the public city services benefactors, with the purpose of providing the end users with advanced and modernistic services and amenities. However, it is worth mentioning here that not all private transportation companies will be willing to invest their money in order to make the smart transport technologies available to the citizens. Hence, in this case, those will be considered as passive opponents of the initiative, and will not have a role to fulfill in the smart ecosystem. Then, there will be expectantly research institutions and academic organizations (for instance AUB) interested in similar CSR initiatives and ready to support this business opportunity through promoting its usefulness and importance, or possibly private financial institutions (such as private banks, trust companies, insurance companies, investment dealers, or community development finance institutions) which might be enticed to provide the funds needed for community development. The involvement of AUB as an active secondary stakeholder will definitely accord more credibility to our initiative, given that AUB is an exemplary teaching-centered research university having a unique educational philosophy that seeks to graduate people devoted to critical and creative thinking, learning, communal responsibility, and leadership. While in some instances, AUB can play an active primary role by being a test bed for smart city initiatives, and providing the infrastructure resources, i.e. its campus, on top of which the smart technologies are to be retrofitted. However, utility and service providers, in addition to research, academic, and financial institutions, should be given the right grounds and motives so as to devote their time, or their money to shift the status of the city towards a higher level of maturity in relation to technological advancement and quality of the civic life. Private companies should be able to capitalize their costs by making sure that they will get, in return for the resources they spend, some tangible benefits or reimbursements; and for that reason, their expenses will be recorded as assets. For instance, the private city services providers might omit the historical legacy of a flat rate pricing schema and charge higher tariffs per ride since the services offered will be definitely of first-class quality and much more convenient than they were before this move into the smart ecosphere. Still, the feasibility of this idea needs to be validated in Lebanon since people might prefer to use the cheaper transportation services instead of the more convenient, but fairly expensive ones. The private associations in general are driven by the profit they make, whereas governmental authorities mostly care for the public welfare and strive for solutions that attend to the civilians, notwithstanding the exceptions happening in some countries such as Lebanon. But through this project proposal that serves the community above all, we are sending a pledge of aid to the Lebanese government which has the means now to refute all claims of bureaucracy and corruption and prove them wrong by prompting a drive of restructuring and reform with its basics founded on the success of the smart transportation project under deliberation. Therefore, for all private and public stakeholders partaking in a similar project, the optimum result would be to seek balance and find the point of intersection between the two worlds; the world of financial profits their corporation is supposed to make in order for it to remain stable and grow, and the world of physical and cognitive implications on the community life that their business must endow the citizens with despite all externalities and pressures.

After we clarified both public and private sectors 'contribution to the project, the remaining stakeholders in our smart ecosystem are the NGOs such as YASA and the Multinational Organizations such as the United Nations Agencies, and when all is said and done, the end users for which these community services are being improved. YASA, as we pointed out before, has collaborated with Touch to commercially launch the "Don't Text and Drive" campaign, which was organized in two phases, the "Whistle and Drive" and the "Text if You Can" drives. Both were intended to highlight the negative consequences of texting while driving, as part of the ongoing efforts of Touch to spread road safety awareness in Lebanon. The two drives, with the support of YASA, went viral directly after being dispatched, and were very successful in making Lebanese people become themselves true ambassadors of this social cause. With reference to the smart transportation project under consideration, YASA, having a wide responsibility towards health and safety, social welfare and environmental values, will play an active primary role by investing its human resources to mobilize support for the social causes sustaining the project. The subject civil society organization will form pressure groups to facilitate communication downward from the government to the people as well as horizontally through networking between other organizations; all of which will help support the project and give it the empowerment it needs to succeed. While UN agencies are more likely to provide financial resources instead of people, which eventually will help empower the initiative, and make of them active primary contributors as well. On the other hand, the end users can play different roles in our business model. They can either be passive supporters of this project if they decide not to participate in the decision-making process but rather be affected by the decisions made, or they can be active secondary players by empowering the usefulness of the initiative through developing applications that will give them direct access to the community services available. In the former case, the Lebanese citizens will only enjoy the state-of-the-art services and facilities offered, while in the latter case, they will have the possibility to actively invest in the project through putting the time and efforts to decide on and build the kind of interface with the network they would like to have. This will ultimately connect them with the efforts and concrete work being done by the rest of the active secondary stakeholders which are indeed enabling the initiative and promoting its importance. Basically, the citizens will be assimilated into the list of private IT companies authorized to develop the application programs and electronic platforms that will license the end users to benefit from the services accessible on the market. In all cases, the citizens, even if they were only passive beneficiaries of the smart solutions to be deployed, are vital agents in this ecosystem because if they don't actually use the community services, then all the work and efforts will be wiped out and the project will eventually go pear-shaped.

To sum up, all partaking stakeholders, one by one, have to be fully engaged and committed to their work, regardless of the significance of the role they are assumed to fulfill. But on top of that, they have to be always tangled with each other and highly coordinating on all matters in order to preserve alignment and agreement among them and with respect to the unified goals of the impending smart city, ultimately leading the project attainment. The business model derived and thoroughly explained above, represents in point of fact, the optimal engagement model to be embraced in Lebanon under the current circumstances that are governing in the country. Despite the instability of the political situation and the economic recession, people still follow their political leaders and consider the local authorities as the ultimate source of power. The mentality of the Lebanese people is behind the fact that all change initiatives in Lebanon will not have a chance to be espoused by the civil community unless they come from the government; although, some might not be adopted even if crafted and imposed by the government. However, the manner through which we formulated our business model was optimized by taking into account all externalities in the country that might have an impact on the milestones set by our project, in addition to fitting in all potential stakeholders that are likely to add value to the project, while considering the dynamics of the relationships among the chosen participants and the extent to which they will form a coherent group working in sync for the benefit of the initiative. Finding the right combination of stakeholders, assigning the role of each, and outlining the interactions among them, are not in fact random steps that can be straightforwardly accomplished when designing the optimal business model pertaining to a change initiative. But if put and analyzed in the right context, likewise we did above, the smart city project under deliberation will definitely have a better opportunity to be effectively implemented and fully operational in its country of origin.

G. The Project ICT Requirements and Role of ICT Companies (Touch Mobile Operator and IT Firms)

We will delineate subsequently the various responsibilities to be held by the ICT companies involved in this project, namely the government-owned Telecommunications company Touch and the private IT companies, as well as their significance and implications considering the political, social, and topographical changing aspects of Lebanon. The target of the ICT companies in general is to congregate people and traffic so that data can be shuffled accordingly, patterns and trends can be detected and urban planning carried out more responsively through a vast and incremental pool of data collected from various devices like, mass transportation vehicles, utility meters, video cameras, etc. Now we will describe in details the individual and cooperative role of Touch Telco and the required IT companies in triggering and actuating the project.

1. Touch Telco's Contribution

Since Touch is a government-owned entity, and since the local authorities of Lebanon, despite all glitches, strive to enhance the quality of life of the Lebanese citizens and actively promote making Lebanon an ecologically safe and prosperous environment, the motives as stated by Touch behind this Brownfield smart city project are in sync with the government intentions and enabled to become actions since both stakeholders are intuitively one. MIC2 Operator will provide essentially the network and the integration between all network elements as well as the analytics, and part of the applications that will be accessible to customers. Implicitly, all the layers require the intervention of IT companies. At the network level, all hardware equipment is being purchased from IT vendors and all software systems and IT services to connect, monitor, and preserve the network are also being subcontracted. The same is happening at the analysis layer which consists of analytical tools and solutions being acquired from external parties and integrated with MIC2's network, and at the application layer which enfolds the applications linking the end users to MIC2's network and vice versa. So what is specifically the added-value of having a Telco in the value chain of a smart city? Despite the fact that the majority of the ICT layers to be provided by Touch are subliminally referring to IT companies to be fulfilled and functioning, the role Touch plays is actually inevitable and vital for the success of this project on the Lebanese territory. The strengths of Touch in front of conceivable competition from IT companies are as follows:

- Touch has already an established network in place and an area coverage spanning and linking all the regions of Lebanon;
- Touch mobile network is more secured than the fixed networks because it operates in licensed spectrum and its IP addresses are more difficult to be spoofed;
- Touch has intertwined data centers which expedite the storage and processing of the information flooding the network, in addition to having sophisticated billing capabilities that would permit dynamic pricing schemes based on the end user consumption and type of service he/she is subscribed to;
- The already existing mobile network of the operator would be more cost effective to use, instead of having to lay fiber optic cables specifically for this Brownfield project considering its nature and small scale;
- Touch knows well the Lebanese market and the needs of the Lebanese population, and has trusted marketing channels; and lastly
- Touch is affiliated with the government which should be by all means a major stakeholder to attain the desired urban transformation.

Throughout all my readings about smart cities which mainly fall in the developed countries, I have come to recognize that their culture and political life outstandingly differ from the culture and political life of Lebanon or any other Arabic country or developing nation around the world. There are, in point of fact, numerous smart cities established all over the world by the government bodies alone or by private institutions alone or through the combination of efforts from both public and private sectors. However, all the available business models adopted in the developed countries where smart cities have been deployed, have clear boundaries and segregation of duties between the economic actors partaking in the project. The divergence's roots go back to the mere fact that the governments in developed and wealthy countries have different agendas and priorities than those ruling developing republics. In most of the developing nations, there are still more critical issues to be tackled before the people can even start dreaming about a better quality of life through technological advancement. Smart cities are, undeniably, stretch goals for this category and those will not be within reach until all the unavoidable problems of corruption and poverty come to an end. Furthermore, budgets are usually tight in these countries, and any source of income would rather be spent on solving the more important issues. Not to mention the totalitarian regime prevailing the life of people, despite all claims of equality and democracy. There are definitely exceptions to the countries listed as developing countries, but which we have seen thriving and prospering during the last ten years. Examples of such nations are Qatar, Dubai, and China, where smart city projects have been undertaken and successfully accomplished because those countries, although being identified as developing, have wealth and money from the huge exports of oil, gas, and other goods to the rest of the world. If we keep our focus on Lebanon, we can clearly see that this country is by far ruled in the same manner as the remaining developing countries are. Public finances are constricted and scarce, and private investments are very reluctant, especially that the return on investment is very difficult to measure in similar circumstances. Consequently, the only workaround solution to urbanization would be to leverage the existing infrastructure and resources through a Brownfield project rather than a Greenfield approach. And since the existing infrastructure, be it pertaining to ICT or the city itself, is mostly owned by the public sector, then the safest tactic would be to involve the Lebanese government and all its associated entities including MIC2 Operator. This would save on costs and time to market, particularly without any obvious outside interest in shifting the life of the citizens in Lebanon from a meager survival to a more luxurious way of living.

Going back to contribution of Touch in this project, its role would be primarily concentrated on operating and managing the connectivity side, giving each of the enabled devices access to the carrier's network, in addition to doing the aggregation and analysis through its Intelligent Systems, and making sure that all kinds of communications between each of the network knobs are secure. All of these activities will ultimately allow delivering real-time data and information to people and to machines, and thus enabling them to achieve their needs in the smart city. The interface with the customer, shaped through mobile applications, websites, promotion messaging, portals and call centers, was incorporated not for so long within the lateral businesses of Touch, but the Telco might have to give away this activity or at least part of it to a third party due to the imminent workload on the network side. Although the analysis part could be outsourced to some IT company like IBM which has a machine-to-machine “M2M” Intelligent Operations Center dedicated for that purpose, Touch has in fact all the requirements needed to outperform this task on its own as we will see next its competencies in relation to the analysis layer. By straightening out the four ICT components, we will explain how Touch can add value in relation to each of these layers demarcating the ICT infrastructure of a smart city in Lebanon:

a. Application Layer

All mobile and website applications are being developed by external vendors such as Foo S.A.L in Lebanon. However, whenever the application is developed and ready to go to market, it becomes Touch property but the vendor continues to offer support and bug resolution if any.

b. Analysis Layer

This layer requires the acquisition of an intelligent system capable of aggregating all the data flowing through the network into its back-end systems in order to analyze that data and provide useful insights to customers. A similar system, considered to be an IT service, is the Business Intelligence system which comprises various functionalities including but not limited to benchmarking, real-time reporting, key performance indicators' optimization, data mining, online analytical processing, business performance management, and prescriptive and predictive analytics (Source: Wikipedia, Business Intelligence). Such a system will be purchased by Touch and not built internally, yet it will also become a property of the company once bought. According to the Technology Procurement Team in the finance department (which is the team I work for), Touch will launch at the end of September 2015 a Request for Proposal (RFP) to get the Business Intelligence System which is conceived to contain as well Customer Experience Management (CEM) functionalities and modules, particularly since the customer is the focal point in Touch business activities. The vendors that will potentially participate in this RFP are Oracle, SAP, Microsoft, IBM, and SAS. According to the Service Quality Team in the technical department, Touch has already, on top of the BI system, a tool for network monitoring and subscriber intelligence since 2014 acquired from Astellia. The probes of this solution are vendor-independent and compatible with all the vendors' equipment installed on the network; they give real-time monitoring and troubleshooting capabilities that cover end-to-end 2G, 3G and 4G from radio access to core network. Astellia's proficient solution responds to the needs of MIC2 operator's full value chain from CEM to network performance to customer care to marketing and commercial inspection. Similarly to all applications and systems taken on board by Touch, the monitoring tool from Astellia was registered among the company's assets after it was installed and commissioned; but the support continues to be provided by the vendor for now and the years to come.

c. <u>Network Layer</u>

This is the core business of the company and its point of strength, seeing that it will not be able to compete by itself in areas pertaining to the three remaining ICT layers. Conveniently, as explained by the Service Quality Team in the technical department, Touch network spans all Lebanon from North to South, along the coastal line near the Mediterranean sea, and internally through the different series of mountains arriving to Baalbek on the east side border with Syria. The number of existing sites continues to grow whereby at the end of Q2 2015, the 2G population coverage was 99.29% and geographical coverage 98.08%, the 3G population coverage was 94.65% and geographical coverage 86.43%, and the 4G population coverage was 30% and geographical coverage 2%. Those percentages require some explanation especially in relation to LTE since it is the subject matter of our project. The 30% 4G population means that if all the current data customers were to be present in the area where LTE sites are implemented and which represents only

2% of Lebanon's territory, then 30% of those data customers will be able to use LTE services and not all of them. This is due to the fact that only 200 LTE sites are deployed in this area, which is obviously not a large number to cater for all the data customers accessing the Internet through LTE. The 30% 4G population depicts thus the LTE capacity in its 2% area of availability, The same concept applies for the remaining percentages related to 2G and 3G population coverage and geographical coverage, and which clearly show that the 2G and 3G network capacity in Lebanon is leveraged to the maximum due to the nationwide 2G and 3G sites' implemented. Moreover, the total number of sites increased during Q2 2015 by 45 2G sites, 36 3G sites, and 2 4G sites, closing the second quarter with 1,122 On Air 2G sites, 1,206 On Air 3G sites, and 200 On Air 4G sites.

The main vendors Touch deals with for network related equipment, tools, and software are Huawei, ZTE, Nokia, and Cisco. Touch maintains very good relationships with these vendors, which are considered to be among the best; but for the sake of our transportation project, any network expansion or acquisition of new equipment and tools will go through the usual tendering process so as to choose the best offer among a pool of suppliers including those Touch already purchases its necessities from. The four main vendors listed above work on contractual terms to install the needed equipment, perform all necessary changes on the network, upon Touch request, and provide maintenance and support after deployment. However, network planning, setting up, connection, and management are also being pursued by Touch Technical Team composed of qualified engineers to work in conjunction with vendors and monitor that all change requests are being executed and all Key Performance Indicators are being met and sustained.

Eventually, vendors will do a complete handover to Touch personnel whenever those feel they are ready to take on the lead. This is the case actually for all 2G ZTE equipment mounted on the network, which will be fully managed and maintained by Touch Technical people starting Q3 2015, as confirmed by the Network Operations Center and Site Implementation & Maintenance Teams in the technical department. Likewise the software and systems necessary at the application and analysis layers, all network equipment and software become part of Touch properties at the moment the Purchase Order payment to the subject vendor is settled. In other words, if Touch decides to terminate a contract with a specific vendor and enter into agreement with a new one, all items purchased from the former vendor will remain operational because replacing vendors might incur very high capital expenditures if all equipment is to be swapped too. This might happen, in fact, after several years of commitment to a vendor for an example, and after making sure that the technical personnel at Touch are absolutely capable of taking over the planning, positioning, and upkeep of the network related equipment. On another note, the majority of IT services are outsourced such as storage and backup, servers and databases, security, accounts and access rights, automated queuing system, business telephone system such as private branch exchange (PBX), IP Telephony, or Call Center, and so on. As said by the Enterprise Applications and System Database & Storage Teams in the IT department at Touch, the key vendors providing similar IT solutions for Touch are the multinational gurus Cisco, EMC, VMware and the two local companies Creative Hardware for Integrated Products “CHIP” and Produits Et Solutions Informatiques “PSI” which are partnering indeed with international, accredited, and certified suppliers. All equipment are considered part of Touch belongings after being purchased, but the terms of agreement with the vendors for maintenance and support, spare parts, and upgrades are always scheduled on contractual basis.

As a matter of fact, owning a wide-range network represents an early mover advantage for Touch and a sustainable competitive edge that sets high barriers for other ICT companies to enter the market. According to the Business Planning Team in the commercial department at Touch, having a ready network covering and connecting all of Lebanon and a database of almost 52% of the Lebanese citizens will definitely save on millions of dollars and years of time that could be spent instead on expanding the network capabilities to reach the standards required in a smart city. Not to forget that if Touch outpaces its competitor Alfa by bringing in the smart city concept to the Lebanese urban life, then undoubtedly Touch market share will heavily increase. After we finish listing all the likely stakeholders to take part in this project together with their roles, contribution extent, and the dynamics of their interactions, we will dig deeper into the ICT capabilities of Touch in relation to the network layer. The ultimate goal from this descriptive and extrapolative analysis of Touch network will help us assess where the company stands and how much extra efforts it needs to put so as to match the global ICT requirements of a smart city as well as to be highly competent in setting the barriers of entry even higher for competitors such as Huawei, Ericsson, ZTE, Nokia, Alcatel-Lucent, IBM, etc. which have already offices in Lebanon and the capabilities of laying fiber optic cables all over the country to account for the network and connectivity needed in a smart city, if this was to be approved by the regional and local authorities in Lebanon.

2. *IT Companies' Contribution*

Since Touch is in charge of the analysis and network layers, and part of the application layer, the need for IT companies will be narrowed to cover only those specialized in affording the necessities at the sensory level, in addition to any lack of provisions in end user applications. As stipulated before, the Brownfield project in hand targets the transportation industry sector in Lebanon only, hence the devices needed are mainly wireless motion sensors, actuators, radars, video cameras, smart meters, and smart grids which are extensively booming and used for their role in reducing energy usage all over the city. The pioneers in smart grid systems are Accenture, IBM, and Siemens according to GreenTechMedia (GTM) online magazine, while suppliers of sensing and detecting equipment include General Electric and Johnson Controls. Furthermore, some of the IT companies have turnkey software solutions for the problems caused by traffic congestion; however, for the sake of this project, all data collection and exploration are to be done by Touch which is already in the field of network analytics and has the requisite systems whereby any add-on feature or module can be easily assimilated.

H. The Gap Analysis between the ICT Network Layer Requirements and Corresponding Capabilities of Touch Network Operator

The leading role of Touch being exhaustively deliberated in relation to providing three out of the four ICT layer requirements, we will now give further focus to the network layer requirements in comparison with the global standards and practices in order to perform a gap analysis as to what additional capabilities Touch needs to acquire or improve to become highly competitive and adept at developing the network infrastructure required in a smart city. The two fundamental and mandatory network related ICT requirements in a smart city nowadays are:

- The availability of the LTE (Long Term Evolution) technology that has a low latency, and that is reliable, secure, and wide-ranging in coverage to ensure that the cities of Lebanon pertaining to our smart city project are properly deployed for the forthcoming transition; bearing in mind that few smart cities started to leap into the LTE-Advanced technology which can reach an average of 1 Gbit/s data throughput; and
- The availability of a high bandwidth/capacity medium of connectivity on both Radio Access Network (RAN) and Core or Backbone Network to be able to let users enjoy fast speed real-time Internet services as imposed by LTE standards, and required for smart cities.

The two requirements above are requisite to have in every smart city, in addition to being linked by a cause-effect relationship meaning that the execution of one condition will necessitate the implementation of the second in order to achieve the desired network performance. In point of fact, these technologies are a pre-requisite to any smart city project, irrespective of the industry sector being revolutionized, which implies that the readiness of such technologies within Touch broadband network will eventually serve our smart transportation initiative, or any other change initiative that might be started in the future. The ICT requirements, as described previously, are generic requirements and have to be available for the implementation of smart urban initiatives to actually occur. Subsequently, we will be comparing and contrasting Touch LTE network capabilities in relation to both requirements above, with the global standards and principles applied in smart cities. Given that the smart transportation project under deliberation is to be realized, this benchmarking exercise will help assess the supplementary competencies Touch has to develop so as to be able to deliver advanced smart solutions and services. The following in-depth technical report was prepared by gathering exhaustive information from the four main divisions at Touch; that is the Commercial, Technical, IT, and Finance Departments. On a side note, throughout the analysis of Touch ICT capabilities, our focus will stay on comparing those to the 4G/LTE technology standards and we will not be talking over the specifications of the more developed release, the LTE-Advanced, since it has started to be deployed in only few of the smart cities and thus cannot be considered a requirement to have. Lebanon will definitely need some time to catch up on this technology especially that the LTE network itself is not fully industrialized yet.

1. LTE Network Specifications in Touch

By and large, the LTE Radio is named eUTRAN (Evolved UMTS Terrestrial Radio Access Network), with UMTS (Universal Mobile Telecommunications System) corresponding to the 3rd generation mobile cellular system for networks which is based on the GSM (Global System for Mobile Communications) standards of the 2nd generation mobile networks. The eUTRAN is composed of the eNodeB (Evolved Node B) that encompasses the functionalities of the Node B and RNC (Radio Network Controller) in 3G. The eNodeB represents the air interface directly communicating with the UE (User Equipment) or mobile handsets, and the interface with the LTE Core network named EPC (Evolved Packet Core). The EPC is provided by Huawei and comprises the MME (Mobility Management Entity) which is similar to SGSN (Serving GPRS Support Node) in 3G, and is the key control-node for the LTE access network, as well as the S-GW (Serving Gateway) and P-GW (Packet Gateway) which are co-located in one box called U-GW (Universal Gateway) similar to the GGSN (Gateway GPRS Support Node) in 3G. U-GW acts as the mobility pillar for the UE during inter eNodeB handovers and between LTE and other 3GPP (3rd Generation Partnership Project) technologies such as GPRS (and related 2G or GSM standards), EDGE (and related 2.5G standards), and HSPA and HSPA+ (and related 3G or UMTS standards), and also connects the UE to the Internet by being the point of exit and entry of traffic for the UE. The last subcomponent of the EPC is the HSS (Home Subscriber Service) similar to HLR (Home Location Register) in 3G. The HSS is provided by Nokia and is the main database that includes all user related and subscription related information.

To begin with, we will briefly describe the current LTE market status in Lebanon and provide an overview of the main characteristics of Touch LTE network capabilities in coping with the requirements of low latency, full geographical coverage in the needed areas relevant to our project, network load capacity, and advanced technologies and services so as to identify the major discrepancies with respect to the mature LTE networks and markets in smart cities. The following data was assimilated with the support of the Research & Development Team in the technical department at Touch:

- LTE was first deployed in Lebanon in December 2012, the moment Touch has recognized that all new services and technologies that will be launched in the future will depend on the 4G LTE networks, such as voice over IP, video streaming, video and voice conferencing over IP, online gaming, real-time apps, application sharing, mail and file sync, etc. Initially, 200 LTE sites were installed on top of existing 2G/3G sites and they were all exclusively centered in the most crowded and renowned areas of Greater Beirut. This was the last time any new LTE site was deployed, so as of June 2015, we can declare that LTE is operational in Lebanon via its 200 sites co-located with already existing 3G sites and covering limited parts of GBA.
- 200 LTE sites are operational and located in areas of the GBA, representing only a 2% geographical LTE coverage with reference to the entire countryside. LTE network capacity in this 2% area of availability can tolerate a 4G population of 30% of the total Touch customers (voice and data), or 19% of the total data customers. This infers that if all Touch data customers were present in the 2% LTE geographical span and were all actively accessing the LTE network, then only 19% of them will be attended to by the network. Obviously, the LTE geographical coverage and network load capacity are still primitive contrasted with the requirements of our smart transportation project and smart cities altogether. Usually a Greenfield city necessitates a full area coverage with a maximum capacity to cater for the peaking user demand; however, for a Brownfield city which is conventionally engaged in one specific industry sector alike our transportation project, the

LTE coverage should at least cover the main areas laid out in the project proposal as well as be able to serve at least 50% of all the potential 4G customers.

- Around 18,000 of Touch Lebanese customers use 4G LTE enabled devices, representing only 1.3% of Touch data customers, which is noticeably a very low penetration rate compared with the LTE diffusion rates in smart cities.

- There are 27 different 4G LTE smartphones used in Lebanon, namely iPhone, Samsung, LG, Nokia, Blackberry, and HTC, in addition to 3 types of LTE enabled tablets including iPad, Samsung Tab, and several Chinese tablets. LTE compatible devices are still hardly available and very expensive to acquire in Lebanon; however, their number and variety will rise consistently with the expansion of our LTE networks, and particularly with the accomplishment of the smart transportation project in hand which requires that people have LTE enabled devices so as to benefit from all the e-services and community services to be offered.

- USIM cards (Ultra Subscriber Identity Module) are used to communicate on LTE networks in Lebanon and all the cities where LTE networks are reachable by the community. With the introduction of UMTS and then LTE, it became highly recommended to use a USIM card to access the 4G network for it has many advantages over the normal SIM including speed, security and backup.

- Reselection from 3G to 4G and from 4G to 3G is available, whereby reselection is an idle mode procedure triggered whenever the UE is in idle mode for more than one second in its current serving cell or finds that the received signal quality or power of the neighbor serving cell is better than that of its current serving cell, irrespective of the priority of the neighboring cell. The terms "cell" and "sector" will be interchangeably used from now on, while every site is divided into several sectors and on each sector, all three technologies, namely 2G, 3G, and 4G/LTE, can be enabled at the same time.

- Redirection from 4G to 3G is available only, whereby redirection is a connected mode procedure triggered whenever there is a measurement gap between the current serving cell's received signal power and that of the potential neighbor cell. In this case, the target cell which the UE intends to move to, will not allocate any radio resources upfront. Hence, the UE will have to release the radio connection in the current serving cell and then request for the radio resources in the target cell. Meanwhile, the UE goes to idle mode in the serving cell and becomes connected once it shifts to the target cell. However, this radio connection release from the source cell and connection request to the target cell will not be perceived by the UE which will remain seemingly connected.
- Redirection from 3G to 4G is not available on Touch LTE network, in which case the UE in connected mode continues and finishes streaming or downloading on the 3G network, and then shifts to idle mode. Whenever it becomes in idle mode, the UE is released from the 3G network and the reselection procedure from 3G to 4G applies.
- Handover from 3G to 4G and from 4G to 3G are not available, whereby handover is also a connected mode procedure triggered exactly for the same conditions as the redirection procedure. The main difference is that the UE will not have to release the radio connection in the current serving cell and then request for the radio resources in the target cell because the target cell itself will allocate all the required radio resources upfront for the UE to move seamlessly. Nowadays, opting for redirection or handover remains the choice

of the managing operator; however the bidirectional redirection and handover techniques are both enabled by most of the advanced network operators around the world.

- Continuous coverage is preferred over Hotspot, in opposition to well-developed smart cities in which continuous coverage is supported by the LTE network through a variety of cutting-edge technologies such as Wi-Fi Offloading, Carrier Aggregation in LTE-Advanced, etc. which will be disclosed and explained in the part relating to the future plans of Touch.

- Voice is supported by CSFB (Circuit Switched Fallback) to 3G network which is nationwide. CSFB is a technology whereby voice and SMS services are delivered to LTE devices through the use of GSM or UMTS or another kind of network. However, in most of the smart cities universally, VoLTE (Voice over LTE) which is based on IMS (IP Multimedia Subsystem) was commercialized due to its mutual benefits for the service providers and the users. Those chiefly include higher spectral efficiency that allows LTE networks to hand on voice calls with half the spectrum required for 3G voice calls, superior and mobility-enhanced call quality over the basic VoIP (Voice over IP) and normal voice calls, lower power consumption of the phone, and the availability of interactive services whereby the user can simultaneously transmit and receive data traffic and add messaging or video capabilities while making a voice call. Despite the many advantages of VoLTE above the circuit-switched 3G or 2G voice calls, few customers actually realize that their LTE enabled smartphones do not naturally support VoLTE, causing the VoLTE benefits to remain utterly intangible to them.

- LTE QoS (Quality of Service) is currently being tested on Touch LTE network.

LTE QoS is applied between the UE and the P-GW of the EPC, and is used to define priorities for specific customers and/or services (which are intrinsically associated with certain data packets or type of traffic) during the time of high congestion on the network. Such services include VoLTE, interactive gaming, video calling, browsing, chatting, etc.

- LTE Key Features

  - The Cell Range is 8 km on average, whereby internationally 5 km cell size is the optimal choice, 30 km cell size has reasonable performance, and up to 100 km cell size has degraded yet acceptable performance.

  - The Cell Capacity can reach up to 350 connected mode users and 75 active data users, which is acceptable considering the prevailing circumstances. Normally, a user transitions from the idle state to the connected state and then to the active state. On average, the weekly number of connection attempts to the eNodeB is 172,350 (those might not necessarily be successful) while the weekly average number of active users per cell is 7.

  - The Cell Mobility is optimized for low mobility (0 – 15 km/h) but supports also higher mobility speeds.

  - The Latency on the User Plane is related to the real user data transmission. It is measured by the round-trip time it takes for a small IP packet to travel from the UE to the antenna, then through the network to the Internet server and back, and is usually between 10 and 20 msec. However, for Touch, the actual ping is between 15 and 25 msec, and the average webpage loading is between 500 and 800 msec. This moderately high latency on the user plane affects the user performance and is chiefly due to limited transmission capacities at air interface.

- The Latency on the Control Plane has to do with signaling and control, and is measured by the time it takes the UE to make the switch from idle mode to active mode. Touch is acting in accordance with the expected latency on the control plane, which should be below 1 sec.

- The count of Active Cells per week is 527 on average, corresponding to 88% of the total number of LTE cells in the network.

- The average LTE total volume (MB) per cell per week is 21,917 MBs (i.e. 21.4 GBs).

• Currently, the implemented 200 LTE sites are operating on Band 3 (1,800 MHz) LTE frequency band which uses FDD (Frequency Division Duplex) operation, with 20 MHz spectrum:

- Band 3: DL (Downlink) 1,860 → 1,880 MHz: 20 MHz BW
  UL (Uplink) 1,765 → 1,785 MHz: 20 MHz BW
- Band 20: DL 791 → 806 MHz: 15 MHz BW (off air)
  UL 832 → 847 MHz: 15 MHz BW (off air)

LTE is in fact determined to support both duplex modes, FDD (Frequency Division Duplex) using the paired spectrum and TDD (Time Division Duplex) using the unpaired spectrum. Primarily the choice between whichever duplex schemes is driven by the spectrum availability, but most of the operators are recently deploying both modes to leverage their spectrum assets, especially that TDD has come to have some advantages over the FDD operation. To name a few, TDD is more flexible and adaptive to the varying global spectrum allocations because it requires a single channel for both DL and UL while FDD uses paired channels, in addition to being less expensive than FDD while providing the same performance and spectral efficiency. As to the channel bandwidth, LTE defines a number of scalable channel bandwidths: 1.4, 3, 5, 10, 15, and 20 MHz. Obviously, the wider the bandwidth the greater the channel capacity and therefore, the 20 MHz BW characteristic of the FDD band 3 being used by Touch LTE network is decidedly apt for the higher capacity requirements.

Touch LTE uses the OFDM (Orthogonal Frequency Division Multiplex), with its supplementary multiple access schemes, OFDMA (Orthogonal Frequency Division Multiple Access) on the DL and SC-FDMA (Single Carrier – Frequency Division Multiple Access) on the UL. As detailed in the tutorial "What is QAM – All the Essentials" by Ian Poole, published in the Radio-Electronics online magazine, OFDM is the most appropriate modulation format for transferring high data rates, which is a chief requirement for LTE. It consists of dividing a high data rate carrier into a great number of subcarriers which are closely spaced and modulated with low data rates using QAM (Quadrature Amplitude Modulation) formats, i.e. QPSK (same as 4 QAM) or 16 QAM or 64 QAM. Those subcarriers are also orthogonal to each other so that no interference and multi-path fading or delays of the signals occur. More specifically, on the UL side, only QPSK and 16 QAM are used; whereas on the DL side, all three digital modulation schemes are available to use. Conventionally, as stated by the Service Quality Team in the technical department at Touch, higher modulation contributes to a better user experience but it was noticed through the actual drive test hours that the 16 QAM and 64 QAM are both giving almost the same efficiency at the UE level. OFDMA uses OFDM; but has the distinct characteristic of scheduling and assigning radio resources to multiple users. Its role is to assign for each user the bandwidth required for their transmission (among the subcarriers obtained from the original signal), whereby all unassigned subcarriers will fade. Unlike OFDM, the user will not be having the entire bandwidth (or subcarrier) for a given period of time, but multiple users can be sharing the same available bandwidth during that same period.

- LTE CA (Carrier Aggregation) trial was done between Band 3 & Band 20 and the maximum DL speed reached 250 Mbps, but CA is not presently functional in Lebanon since it is a feature of the LTE-Advanced networks which started to commercially move forward in some of the smart cities. CA is performed by adding bandwidth and is the most straightforward way to increase the user throughput and overall capacity of the network as well as to leverage fragmented spectrum distributions. Every aggregated carrier is called component carrier and a maximum of five component carriers can be aggregated together, with each having a bandwidth or frequency of 1.4, 3, 5, 10, 15, or 20 MHz so that the maximum bandwidth can reach 100 MHz. The number of component carriers aggregated can be different in DL and UL, and each can be of different bandwidth as well. The frequency allocation can either be intra-band, meaning that the component carriers have different bandwidths but are affiliated with the same operating frequency band, or it can be inter-band, whereby the component carriers belong to different operating frequency bands. Additionally, for each component carrier, there are several serving cells, but their coverage might differ based on the component carriers' frequencies.

After delineating the LTE market positioning and geographic coverage in Lebanon as well as the enabled technologies and services, it is obvious that the covered regions at present are minimal and not sufficient to accommodate the cities pertinent to the smart transportation project proposed. For that reason, we will disclose the LTE coverage map updated until the end of Q2 2015, as provided by the Packet Core Team in the technical department at Touch, in order to identify the gaps that require fulfillment.

- 200 LTE sites are currently on air, whereby 100 LTE sites are provided by ZTE and cover Bir Hassan area, Beirut suburban region, and another 100 LTE sites provided by Huawei covering Beirut and the north cost.
- The coverage in Grand Beirut Area (GBA) corresponds to only 2% of Lebanon's territory, as per the below figure:

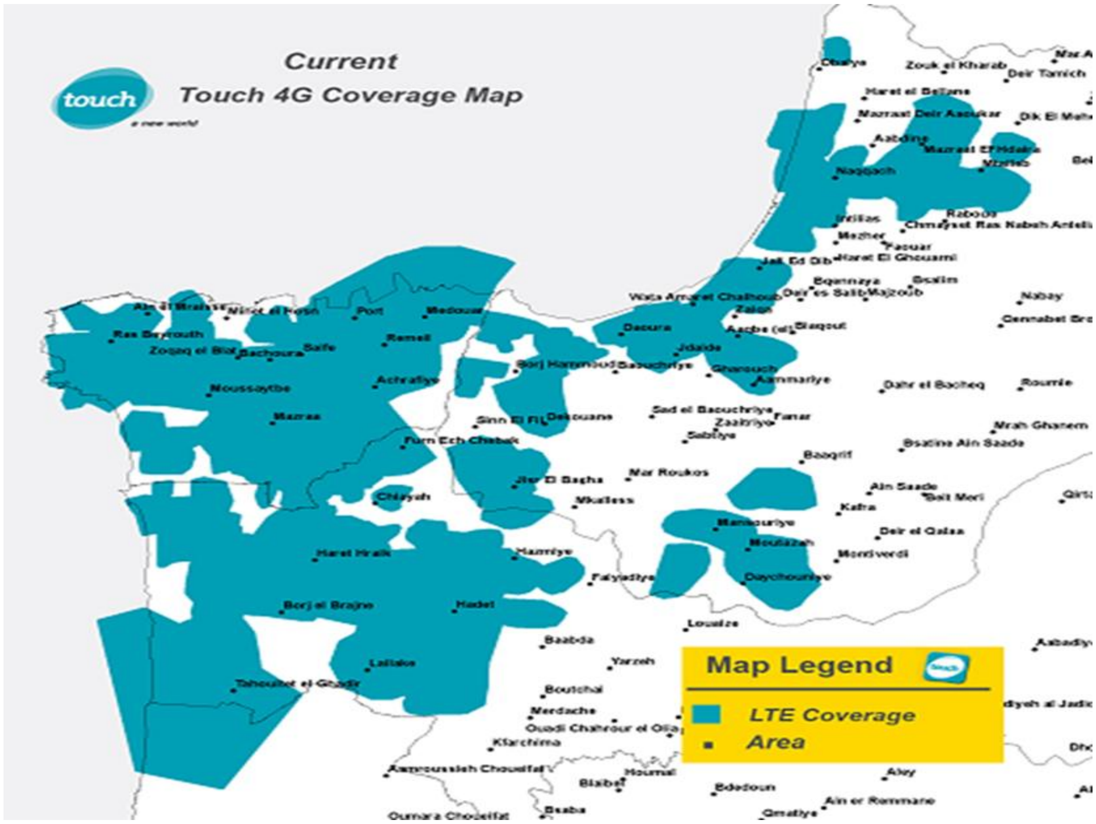

Figure 3 – LTE Geographical Coverage in GBA

The GBA consists not only of the areas surrounding Beirut city, but also enfolds some cities pertaining to other Lebanese districts. However, the GBA alone, even if it were fully under LTE coverage, wouldn't be suitable for our project, which mainly includes the main and largest cities of the country, allocated as follows:

- Beirut Governorate or Beirut City including Achrafieh, Dar El Mreisse, Bachoura, Mazraa, Medawar, Minet El Hosn, Moussaitbeh, Port, Ras Beirut, Rmeil, Saifi, and Zuqaq al-Blat;

- Mount Lebanon Governorate including the largest cities of the districts of Baabda, Maatn (Antelias, Dbayeh, Mtayleb…), Aley, Keserwan (Jounieh, Jeita, Kfardebian…), Chouf, and Jbeil;
- Beqaa Governorate including the largest cities of the districts of Baalbek, Hermel, Rashaya, Western Beqaa, and Zahle;
- Nabatieh Governorate including the largest cities of the districts of Bint Jbeil, Hasbaya, Marjeyoun, and Nabatieh;
- North Governorate including the largest cities of the districts of Akkar, Batroun, Bsharri, Koura, Miniyeh-Danniyeh, Tripoli, and Zgharta; and
- South Governorate including the largest cities of the districts of Jezzine, Sidon, and Tyre.

In view of that, and considering the scope of our project, the 2% LTE geographical coverage should be undoubtedly expanded to embrace the regions denoted above and to be able to serve not only 19% of all potential 4G data users, but around 50% of them in its area of coverage. Since the project tackles only the transportation industry sector in the major cities of Lebanon, then it will be appropriate to have a LTE network that can bear half of the data population present in that region.

Luckily, the Research & Development Technical Team at Touch has already prepared a business case to enlarge the current LTE coverage map through securing 300 additional LTE sites (eNodeBs and Antennae) to cover most of the major cities of Lebanon. The question remains whether those 300 new sites are able to satisfy the geographic span and network capacity looked-for in our project. Currently, as we have already mentioned, Touch has 1,222 2G sites on air, 1,206 3G sites on air, and 200 4G sites on air, whereby 90% of the 3G sites are co-located with 2G sites, and all the 4G sites are superimposing existing 3G sites' premises. Besides, the same customized approach will be used to deploy the prospective 300 LTE sites, as confirmed by the Network Operations Center Team in the technical department at Touch. The business case has been prepared by Touch and approved by Zain Capex Planning Board which is responsible for approving all Capital Expenditures to be made by Touch before the spending actually occurs. Besides, a RFP (Request for Proposal) has been formulated, but not launched yet, pending the approval from the Ministry of Telecommunications in Lebanon. Conveniently, the latter is an active primary player in our smart city value chain, so optimistically the approval will be granted and installation and commissioning of the needed extra 300 LTE sites will kick off immediately after.

As it was previously mentioned, the 1,206 existing 3G sites are spread over 86.43% of Lebanon's geography, while the 200 current LTE sites, although they represent 17% of the total count of 3G sites, are dispersed over an area of only 2%. The fact that LTE sites are presently not so scattered and disseminated over closely spaced parts of the GBA explains this mere 2% geographical LTE coverage. Consequently, the number of sites deployed cannot be directly related to the geographical span because a large number of sites condensed in a relatively small area will not impact much the percentage of geographical coverage by those sites. So in order to increase the land coverage, the sites have to be distributed and spread across the country and not concentrated around one specific area, as is the case for the current LTE sites. Now with the subject expansion taking place, the share of LTE sites will be stretched from 17% (200 LTE sites) to 41% (500 LTE sites) of all existing 3G sites, but this will affect the geographical coverage only if the sites to be implemented are widely spread across all the Lebanese regions. Only then, we can hope for a wider LTE area coverage in Lebanon, with the latter being the purpose of our smart transportation project and eagerly that of the proposed expansion. Assuming that spreading out 300 new LTE sites is set to actually cover as many locations as possible all over the country, we still need to verify with the concerned that 300 new LTE sites are enough and capable of embracing all the cities put forward in our project. Henceforth, the only factor influencing the LTE space coverage in Lebanon is the manner in which the new sites are distributed, and not the number of sites since those can be concentrated in a small space and not impacting much the overall area coverage. Whereas the feature impacting the LTE network capacity in a certain location, i.e. the ability of the network to serve more LTE users in a specific location despite being geographically not so wide-ranging, is the amount of sites physically mounted in that location. Practically, if the pending expansion succeeds at assimilating the acknowledged cities of “Smart Lebanon”, this would be sufficient to cover up an appropriate part of the LTE geographic coverage deficits in Lebanon as well as to meet the coverage requirement in our project proposal. Bearing in mind that the 4G equipment will be added to the existing cabinets supporting 2G and 3G technologies, the vendor chosen to perform the expansion will have to ensure that there will be enough power in the cabinet to tolerate the newly added 4G equipment, and that the cabinet temperature will not exceed the thresholds.

In the feasibility analysis to follow, we will estimate the costs, ROI (Return on Investment), and payback period of such an investment, in order to assess accordingly its financial viability for Touch. The study mainly gives emphasis to the estimation of the LTE penetration rate following the expansion. The latter is highly correlated to where the sites are distributed, more specifically to the nature of the location where they are commissioned (urban/central vs. rural/peripheral), and not how much geographical area they span. In fact, deploying the 300 new LTE sites in urban and crowded areas, such as the focal Lebanese cities recommended in our project, means that the number of data users there is normally higher, which signifies that the number of people having LTE compatible devices is also higher, and which in turn implies that there will be a higher probability of LTE diffusion in this area, given that there is enough network capacity available to cater for the prospective LTE user demand. To facilitate the speculative study in relation to the LTE penetration rate performance, as well as the financial viability of the 300 LTE sites' expansion, I sat with numerous people working at Touch and an engineer from Huawei which is the solo vendor in charge of all 3G sites in Lebanon and which will definitely bid for the prepared RFP once it is launched. The various contributing Technical and IT Teams include Site Management (Infrastructure), Radio Transmission, Service Quality, Corporate & Internet Services, and Research & Development, all of which assisted to gather and foretell the data and figures needed to complete the study.

Based on the statistics done by the Service Quality Technical Team at the end of Q2 2015, the total number of voice and data customers was 2,242K out of which data subscribers count 1,383K. So the percentage of data customers out of the total Touch population is

62%. Additionally, the number of LTE subscribers at the end of June 2015 was 18K representing only 1.3% LTE penetration rate in Lebanon. As we notice, this percentage is very low due to the fact that only 2% of Lebanon has LTE enabled sites, with those being able to cater for 30% of all Touch customers, i.e. a maximum of 672K customers if all Touch users were to attach concurrently to the LTE network in this 2% area of LTE coverage. But in fact, 62% of all customers have data subscription, which implies that only 19% or 263K of those data customers will be able to simultaneously access the LTE network in this 2% area of coverage. Obviously, 18K out of 263K potential LTE connected customers in the existing circumstances means that only 7% of the LTE current network capacity is being exploited. Another way to compute the utilization rate is by dividing the actual number of LTE subscribers by the product of one cell capacity (350 users in connected mode) with the number of LTE cells that can be integrated in one site (3 cells per site for a total of 200 sites). This approach is more theoretically verified since it uses less speculation, whereby all the parameters are known. The utilization rate turns out to be 8.5% which is very close to the first estimated figure. It is very critical to differentiate between the Capacity of the LTE network being used here, and the Capacity of the MW transmission links described earlier. The capacity of the network means its ability to tolerate a higher number of coexisting connected users and higher capacities are achieved through adding sites or sectors. On the other hand, the capacity of the transmission medium represents the data throughput at the air interface between two eNodeBs or between an eNodeB and a user, and higher data rates can be achieved through the several techniques we talked about before. For instance, if we take on that the expansion happens and in total 500 LTE sites are functional now; assuming that the transmission specifications of those additional 300 sites are exactly the same as the incumbent 200 sites, then we can deduct that the network capacity in terms of number of connected users is increased but the speeds at which the data will flow in the network remained unchanged. On another side, let us assume that the expansion doesn't occur but the transmission equipment are upgraded to tolerate higher throughput on the MW links; in this case the capacity of the LTE network to accept more connected users will be unaffected, but the capacities at air interface will become higher to provide a faster and better user experience.

Straightforwardly, Touch has to find ways to leverage the available LTE network capacity before it starts adding on LTE sites. But for the sake of our project, the available network capacity and geographical coverage of LTE are both very partial and limited. If Touch were to be actively and primarily engaged in the deployment of "Smart Lebanon", then an aggressive, well-managed, and well-marketed entry would be the option it has to opt for. Hopefully, the smart transportation project under discussion, along with all the enhancements and new technologies it will convey to the life of the Lebanese citizens, will be capable of inducing the needed eventual transition.

In relation to the LTE penetration rate performance which is supposed to improve following the so-called expansion, a series of assumptions were formulated with the profound contribution of Mr. Hussein Helmi Jalloul from the Research & Development Technical Team so as to compute the network related variable resultant from our analysis. The hypotheses we made are the following:

- Based on the long-term trend analysis of the customer base's behavior at Touch, performed by the Business Planning Commercial Team, the curve pertaining to the number of data users over time actually recorded some steep positive slopes when 3G was first launched in Lebanon in November 2011 and when prices on voice and data services were reduced in June 2014; but since January 2015, data subscribers are growing at a steady rate of around 1.1% per month. This additional monthly data penetration rate might drop further due to the seasonality effect and the fact that Touch hasn't offered any new appealing data package since the Web & Talk for prepaid customers propelled in March 2013. For that reason, Touch is urged to come up with new data services to boost its data penetration rate, and accordingly its data revenue, especially that revenue from voice and SMS are decreasing. At present, the 3G network coverage is countrywide, so Touch can start by leveraging the 3G network capabilities to attract additional data customers, until the full deployment of the LTE network which will stimulate new data customers as well as the conversion of users from 3G to 4G networks. The penetration rate of data users will eventually improve, providing Touch decides to take advantage of the 3G network maturity or take on the smart transportation project proposed which is interrelated to the requirement of having a developed 4G network. Still, for the sake of our viability analysis concerning the forecasted LTE expansion, it would be best to aim for the worst case scenario in evaluating all the input variables to our financial model (such as the LTE penetration rate) and their corresponding outputs from revenues to payback period to NPV to IRR. Given that the 300 new LTE sites' expansion will have occurred by the beginning of January 2016, we will start measuring the variables in our study from this month onward. Subsequently, in order to forecast the count of data customers for the future months which we need to account for in our analysis, we will assume that the data penetration rate continues to increase by 1.1% every month throughout the entire year 2015, and then gradually drops during the course of the years to come.

- The 300 LTE sites to be added constitute in fact 25% of all the existing 1,206 3G sites since 4G sites will be mounted on top of the 3G sites. However, we cannot assume that a similar proportion of data customers will be served by this area because the data customers' distribution is not equivocal across all regions. As we move toward the major cities in the country, we notice that those cities are more crowded than others, and thus the percentage of data customers in them will be higher compared to the remaining lateral cities. Thus, the location of those additional 300 LTE sites and where they are distributed will affect the number of people being able to benefit from the coverage they give, while how they are distributed will impact the geographical LTE coverage in Lebanon with no direct affiliation to the number of customers being served. Considering that the 300 additional LTE sites accounting for 25% of the current number of 3G sites will be in crowded urban areas, we will assume that from the total number of Touch data customers, around 35% will be present in the areas covered by the new LTE sites.
- Out of the data customers that will be present in the areas covered by new LTE sites, the percentage of those having LTE compatible devices will be around 18% by January 2016. However, we will assume that this percentage will rise throughout the years to come, to reach a ratio of 80% at the end of 2020. The fact that LTE enabled mobile handsets and tablets are not so diverse in Lebanon at present and very expensive is in reality a major drawback attenuating the increase in LTE penetration rates.

- As to the data customers present in the areas covered by the new LTE sites and having LTE compatible devices, we will be a bit conservative at first in relation to those among them who will actually subscribe to LTE packages and services, and estimate their percentage to be merely 40% in January 2016. This fraction of the real LTE users will progressively increase in the upcoming months to around 90% towards the end of 2020. Still, as long as this expansion is linked to the smart transportation project in hand, and marketed to the people accordingly, then this LTE penetration rate will definitely be higher. Whenever the citizens are passive receivers of the new forthcoming technologies, the major players in this project should make them support the undertaken project by heavily promoting that it is essentially targeted to serve the Lebanese citizens and enhance their quality of life. Through communicating the right message in the right way, people will be entranced to try the smart solutions and services that require LTE data usage, which will ultimately lead to more and more people subscribing to LTE bundles.
- The average estimated additional revenue per customer, following his/her subscription to LTE and taking into account the increase in data consumption and the subscription to higher bundles, is estimated to be $ 3.5 per user, as per the Business Planning Team in the commercial department at Touch. This added revenue does not include the possible extra revenues from downloading applications and streaming multimedia content, which might also be offered to customers at a certain fee specified by Touch, provided that the applications and photos/videos are exclusive to Touch and cannot be accessed otherwise.

- In order to cater for the new air interface demand, it is assumed that the total Internet Capacity from Ogero (Organisme de Gestion et d'Exploitation de l'ex Radio Orient) ISP (Internet Service Provider) has to be increased by extra 500 MB per month to account for the supplementary data usage of the new LTE customers spanning the newly commissioned locations. My calculations were based on the fact that Touch acquired, for the month of June 2015, 5.4 GB of Internet Capacity in total, including all kinds of data usage (GPRS, EDGE, HSPA, HSPA+, and LTE). According to the Corporate & Internet Services IT Team at Touch, this total data consumption on the Gi interface (which is the interface to external packet data networks, e.g. Internet), has been increasing by around 4% on average per month during the first semester of 2015 (corresponding to around 221 MB). Probably this monthly increase in the Internet Capacity from Ogero has been kind of stable during the first six months of this year since no major expansions have been done on the network, and no booming data bundles have been released. However, if the 300 additional LTE sites were to be deployed, then, according to the Research & Development Team in the technical department, Touch would definitely have to further increase that monthly figure by around 9% per month, taking into consideration the UE behavior, the eNodeB expansion and the number of sites' rollout under deliberation, and ultimately the 4G penetration in terms of services and smartphones. Doing so, the extra Internet Capacity to supply the new 300 LTE sites will be around 500 MB per month, inferring the need to lease additional 250 E1 lines from Ogero each month. With a $ 333 rental fee per E1 per month, the corresponding yearly operational expenditure pertaining to this LTE expansion will be around $ 1M.

- Last of all, some of the hypothetical numbers used in our breakdown are founded on the budgetary figures provided by the concerned technical units at Touch, whereby each unit based on its field of expertise, experience, and trend analysis of the costs incurred in similar deeds, predicted the expenses to be forfeited for the additional 300 LTE sites expansion. The cost estimates of this expansion include all needed requirements regarding the civil work, power, equipment, sites' rental, transmission, services and training, Internet Capacity from Ogero ISP, etc. As we will uncover in the following sections, the major challenges that Touch is facing are on the radio links (which explains the reason for this expansion), the transmission links, and the links from Touch Core Network to the Internet; whereby solutions for the different shortfalls were suggested to mitigate the gap in comparison with developed mobile networks. The cost evaluation of the proposed expansion entails the expected rental fees of the additional required links to Ogero ISP, in addition to the costs of transmission requirements for the new 300 LTE sites, provided that the transmission equipment purchased/used for this expansion are up to the standards requested by the solutions proposed to improve the current microwave capacities. Hence, the return on investment or IRR (Internal Rate of Return) computation for this expansion accounted for all the above network-related costs and their related estimated figures.

The assumptions above are kind of conservative, due to the fact that LTE complementary mobile handsets and tablets are still scarcely available in the Lebanese market and very expensive to purchase, in addition to the still not-so-bearable pricing schemes of data services in Lebanon in comparison with other countries, despite the price reduction on all voice and data services offered by Touch that the Ministry of Telecommunications (MoT) endorsed last June 2014. In fact, the transition from the 3G to the 4G network will impose that the converting customers upgrade their data subscriptions so as to have enough balance to pursue their usual behavior besides using all the new e-services that will be introduced following the inception of the smart city community services, because at the end of the day this is the greatest objective of this project.

As to the financial viability of this investment on Touch LTE network, that is one of the two requirements pertaining to the ICT network layer in smart cities, the output variables to be estimated are the NPV (Net Present Value), the IRR (Internal Rate of Return) which denotes the ROI as well, and the payback period. Yet, it is worth to mention that the straightforward calculation of the payback period does not account for the time value of money, while NPV and IRR are based on the estimation of the future cash flows from this investment, and are thus more realistic and reliable to espouse. For that reason, we will use in our analysis a discount rate of 8%, which is the rate of return minimum threshold for the business case financials at Touch, as given by the Financial Planning & Reporting Team in the finance department at Touch, and we will accept that the number of periods during which the project is expected to operate and generate cash inflows is 5 years, as stipulated by the Radio Network Planning & Optimization Technical Team. Accordingly, the one-time Capex (Capital Expenditures) disbursements required for this upgrade are estimated at $ 25.5M, while the 5-year Opex (Operational Expenditures) payouts are $ 6M, which makes the total cost of the expansion over 5 years valued at $ 33M. However, from a Technology Procurement perspective and as asserted by the Technical Teams involved in this feasibility study evaluation, the price will be certainly negotiated with the chosen vendor which will have to guarantee a discount of 10% on the calculated TCO (Total Cost of Ownership) and drive it down to a maximum of $ 30M. With an additional revenue of approximately $ 3.5 for every new LTE comer, the surplus of revenues generated will have need of 3 years and 3 months to break-even i.e. neutralize the estimated 5-year TCO, as well as capitalize the costs incurred, and proclaim making profits from this planned expansion. The calculated output variables are as follows:

- The payback period is 3 years and 3 months (not considering the time value of the money).
- The NPV is $17.66K, so the project is deemed profitable.
- IRR is 23.4%, which is greater than the target rate of return of 12% used in capital budgeting at Touch.

The two tables below summarize the inputs of the study along with the outcomes:

Table 4 – Summary of Inputs and Payback Period Output

Implementation of additional 300 LTE sites							
Number of additional LTE sites to cover the majority of GBA and the main cities	300						
Capex							
Equipment, power, service and training (based on a budgetary figure from Huawei with a 70% normalization)	$15,000,000						
Civil work (based on a budgetary figure from Infra unit)	$ 900,000						
Transmission requirements (based on a budgetary figure from TX unit with a 70% normalization)	$ 9,600,000						
Opex							
Yearly increase in the Sites rental fees (based on budgetary figure from Sites Management unit)	$ 500,000						
Yearly increase in the Internet Capacity rental fees from Ogero corresponding to additional 500 MB per month	$ 1,000,000						
Total cost of the upgrade over 5 years	$33,000,000						
Maximum estimated total cost of the upgrade over 5 years after RFP, negotiations, and discount	**$30,000,000**						
Estimated return from the generated traffic and subscriptions following the implementation of 4G in the new locations							
Month	**Jan-16**	**Jan-17**	**Jan-18**	**Jan-19**	**Mar-19**	**Jan-20**	**Dec-20**
Total number of customers with data connection (based on the current nb of customers and on the long terms increase trend)	1,493,070	1,695,468	1,845,123	1,858,823	1,860,682	1,868,885	1,877,125
Number of data customers in the area covered by the new sites	522,575	593,414	645,793	650,588	651,239	654,110	656,994
Number of data customers in the area covered by the new sites and having an LTE compatible device (based on the current distribution of LTE enabled devices and its minimum expected increase)	94,063	207,695	322,896	455,412	455,867	490,582	525,595
Number of data customers in the area covered by the new sites and having an LTE compatible device and adding LTE after the additional sites implementation	37,625	145,386	258,317	409,870	410,280	441,524	473,035
Average estimated additional revenue per customer (in USD) following its subscription to LTE taking into account the increase in the data consumption and the subscription to higher bundles	$ 3.50	$ 3.50	$ 3.50	$ 3.50	$ 3.50	$ 3.50	$ 3.50
Additional data revenue from all subscribing customers to LTE	$ 131,689	$ 508,852	$ 904,110	$ 1,434,546	$ 1,435,981	$ 1,545,334	$ 1,655,624
Accumulated data revenue from all subscribing customers to LTE	$ 131,689	$ 3,679,498	$ 12,441,172	$ 26,723,830	**$ 29,595,075**	$ 44,814,426	$ 62,989,925
Payback period	**3 years 3 months**						

Table 5 – Summary of NPV and IRR Outputs

	Initial Capital	Cash Flow 2016	Cash Flow 2017	Cash Flow 2018	Cash Flow 2019	Cash Flow 2020
	$ (30,000,000)	$ 3,170,646	$ 8,366,416	$ 13,752,222	$ 17,979,808	$ 19,720,833
NPV	**$ 17,662,957**					
IRR	**23.4%**					

Considering that the sites' implementation will take place between August and September 2015, and finalized by December 2015 at the latest, the LTE network expansion is planned to start securing revenues and subscribers as early as January 2016, whereby the 30% 4G population depicting the LTE network capacity to serve all Touch customers in its mere 2% area of availability will be stretched to 75% (this is equivalent to a raise from 19% to 48% of all data customers). This result, in addition to an eventual improvement in the geographical LTE coverage after adding the 300 sites in all the main cities purported in our smart transportation project proposal, will be categorically a remarkable achievement for Touch especially that the LTE penetration rate is estimated to attain 90% in all the areas covered by the new LTE sites by November 2018, i.e. after 2 years from the deploying those sites. Although the LTE network capacity and geographical coverage are both very important factors ahead of the increasing user demand or penetration rates, the throughput rates (or capacity at air interface) at which the UE can send and receive data is as well a critical factor in the attempt to improve the customer experience and satisfaction. There are in fact many dynamics to be considered when planning for the LTE network (such as coverage vs. capacity), and not all of them can be optimally tuned; however, the decisions made in relation to each factor alone and all of them together, despite being not so idealistic sometimes, will hopefully contribute at the end of the day to satisfying the pre-defined baseline LTE network requirements. Given the scale and scope of our Brownfield project plan, the resulting assessment is deemed to be an accomplishment for Touch as an active primary stakeholder highly influencing the success of this project. Yet, this does not eliminate the fact that Touch has to keep up the efforts to further expand the LTE network's geographical coverage to become countrywide, as well as its capacity to tolerate at least 90% of all potential LTE customers. In view of this, I was told by the director of the Packet Core Technical Team, Mr. Jad Kahi that Touch will drop this expansion if no approval from the Ministry of Telecommunications is received by the end of July 2015. Meanwhile, a new business case for having 1,015 additional eNodeBs along with the corresponding microwave transmission capacity and core requirements is being drafted internally at Touch and will be sent to Zain Capex Planning Board in due time. The desired network will be based on the latest technologies available in the market, namely the LTE-Advanced, and will cover the entire Lebanese territory.

On a side note, in order to fully grasp the size of the investment under discussion, it is necessary to get an approximation of the yearly Capital expenditures that Touch is allowed to expend, mainly since the bulk of the estimated TCO of this expansion is integrated in the financial books of Touch as Capex outlays. For the year 2014, the total Capex spending amounted to $ 82 M, accounting for 10% of the total revenues made by Touch during this year, and served chiefly to develop the company's network across the Lebanese territory. This financial figure, as confirmed by the Financial Planning & Reporting Team, has been stable for the past years. Therefore, the $ 30M cost of the proposed LTE expansion over 5 years will be incorporated in the Technical Department's Capex budget for 2016, representing 37% of the total Capex spending in 2014, which is not a very large share of the yearly Capital expenditures considering the importance and significance of this assignment. Evidently, this fact along with the $ 63M additional revenues throughout the 5-year expected lifetime of the expansion, make the acquisition of the 300 new LTE sites a reasonable decision to take.

2. *LTE RAN and Backhaul Network Capacities in Touch*

a. LTE RAN Capacities

We will start by discussing the LTE RAN architecture at Touch with an emphasis on the microwave transmission capacities, and associated stimulating parameters as well as data throughput implications. Meanwhile, we will be comparing all Touch findings with the global RAN understandings and practices realized in mature LTE networks, namely in smart cities.

At Touch, all the deployed LTE sites are co-located with existing 3G sites with the majority of them also co-located with 2G sites, which implies that a single site is used to accommodate the three technologies, GSM, UMTS, and LTE. Almost all of the sites on Touch network are currently made up of three sectors, and each sector is enabled to support the three available technologies, each having its own radio equipment, except for the antenna which might be shared to collectively transmit 2G and 3G signals or 3G and 4G signals or sometimes 2G, 3G, and 4G signals all at once. At Touch, there is more than one frequency for sending and receiving 2G signals, and the same applies for the 3G traffic, with only one frequency enabled currently for the 4G traffic (Band 3 at 1,800 MHz). At present, Touch uses a diversity of one-band, dual-band, tri-band, and quad-band antennae. Basically, the sites where 2G, 3G, and 4G coexist together require that the antennae have more poles, so as to accommodate for the various frequencies at which 2G, 3G, and 4G networks operate. Regardless of the number of poles/bands on every antenna, only a single frequency pertaining to one of the technologies can be enabled on every pole. Antenna sharing is subject to the number of poles or bands available on the antenna. For the case of 2G and 3G, only one pole is required to convey either type of traffic. In a typical 3G download session for instance, we will need one transmitter antenna (more specifically pole) at the base station operating on one of the available 3G frequencies, and one receiver antenna at the mobile irrespective of how many poles the antenna has. Assuming the antenna is dual-band, one likely scenario could be that one pole is assigned one of the 2G frequencies while the other is given one of the 3G frequencies. This is an example of a co-located 2G/3G site sharing the same antenna to transmit and receive 2G and 3G traffic. Another scenario could be that both poles are functioning on two different 3G frequencies. The lower frequency would help enhance the coverage in the area surrounding the site while the upper frequency would help enhance the transmission capacity. However, for LTE specifically, two poles are needed to convey the 4G traffic passing through one LTE cell. This is done by means of the 2x2 MIMO (Multiple Input Multiple Output) scheme which uses two transmitter antennae (specifically poles) and two receiver antennae operating in the same frequency channel for every ongoing 4G data session between the base station and the UE. The 2x2 MIMO techniques are compulsory in order to support the baseline RAN (Radio Access Network) capacity requirement of LTE which consists of higher data rates into the microwave links compared with 2G and 3G required throughput. Whenever the UE is downloading a video from the Internet, each receiver antenna at the mobile is getting two streams of data, one from each transmitter antenna at the base station. Using MIMO techniques allow the capacity to be multiplied by a factor equal to the number of transmitters in the MIMO system; in this case the capacity at air interface is hence doubled. In parallel with the more advanced LTE RANs, 4x4 MIMO techniques are being used to get two-fold the capacity resulting from a 2x2 MIMO assuming all other conditions are the same. As we revealed, the 2x2 MIMO process will use two poles (that can either belong to the same antenna or to two different antennae very close to each other) closely aligned and operating on the same frequency band (which is 1,800 MHz in the instance of Touch LTE) to convey the 4G traffic through every LTE cell. Thus, the main difference in the way 2G and 3G data traffic is transferred is that they utilize a SISO technique with only one transmitter antenna and one receiver antenna at each side. So, as it was mentioned earlier, Touch is using multi-band antenna, contingent upon how many technologies are enabled on every sector, whereby the more technologies supported means that higher-order antennae are needed to accommodate the different frequency bands at which the three technologies function. Currently, all antennae pertaining to LTE cells support the 2x2 MIMO schemes which provide higher quality microwave signals and enhanced data rates and performance over larger areas. Each site having several sectors/cells has its own story; there is no unified approach to how the antennae distribution between 2G, 3G, and 4G is being planned or to how many antennae are mounted onto every site.

Theoretically, the LTE sector peak throughput is 150 Mbit/s for DL and 50 Mbit/s for UL, so an LTE site with 3 sectors will have hypothetically a peak rate of 450 Mbit/s. Practically, the LTE average sector throughput under real world conditions is not far at all from what is being achieved in the countries where LTE networks are mature enough, whereby the average DL bit rate ranges from 25 to 35 Mbit/s (highest achieved is 55 Mbit/s) and the UL from 5 to 10 Mbit/s (highest achieved is 15 Mbit/s). According to the online article “Deep dive: What is LTE?” by Neal Gompa published in ExtremeTech Newsletter on April 1st, 2015, Verizon’s LTE services for example were esteemed to have an average download bitrate of 31.1 Mbit/s and an average upload bitrate of 17.1 Mbit/s, whereas T-Mobile’s LTE services scored an average download bitrate of 20.5 Mbit/s and an average upload bitrate of 13.5 Mbit/s.

The air interface, as designed by Touch Radio Transmission Technical Team, entails currently a point-to-point transmission from the eNodeB of a site to the UE or between eNodeBs of two sites having a Line of Sight, through MW (Microwave) links procured from Huawei vendor. Initially, the baseband signal is modulated in the IF Board (a unit that is incorporated in the RTN (Radio Transmission Node)) using digital modulation techniques to the Intermediate Frequency (IF) signal, which is in turn converted to the Radio Frequency (RF) or microwave signal by the ODU (Outdoor Unit that can be either integrated with the antenna or connected to it via a soft short waveguide) before it is transmitted in the air through the antenna. To be noted that the notations “IF Board”, “RTN”, and “ODU” are specific to Huawei vendor and might be differently labeled if acquired from other vendors, although the concept explaining how the signal is transmitted is the same. The universally used frequency bands in digital microwave communication comprise 6GHz, 7 GHz, 8 GHz, 10 GHz, 10.5 GHz, 11 GHz, 13 GHz, 15 GHz, 18 GHz, 23 GHz, 26 GHz, 28 GHz, 32 GHz, 38 GHz, and 42 GHz; all of which are being used by Touch. In addition, every LTE site with three sectors has one MW link to communicate with adjacent sites or with the UE, because from the eNodeB, there is a single connection to the transmission equipment. The below figure, provided by Mr. Spiro G. Kolakez working as a Team Leader in the Wireless Department at Huawei Technologies, illustrates the transmission equipment used at Touch, namely the RTN and its components, the ODU, and the antenna.

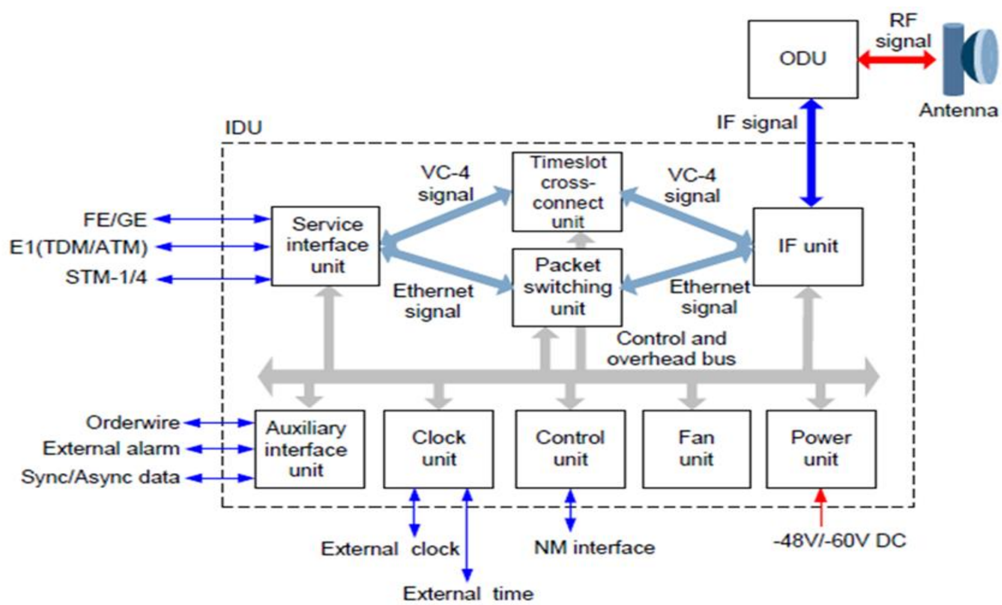

Figure 4 – RTN Prototype

The capacity of the air interface on every MW link is restricted by five factors:

- The IF Board type which specifies the modulation format used;
- The channel spacing or BW within the chosen frequency band, whereby a wider channel spacing results in a better MW link capacity;
- The frequency used whereby some frequency bands do not support wider channel spacing;
- The ODU type whereby some ODUs do not support wider channel spacing; and
- The type of the site i.e. hub site or access site: An access site has a Line of Sight with only one other site, and can send to and receive microwave signals from only one site, irrespective of the nature of the site with which it is communicating. On the other hand, a hub site is one that can transmit to and receive microwave signals from multiple sites at the same time.

All the factors postulated above, affect actually how the calculation of the capacity on every MW link is being done. Briefly said, the radio air interface depicts or puts rules for the design and planning of the MW links, whereby for a site having the three active modes GSM, UMTS, and LTE, we take the peak data rate of each technology corresponding to one sector (i.e. 150 Mbit/s for LTE, 21 Mbit/s for 3G, and 2 Mbit/s for 2G) and add them up 150 + 21 + 2 ~ 175 Mbit/s. It is true that one site is ordinarily made up of three sectors; however, in setting up the capacity of the MW link pertaining to a site, we only consider the peak rates generated by one of the three sectors because it would be impossible to have all three sectors peaking concurrently. The 175 Mbit/s figure is a prerequisite capacity to be considered in order to be able to access each site. Nevertheless, when scheduling the MW link capacity of a hub site, the capacities of all the converging links have to be taken into consideration. The straightforward way is to add the capacity of each of the congregated links, which is not usually used since in this case, we are assuming that all the converged sites are peaking at the same time all the time, which would never eventually occur. The more practical and realistic approach to use is statistical multiplexing which consists of some formula that gives a more real-world concrete value of the MW link capacity needed for a hub site.

In relation to the modulation scheme dynamic that is regulated by the type of the IF Board, QAM digital modulation formats are being used on all transmission links, extending from QPSK (or 4 QAM) to 2,048 QAM in multiples of 4. In fact, QAM provides higher spectral efficiency than other forms of modulation by using two carriers on the same frequency offset in phase by 90 degrees, and uses varying symbol rates to increase throughput of MW links. The lower forms of modulation i.e. QPSK do not necessitate a large SNR (Signal-to-Noise Ratio); however, they are not capable of transmitting the data as fast as higher-order modulation formats which are used only when there is an excellent SNR because the points are very close to each other, making them more vulnerable to noise and data errors. Although the higher-order modulation formats help meet the LTE RAN capacity requirements by delivering higher data throughput, they are not fundamentally a must-have for all network operators. In point of fact, the incremental capacity gain declines as we move up the modulation order ranking, and hence we can conclude that higher-order modulation levels are not capable alone of improving the capacity. Accordingly, the choice of the most suitable LTE modulation format depends upon the prevailing conditions. The table below will help illustrate the several commonly used modulation formats and related bits per symbol, as well as the additional capacity improvement beyond the lower level modulation format (Source: AVIAT NETWORKS: Official Wireless Transmission Blog, “8 Questions You Need Answered about Higher-Order QAM Usage” posted on February 22nd, 2013).

Table 6 – QAM Modulation Schemes and Incremental Capacity Improvement

QAM Modulation Format	Bits per Symbol	Incremental Capacity Gain
4 (QPSK)	2	-
8	3	50%
16	4	33%
32	5	25%
64	6	20%
128	7	17%
256	8	14%
512	9	13%
1,024	10	11%
2,048	11	10%

At Touch, the transmission medium is an all-IP design microwave radio system. At the RTN layer, the mostly used fixed modulation formats range from QPSK to 512 QAM depending on the type of the IF Board, and either 28 MHz or 56 MHz is used for channel spacing (56 MHz being the maximum channel spacing that can be achieved using the traditional microwave frequencies listed formerly); however, no traffic compression features or frequency reuse and interference protection schemas are currently enabled. The majority of IF Boards currently used are of the type IFU2 or IFX2, in addition to some ISV3 boards; whereas the SP and HP ODUs tag along the IFU2 and IFU2 Boards and XMC-2 and XMC-2H ODUs consort with the ISV3 Boards. To be noted that ISV3 Boards can support higher-order modulation formats of 1,024 QAM and 2,048 QAM and thus have the ability to provide higher throughput on the associated MW links. The modulation, channel spacing, and ODU type, along with the frequency band selected and the nature of the site (access or hub) will impact the overall capacity that can be achieved on the MW link. The total number of MW links on the network is 1,313 out of which 1,017 have the RTN 950 type and 296 have the RTN 980 type. The links are divided as follows:

- 549 links using SP ODUs and either IFU2 or IFX2 Boards (IF Boards are integrated in the RTNs and ODUs are mounted next to the RTNs and are directly connected to the antennae);
- 202 links using HP ODUs and either IFU2 or IFX2 Boards;
- 377 links using XMC-2 ODUs and ISV3 Boards; and
- 21 links using XMC-2H ODUs and ISV3 Boards.

The below table summarizes the native (untagged or peak) Ethernet throughput at the air interface, and not the average data rates which depend on the real traffic being transmitted and received.

Table 7 – Summary of Input Factors' Disparity on MW Output Capacity

ODU	SP		HP		XMC-2		XMC-2H	
Channel Spacing	28 MHz		56 MHz		56 MHz		56 MHz	
IF Board	IFU2 or IFX2		IFU2 or IFX2		ISV3		ISV3	
Modulation Scheme	128 QAM	256 QAM	128 QAM	256 QAM	256 QAM	512 QAM	256 QAM	512 QAM
Throughput	160 Mbit/s	180 Mbit/s	310 Mbit/s	360 Mbit/s	450 Mbit/s		500 Mbit/s	

In parallel with the international applications of LTE RAN in smart cities, microwave transmission links remain the most cost-efficient solution to satisfy the increasing demand on higher data transfer speeds in a reliable and flexible manner as mobile operators are moving from 3G to LTE/4G, primarily since they replace the need to excavate the streets and pay for pricy fiber leased-line alternatives, and they serve those end users on their smartphones, in remote areas, or mountainous environment that cannot be reached through fiber (Source: Ceragon Networks Ltd., White Paper: Microwave Backhaul – Capacity Matters by Tzvika Naveh, Director of Product Marketing, July 2013). The radio spectrum across a microwave link is much more efficiently used in developed LTE networks to cater for a higher radio throughput and guarantee continuous, high-quality voice and data services, along with a premium user experience. Additionally, in order to accelerate the data rates and enhance spectral efficiency, as well as to reduce the volume of the information before it is conveyed across the microwave link, mobile operators worldwide are taking advantage of many processing optimizations and technologies that can be enabled at the RTN level, such as higher-order modulation and adaptive modulation schemes, wider channel spacing, header and payload compression, as well as CCDP (Co-Channel Dual Polarization) and XPIC (Cross-Polarization Interference Cancellation).

b. LTE Backhaul Capacities

Now is the turn to expound Touch LTE Backhaul design and associated capacities, and then relate them as well to the global LTE backbone requirements and best practices. What is meant by Backhaul is the LTE EPC network that comprises the MME, S-GW and P-GW (or U-GW combined), and lastly the HSS, and that constitutes the interface to the external packet data networks, e.g. Internet. Since the RAN has been carefully explained, our emphasis will be on the interconnections within the EPC and to the ISP, that is to say Ogero. To be noted here that Ogero represents the main operator of the fixed telecommunications network in Lebanon and acts under the supervision of the Ministry of Telecommunications. Ogero embodies the backbone infrastructure for all Telecom networks in Lebanon, including Mobile Operators such as Touch, and other privately owned ISPs. At this point, we haven't explained yet the interconnectivity type between Touch EPC and Ogero ISP; but irrespective of that, it is worth mentioning that there are local ISPs such as IDM, Wise, Sodetel, etc. which can provide Touch with the internet capacity needed for its operations. Yet obviously, the MoT wouldn't go for any local ISP while it has Ogero under its control. Ironically, this is the rational choice to make, but is it the most efficient and cost-effective approach? As it will be clarified next, the physical connections from Touch EPC to Ogero ISP have very low capacities; in which case, their count and associated rental costs are tremendously increasing month after month, because the internet bandwidth needed by Touch is increasing in parallel. Despite of this, nothing has changed until now; Ogero has still not upgraded its internet services and Touch is still not able to purchase the internet capacity it needs from any other local ISP, having definitely enhanced means of connectivity, and thus higher quality and lower costs. Are you asking yourself why it is the case? Clearly due to the politics in Lebanon, whereby the government follows this expropriation approach because it wants to have it all, without really offering any value in return. The Telco sector is being monopolized and impounded by an entity that did not prove its competences to run this industry sector until now. But how will it be able to really do its job as the Ministry of Telecommunications in Lebanon managing Ogero, the main operator of the fixed telecommunications network, as well as Touch and Alfa, the two only mobile operators, if the dogmatic corruption persists and the personal interest of the people in charge is always ahead of the community / public welfare of the country? Lebanon is among the developing nations that lack the resources to thrive and the empowerment to make decisions, which are both compulsory for them to go up the ladder. However, our country will never be able to make money if it does not cut on the slack happening within all its governmental entities, and work instead on improving its infrastructure and the quality of the services offered to its locals. In addition, our country will never be able to become the master of its decisions if its politicians do not put the community interest above all other aside connections they have. In my opinion, it is the political life in Lebanon that constantly keeps on drowning the country and concealing all possibilities of a potential reform, despite how small they might be. The smart transportation project under consideration, if properly carried out with the commitment of the stakeholders partaking in its execution, will be the first step but also a great opportunity towards the prosperous Lebanon we all dream about.

With reference to the building blocks of the ICT network layer required for our smart transport initiative, but before we start dissecting the intra-connectivity pertaining to the EPC and the inter-connectivity of the EPC periphery with Ogero ISP, one should realize that there are three types of connectivity wires currently being used at the link/physical layer to join the various network elements with each other and to provide the medium for the Ethernet link layer protocol to pass the information from one entity to another. The three main categories are the optical/fiber cables, the electrical/copper/twisted pair cables, and the coaxial cables. The comparative table hereafter portrays the differences between fiber and copper or coaxial cables (Sources: Laser Motive, Comparison of Optical Fiber to Copper Wire, January 2013 & For Your Information, Fiber Optics vs. Copper Wire or Coaxial Cable).

Table 8 – Comparison of Fiber vs. Copper or Coaxial Cables

Measure	**Fiber**	**Copper or Coaxial**
Safety	+ (non-conducting)	-
Weight	+ (thin)	-
RF Effects	+ (no RF interference)	-
Data Bandwidth	+ (over longer distances)	-
Durability – Robustness	+	+
Cost	-	+

The diagram below was drawn by hand after assimilating the entire LTE ecosystem structure and connectivity (excluding the 2G and 3G network topologies). It exemplifies Touch LTE network architecture including the connections within the LTE radio access and core networks, as well as the connections to the external packet data network, i.e. Ogero ISP. This diagram is replicated in each of the four main locations Jdeideh, Bir Hassan, Saida, and Tripoli enclosing all of Touch network topology. Touch uses all three types of physical links, in addition to the microwave wireless links at the air interface, with the fiber deployed more as we go closer to the backbone and into the core network.

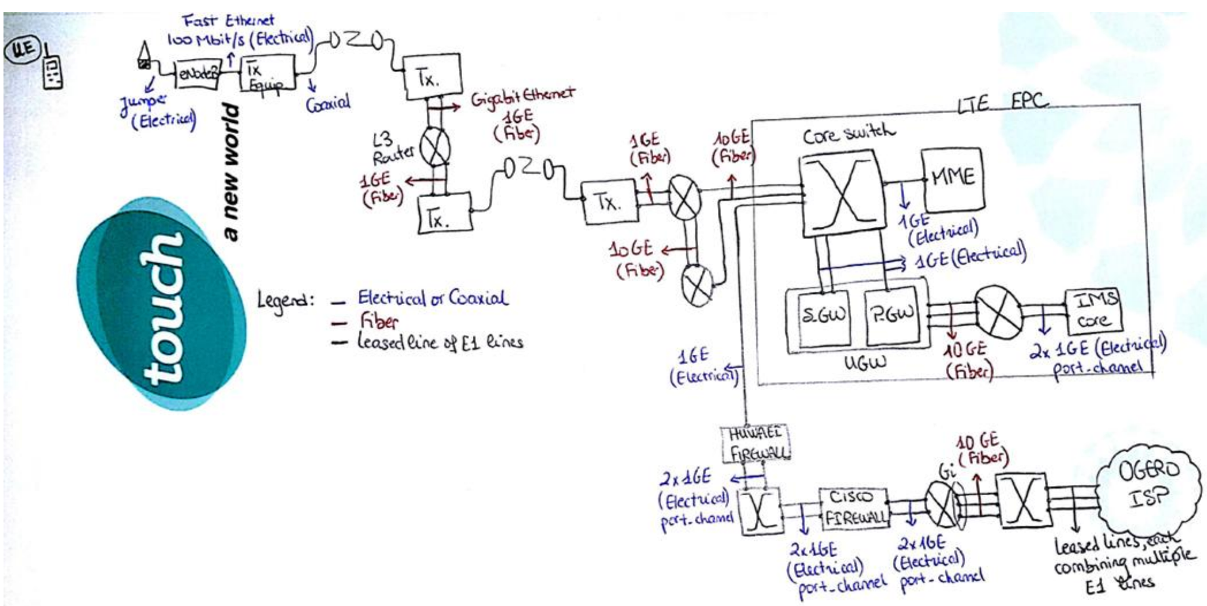

Figure 5 – Touch Network Topology

As the schematic shows, the entry wires from the Aggregation layer (where multiple sites on the access network are grouped and loaded onto a hub site interfacing with the backbone EPC network) to the core switch are made up of fiber having a bandwidth of 10 Gbit/s. Once inside, most of the links are electrical/copper cables that can support 1 Gigabit-Ethernet speed, expect for the connection between the U-GW and the core router which attaches the IMS to the EPC. The latter connection consists of an optical cable with a bandwidth of 10 Gbit/s to sustain the huge amounts of data passing through the router. To be noted that the port link aggregation technology, also known as port-channel architecture and used primarily in the backbone network, is enabled between the core router and the IMS hardware, whereby several physical Ethernet links are combined to form one logical Ethernet link so as to ensure fault-tolerance and high data rates between the subject network entities. In this case, each Ether-channel is created from two active Gigabit-Ethernet electrical ports, similarly to all port-channels molded between the network components at the interface with the external ISP. The core switch of the EPC establishes the boundary to the external packet data network, and is connected to the Huawei Firewall system (which is the first block outside the EPC on the way to the ISP) through a Gigabit-Ethernet electrical cable. The path toward Ogero ISP comprises respectively a Huawei Firewall, a switch, a Cisco Firewall, a router, and another switch. The two switches here are used for port density, whereby having more ports on the switch will give permission to have more lines supported by the switch, which ultimately will allow implementing the port-channel technology in order to deliver higher throughput at each port. Additionally, the Firewalls are programmed to convert the private IP addresses into public IPs, as well to filter the Internet traffic being fed by the ISP into Touch network. The links up to the router are Ether-channels made up of two Gigabit-Ethernet electrical links, while the router, symbolizing the Gi interface, and the second switch are connected via a 10 Gbit/s fiber link. To end, this last switch is directly related to Ogero Central Office by means of leased lines, in which case a single leased line stands for multiple E1 lines. For the month of June 2015, the total number of E1 lines lent from Ogero ISP amounted to 2,688, each with a monthly rental fee of $ 333 and a bandwidth of 2 Mbit/s. The aggregate Internet capacity Touch bought from Ogero during this month reached 5.4 GB, and it is expected to increase at an average rate of 4% per month. But if the 300-site LTE expansion occurs, Touch will require additional 9% Internet capacity every month on top of the customary 4% monthly increase. Accordingly, besides the expected 4% increase corresponding to extra cost of $ 36,830 every month, the planned expansion will require renting additional 250 E1 lines, which will incur new monthly overheads of $ 83,250. This is undoubtedly an irrational approach to acquire the supplementary Internet capacity needed, especially that the rental fees are growing excessively. Piling up E1s lines will incur very high rental charges which will keep on increasing with the upsurge in the internet capacity needed, while simultaneously delivering a very poor quality and increased complexity. The mature global LTE markets have fiber connections within their core network and between their core network and the ISPs to provide higher bandwidths and low latency at the control plane, which will translate into higher data throughputs and low latency at the user plane. In addition to the higher bandwidth on the control side and improved throughput on the user side, deploying fiber optics from the EPC to the ISP external packet data network will result in much lower costs in long run, although its installation might be a bit costly at the outset. To sum up, the aggregation layer is made up entirely of fiber connections of the order of 1 Gbit/s or 10 Gbit/s while the core network has 10 Gbit/s fiber links and other 1 Gbit/s or 2 Gbit/s port-channel electrical links, which implies that they are both designed to support high data rates. In fact, the existing backbone capacities outperform by large the capacities at the access layer and at the interface with the ISP, so any attempt now to further upgrade the connectivity at the core network will be a waste of time and money. The backbone network current capacities are not being leveraged due to the poor capacities at the access layer and the interface with the ISP. Touch has to start by improving those to complement the bandwidths produced at the backbone, before it initiates any upgrade on the backhaul network. There are several techniques and technologies to enhance the RAN capacities, as well as the connectivity to the external packet data networks. We will discuss this in details in the following section; however, generally speaking, fiber technologies remain the foremost ubiquitous solution at present, in which case fiber deployment might be expensive initially, but the savings sooner or later will become significant.

I. The ICT Network Layer Challenges, Compliant Solutions, and Future Work of Touch Network Operator

From what was unveiled above, Touch clearly is facing some challenges in its journey of growth, particularly with regard to the following:

1. *First Challenge: Radio Links*

The radio links refer to the network load capacity to cater for the increasing number of active data users simultaneously accessing the network. It was estimated that the mobile data traffic is exponentially growing since 2011 and is expected to reach 18x more in 2016 (Source: Cisco Visual Networking Index (VNI), Global Mobile Data Traffic Forecast, 2011-2016, Research & Development Team, Technical Department). Consequently, the forthcoming higher LTE penetration rates, especially if the smart transportation project gets executed, will definitely put immense strain on the operator's network and inflict that its radio links' capabilities are leveraged and/or upgraded so as to tolerate the up-and-coming user demand. To overcome this problem, Touch has four primary tools at its disposal:

- Adding Sites, starting with the proposed LTE 300-site expansion which will cost around $30M, is an effective but expensive approach to adding capacity. In general adding new real estate is time-consuming and increasingly prohibitive. With median inter-site distances, dropping from 5 km to 2 km and recently to less than 200 m in dense urban areas, the operator has less choice in selecting affordable property. Doubling the number of sites approximately doubles the network capacity and the throughput per user (assuming the user density stays constant), and greatly improves the aggregate throughput per km2.
- Adding Sectors such as changing from 3 sectors to 6 sectors per site is a useful way, but does not replace the benefits from introducing new sites. In fact, doubling the number of sectors per site does not quite double the capacity as the "petals" of a 6-sector coverage

do not interleave as well as those of a 3-sector coverage, and the fractional overlap of 6 sectors is greater. This is a common approach in dense urban areas where rooftops are available. There is about a 70 % increase in capacity in moving from 3 to 6 sectors in an environment with low angle spread (where the base station is located above the clutter).

- Adding Carriers (or more accurately Bandwidth) directly adds to capacity. The LTE standard is particularly adept at utilizing increased bandwidth without increasing control channel overheads. Currently, the LTE frequency band used is the 1,800 MHz (Band 3) with 20 MHz BW, while the 800 MHz carrier (Band 20) is turned off due to interference from Radio and TV stations and lack of supported LTE devices. It is worth to mention that the 800 MHz off air frequency is not the solution in our case because normally lower frequencies essentially contribute to coverage and are used for their higher and better signal propagation and penetration rates through buildings and walls, and not for their ability to deliver higher network capacities. For example, to cover an area with the minimum number of required sites, using the 1,800 MHz band would take two to four times as many sites as the 800 MHz band. But, even if it were more costly to deploy four times as many sites for 1,800 MHz compared with 800 MHz, the 1,800 MHz network would have four times as much capacity as the 800 MHz network. Since the greatest mobile data usage is happening areas with higher population densities, network operators would rather compromise coverage for capacity, which can be achieved using higher frequencies. In our situation, the 2,600 MHz frequency band represents a more viable option than the existing 800 MHz off air frequency. Evidently, if the LTE sites were to operate on this new frequency channel, then the antennae used have to be upgraded to have additional poles on which the newly added frequency can be enabled. In addition, the LTE sites to be deployed using the new frequency of 2,600 MHz will have to be large in number to deliver the same geographical coverage as with the 800 MHz frequency. However, this wouldn't be harmful at all since the capacity of the network will be increased by the same factor, which is at the end of the day the ultimate reason for choosing the higher frequency band out of the available. Touch, engine of the MoT, will not bear any cost if it were to implement the proposed solution, but will only require a decision from the Telecommunications Regulatory Authority (TRA), owned by the Republic of Lebanon.

- Offloading traffic through Wi-Fi is an emerging business domain with multiple companies entering to the market with proprietary solutions. If Touch were to acquire such a solution from a supplier, the cost will be roughly around $1.5M including the hardware, software, and licenses needed from Touch network side. As standardization focuses on the degree of coupling between the cellular and Wi-Fi networks, the objectives of Wi-Fi Offloading can be resumed by the following:

  - Provide better QoE (Quality of Experience) to indoor customers and indoor coverage improvement;
  - Move traffic to alternative access to deliver cost and performance improvements; and
  - Support the increasing volume of data and user demands.

With respect to the four above solutions against the increasing data traffic and user demand, and as asserted by the Research & Development and Packet Core Technical Teams, Touch is awaiting the approval of the Ministry of Telecommunications in Lebanon to launch the RFP pertaining to the 300-site LTE expansion; otherwise, the latter will be withdrawn. For the time being and to be on the safe side, Touch is working on a new business case to have a nationwide LTE-Advanced network with all the associated microwave transmission and core requirements. The expected network will be fully scalable, using the most effective capacity maximization techniques such as Carrier Aggregation and 4x4 MIMO scheme to deliver a preeminent throughput likewise the universally deployed LTE-Advanced networks, besides enabling VoLTE communications with the best quality of service. Still, the business case has to be sent to Zain Capex Planning Board for their appraisal and recommendation before requesting the MoT approval again to launch a new RFP on this subject. This is actually the internal procedure used at Touch; in which case, the business case pertaining to any new project is sent to Zain Group for evaluation and recommendation prior requesting the MoT approval. The former is an additional validation step that is done by Zain, in addition to the original analysis conducted by Touch on this subject, in order to further strengthen the arguments of the business case in front of the MoT jury. The double verification process, although cumbersome and time-consuming, has proved indeed to be effective until today, whereby the inputs of Touch and Zain together helped the company get the MoT approval on most of its projects.

As it was denoted previously, most of the Telcos around the world were publicly owned until recently, whereby privatization of Telcos increased, especially in the developed countries, due to the high profitability of this business sector. The governments in developing countries have usually critical budgetary conditions and inefficiency in resource allocation which leads to the public sector not being able to mirror the real welfare of the people. In fact, developing countries favor the public ownership of telecom operators, since this will allow them not only to regulate a major business segment in the industry, but also to impose high rates of taxation on the telecommunications goods and services (Source: Telecommunication Reforms in Developing Countries, Emmanuelle Auriol, ARQADE and IDEI, Université de Toulouse, Communications & Strategies, Special issue, November 2005). The purpose of explaining the correlation between the nature of the country and the ownership of telecom operators in that country is to further highlight the context of Touch mobile operator and help better understand the need for an extra level of approval from Zain Group prior seeking the approval of the government to which the operator belongs. Due to the tight government budget in Lebanon, likewise most of the developing countries, the MoT will rather not approve on a project unless it is unavoidable or really appealing. So by getting the consent of Zain Group and using the additional analysis it has done as well, Touch will be in a better position to defend its case and get the go-decision from the MoT. However, this time-consuming process might not necessarily be used by public Telcos in other developing nations, or in developed nations where there is no such constricted budgetary conditions; and clearly, it does not apply to telecom operators owned by the private sector.

Now moving to the second solution for the problem of having a limited LTE network load capacity, the option of adding sectors to the already existing sites is not advocated by Touch technical personnel due to its limited capacity enhancements. Furthermore, Touch has started preparing, since April 2015, new business cases to be presented also to Zain Capex Planning Board with the purpose of adding carriers (through intertwining between the 800 MHz frequency for coverage purposes given that interference is reduced and compatible devices are available, and the 2,600 MHz for its advantageous privilege in relation to capacity, while trying all at once to leverage the operational 1,800 MHz band as much as possible), and subcontracting Wi-Fi Offloading to one of the available companies working in this field in Lebanon.

2. *Second Challenge: Microwave Links*

The microwave links refer to the transmission capacity at air interface. In fact, besides the geographical coverage and network capacity inhibiting the growth of Touch, the second challenge resides in the limited QoE and customer satisfaction the mobile operator is currently able to proffer to its clients due to the capacity constraints on the microwave transmission links. The latter depicts the root cause of the problem, which is seen as hampering Touch from providing its subscribers with higher data rates and faster connectivity speeds. Not to mention that this challenge constitutes one of the major responsibilities assigned to Touch in the proposed smart transportation project, whereby the company is an active primary stakeholder in charge of delivering an integral part of the ICT requirements in the future “Smart Lebanon”. The root cause of the problem, i.e. the capacity constraints on the microwave transmission links have in turn disguised explanations that can be summarized as follows:

- The transmission infrastructure is not mature enough, especially that the fiber is not ready and will not be available in the coming two years;
- The currently used microwave frequencies cannot tolerate a wider channel spacing (56 MHz is the maximum channel spacing used on the microwave links of Touch network at present) and are also being fully utilized by Telecom and other entities including military, TV stations, etc., leaving no room to use any free channel; and
- The ODU types (SP or Standard Power ODUs) used for 48% of the MW links are outdated and cannot support wider channel spacing. Also, the IF Boards (IFU2 and IFX2) interworking with those ODUs cannot support higher-order modulation formats.

To outpace this hindrance, Touch can take advantage of the following five findings:

- Laying fiber optics that can carry higher speed signals than other types of transmission links, over longer distances and without repeaters. This is the main reason for choosing fiber over microwave links to connect the sites and for choosing fiber over coaxial and electrical cables to go up the site and connect the antenna with the network. The advantage for using fiber to connect the antenna to the network is to reduce weight and cost, because the small size and light weight permits one fiber cable to replace many coaxial cables. While the benefits from connecting the different sites with fiber are less deployment costs, less complexity, and much improved transmission capacities in comparison with the microwave links. Yet, the only challenge is that the connection medium from the antenna to the end users will always continue to be through microwave links due to the desire of mobility and the need to use smartphones and tablets to surf the web and access the various multimedia services available, except for the times when the customers are immobile, sitting in their home or office. Accordingly, the need to improve the microwave transmission capacities in the former case remains inevitable. While in the latter case, it would be definitely better to lay fiber optics directly from the ISP to the home or office location, a technique called FTTP (Fiber-to-the-Premises), for the same benefits stipulated above. Microwave transmission will remain persistently prevalent because it allows users to wirelessly connect to the network wherever they are without the need for a patch cord or any wired medium such as fiber cables. Consequently, laying fiber optic cables between the sites and up the site to the antenna is a necessity to prepare for higher data throughputs at the UE level, given that the capacity of the last microwave connection from the antenna to the end user is also enhanced. The two activities are interrelated because the capacities at air interface from the network access point (i.e. antenna) to the UE cannot be improved if all other kinds of connections, which are not so obvious to the end user yet essential, are not upgraded and kept unchanged. Sooner or later, swapping the incumbent connections between sites and up the site to the antennae will have to take place, in order to be able to reap the benefits of the enhancements planned at the level of the microwave transmission links. However, doing so requires large Capex spending, and at present, represents a lower priority for Touch considering the other more urgent requirements of expanding the LTE network coverage in Lebanon, improving the microwave transmission capacities at air interface, and then replacing the E1 lines between Touch EPC network and Ogero ISP with fiber optics.

- Swapping the old ODUs and IF Boards in the sites where capacity is needed, whereby new types of ODUs such as XMC-2, XMC-2H, and XMC-3 can support wider channel spacing (up to 112 MHz using two 56 MHz channels) and new IF Boards such as ISV3 can support higher-order modulation (up to 2,048 QAM).
- Enabling features on the MW RTN such as L2+L3 Header Compression and Payload Compression which can help compress the traffic before it is transmitted and increase the packet MW link throughput , in addition to using CCDP and XPIC features which can reduce interference and achieve maximum spectral performance.
- Using the new emerging highest frequency used for commercial telecommunication networks, the E-band, which operates at 80 GHz (71 to 76GHz and 81 to 86GHz), has a frequency band of 10 GHz and can be divided into 19 channels of 250 MHz each. Besides, by means of higher-order modulation formats, the E-band can offer from 1 Gbit/s up to 2.5 Gbit/s data rates at air interface. Given that the maximum DL peak data rate of LTE is 300 Mbit/s, and assuming that no capacity improvement methods are being adopted, the traditional microwave frequencies ranging from 6 to 42 GHz will have to assign the maximum channel spacing of 56 MHz and use 256 QAM in order to secure the same wireless transmission capacity. However, the latter can be attained by using the E-band with QPSK modulation and 250 MHz channel spacing; in which case higher-order modulation schemes will certainly lead to data rates of at least 1.2 Gbit/s without any capacity enhancement technique. Touch will have to swap the existing RTN equipment with the RTN 380 R2 E-band from Huawei.

- Enabling higher-order Multi-Antenna schemes such as 4x4 MIMO whereby the peak data rates tend to be proportional to the number of send and receive antennas, so 4x4 MIMO techniques are capable of twice the peak data rates as 2x2 MIMO systems.

Touch intends to leverage the capacity of its microwave transmission links through substituting the old SP ODUs with more of the XMC-2 and XMC-2H ODUs and acquiring new XMC-3 ODUs that can tolerate wider channel spacing above the 56 MHz being used, in addition to exchanging all IF Boards with ISV3 boards to allow for higher-order modulation schemes to be used. However, all is correlated to the Capex budget available for such new acquirements. Unfortunately, I was not able to get price estimates for the new ODUs and IF Boards because it requires addressing an official RFQ (Request for Quotation) from Touch to the supplier. Moreover, the four capacity enhancement techniques specified in point 3 of the solutions suggested will also be taken into consideration and configured on all RTNs, whereby Touch will not endure any additional cost, in case such techniques are configured and allowed on the RTN equipment of the MW links. Consequently, implementing the first three alternatives is said to increase the transmission capacity of the MW links to the order of 1 Gbit/s, as per the Radio Transmission (TX) Technical Team. However, the first recommendation to use fiber optic cables instead of coaxial and electrical cables to connect the sites between each other as well as to connect the network up to the antennae cannot be serviceable at present. Fiber optics at the transmission layer will need in fact at least two years to be available, especially since the backbone connections, having more criticality on the network performance, are not all made up of fiber yet. As to the use of the up-and-coming E-band running at 80 GHz, Touch will not reflect upon this proposition until all ODUs and IF Boards are swapped with the more developed versions, especially that it entails changing all the RTNs which obviously requires additional Capex budget as well. Not to mention that Touch plans to enable capacity reinforcing procedures on all incumbent RTNs, for this option represents a more manageable and adaptable alternative to adopt. Finally, using 4x4 MIMO techniques is also unfeasible at present due to the unavailability of LTE devices in Lebanon that are accustomed to communicate with the smarter antennae technologies through four independent data streams.

3. *Third Challenge: Links between the core backbone network and the external packet data networks*

The external packet data networks refer here to the Internet, so the third problem is related to the type of connectivity from the backbone EPC network to Ogero ISP, whereby all links are E1s lines with a mediocre 2 Mbit/s full duplex (i.e. 2 Mbit/s downstream and 2 Mbit/s upstream) capacity on each. The E1 line represents the trunk access to MoT/OGERO telephone network from which Touch is buying the Internet Service through monthly service contracts. In order to cater for the monthly demand, multiple E1 lines are grouped together to deliver the requested Internet capacity every month. Ordinarily, the type of connection technology offered by the ISP plays an important role in the decision-making process of where to get the Internet Service from. However, Touch is an engine of the Ministry of Telecommunications which infers that all conceivable opportunities to get a more advanced type of connectivity and thus a superior Internet Service quality from other local ISPs such as IDM or Terranet cannot be seized. By being the single source of Internet provision to MIC2, the MoT and Ogero have created a monopoly which will backfire at them if they don't constantly update and upgrade their infrastructure to the latest technologies. The above is actually the case in Lebanon, but might also be a major disadvantage for other developing countries where the government owns the telecom operator as well as the ISP providing the internet services to the Telco at the same time, and the project of laying fiber optics between the two ICT providers is not implemented yet. Obviously, even though such expropriation might happen in developed nations, I believe it will not be a problem to the telecom operator there since the majority of developed countries have already mature networks in place, and fiber optics are by now deployed and constitute the main type of connectivity medium between the external packet data networks and the backbone networks of the Telcos; not to mention that the internal links within the backbone, access, and aggregation layers of the telecom operator networks are also mostly made up of fiber cables.

Keep in mind that the capacities of the internal links from the sites on the access network to the core network and within the core network are not the bottleneck that is holding up the network from evolving. As a matter of fact, those connections are split between 1 Gbit/s electrical cables and 1 Gbit/s or 10 Gbit/s fiber cables, reliant on the location of the connectivity within the network, and its implication on the overall network operation and performance. This is an acceptable set-up all together since the link capacities between all the subject network elements are considerably higher than both capacities at the air interface and at the boundary with the external packet data network. Consequently, any upgrade on the inside of the network is deemed useless if the complications stalling the capacities on both end points of the network are not mitigated.

In reality, for many years now, all the consecutive Lebanese Telecom ministers have brought up launching a national fiber optic network that would let the country draw near the rest of the world through providing globally competitive internet speeds and bundles. This plan entails creating a fiber optic backbone to link MoT/Ogero Central Office to the estimated 300 regional switchboards or post offices (known informally as "centrales"), which in turn will run fiber lines to homes and offices across Lebanon. MIC2 mobile operator, considered to be like the other "centrales" of the MoT, will be also tied to Ogero Central Office through fiber optics instead of the legacy E1 lines so as to be able to offer better-quality data services to its customers. Since 2011, Telecom ministers have been promising that this project was nearly accomplished and that almost all the switchboards have been interconnected; yet, the plan has never become operational. We don't really know whether the project is still ongoing because of the long administrative approval cycles delaying its completion or due to the instability of the political situation in Lebanon that is preventing the government from commercializing the project. All we can say is that this project will positively contribute to the economic and technological reform in Lebanon and constitute a rebound for the Telecom sector which is flagging year after year. Touch precisely is not being able to generate more revenues from the usage of data services, while the voice revenues are unceasingly dropping, because the myriad opportunities in the world of Internet of Things "IoT" cannot be tapped – considering the current status of the network infrastructure. The smart transportation project under deliberation is in fact one of those IoT applications which necessitates in order to be effective that all ICT requirements stipulated above, including fiber lines to the ISP, are met.

To my knowledge, fiber optic cables have been laid from Ogero ISP to MIC2 backbone network few years ago, as affirmed by the Corporate & Internet Services IT Team; however, MIC2 is still buying the Internet Service from Ogero via E1 links because the project was put on hold for the reasons discussed previously. If those were to be swapped with fiber optics, MIC2 will be able to:

- Reduce the complexity of the connections to the ISP whereby the count of links for June 2015 reached 2,688 E1s in order to be able to hold out the 5.4 GB Internet capacity needed by Touch during this month. Bearing in mind that the number of E1 lines needed will rise due to the fact that the Internet capacity required by Touch increases with an average of 4% per month (excluding the possible expansion related to the extra 300 LTE sites and the incremental 9% Internet capacity increase every month). Assuming the 4% monthly increase persists and that fiber optics at the interconnection are deployed in July 2015 with a capacity of 20 Gbit/s, one optical cable will be sufficient to meet the Internet capacity required by Touch until February 2018, i.e. for an additional two years and 8 months;
- Decrease the monthly E1 rental fees which will also keep on increasing through aggregating additional E1s to deliver the required Internet capacity, in which case the cost of leasing E1 lines from Ogero reached around $ 895K for the month of June 2015.

Obviously, the initial cost to be paid by Touch for operationalizing the fiber optic cables installed will be higher, but in the long run, the rental fees will definitely drop and Touch will be able to significantly curb the Opex spending; and

- Enhance throughput at the backbone boundary with the ISP, which in turn will affect the data user throughput at the air interface provided that the connections within the backbone network, between the backbone and access networks, and within the access network (i.e. between the sites) are also improved to tolerate higher speeds.

Hopefully, after the Telecom minister Botrous Harb asserted on July 1st, 2015 that the fiber optic Internet services will be rolled out by 2020; Touch will be finally able to reap the expected benefits enumerated above.

4. Future Work

As a final point, Touch aims to implement additional 4G LTE technology advancements to make its network more robust and proffer an enhanced QoE and higher customer satisfaction. Although the work on these advancing technologies has started in many developed countries around the world, their commercial launch in Lebanon will not start before the first semester of 2016 pending the ecosystem maturity, that is to say the device availability and the expansion of the LTE geographical coverage. The below roadmap puts in a nutshell the major steps that Touch is set to accomplish in the near future, in addition to the upgrades documented formerly.

a. Voice over LTE (VoLTE)

The VoLTE service is based on the IMS (IP Multimedia Subsystem) network, which has specific profiles for the control and media defined by the GSMA (Global System Mobile Association). This approach will result in the voice service being delivered as data flows within the LTE data bearer. The factors affecting the choice as well as the pace of deployment of the VoLTE feature depend on the existing mobile technology (3G/2G), the LTE rollout and coverage, the availability of devices, and the operator's business objectives, i.e. whether to stick to basic voice and SMS services or offer advanced services. The VoLTE service requires applying the LTE QoS which assigns priorities for specific customers and/or services in times of network congestion. LTE QoS is being tested by Touch experts and will be supported as soon as VoLTE is activated. In fact, this will befall once the LTE coverage ceases to be spotty, in which case the CSFB technique can be withdrawn and Touch can start materializing the IMS concept in the LTE EPC network to deliver the so-called VoLTE service. The IMS will be used at first to enable VoLTE basically and in the future, to centralize the core for the CS (Circuit-Switched) and PS (Packet-Switched) networks. The network evolution path is illustrated below (Source: Research & Development Team, Technical Department):

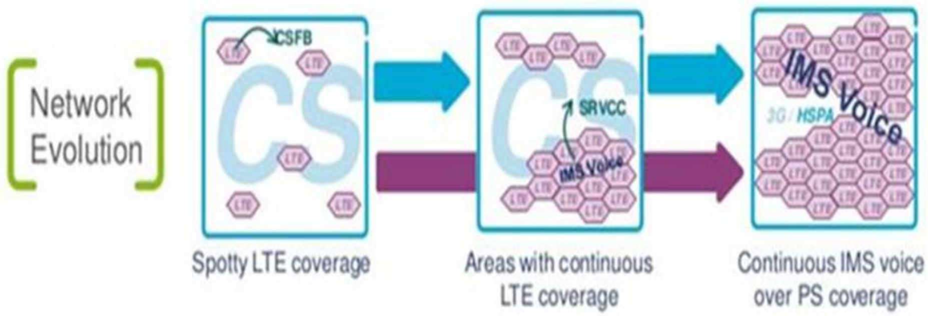

Figure 6 – Network Evolution Path

b. LTE-Advanced

The LTE Advanced is a mobile communication standard and a major enhancement of the Long Term Evolution (LTE) standard. It was formally submitted as a candidate 4G system to ITU in late 2009, and was standardized by the 3rd Generation Partnership Project (3GPP) in March 2011. A major feature of LTE-Advanced is CA (Carrier Aggregation) which was trialed in Lebanon in April 2013 with the Chinese vendor Huawei by combining 800 MHz spectrum with 1.8 GHz spectrum. Touch Lebanon was able to achieve 250 Mbit/s. Moreover, Touch is preparing a business case for having the LTE-Advanced deployed on the Lebanese territory if the 300-site LTE expansion planned to be fully operative by January 2016 is not authorized by the MoT. Unlike the tactic that was adopted for the LTE gradual rollout, the LTE-Advanced project will be all-inclusive and completed at one go because the mobile operator truly acknowledges that it is still far behind the fast-moving technological advancements realized by the global Telecom networks in the developed countries. The approach will consist of upgrading the existing 200 LTE sites and deploying additional 1,015 sites that conform to the LTE-Advanced technologies. The latter necessitates making drastic changes to the incumbent network such as improving the current radio and microwave transmission capacities (e.g. 4x4 MIMO techniques given that compatible devices are available, higher-order modulation schemes, wider channel spacing, etc.), laying fiber optic cables on the access network between the sites, and swapping the E1 lines connecting Touch backbone network to Ogero ISP with fiber links as well.

The subject business case is being conceptualized and studied by the various technical stakeholders involved and will be all set to be presented to Zain Capex Planning Board at the end of July 2015, provided that the MoT does not approve the conception of the 300 LTE sites. Clearly, this large-scale project will span all of Lebanon and will require at least $ 100M to be executed. Touch is substantially exerting all potential efforts and constantly challenging itself to provide the MoT with premeditated proposals in the attempt of catching up with the rest of the world and recuperating its brand image as one of the top mobile operators in the MENA region.

c. Redirection from 3G to 4G

This procedure will allow the UE in connected mode that initiated the streaming or download of any content from the internet on the 3G network to continue and finish the data session on the 4G network without being noticeably interrupted.

d. Self-Optimizing Network (SON)

Touch aims to introduce intra-system and inter-system SON capabilities. This includes self-configuring and self-optimizing mechanisms to dynamically improve the radio network performance and quality against the erratic processes that might happen during operation in the active network. In addition, the self-optimizing functions will reduce the cost of manually configuring and designing the network at the time of deployment. This is entitled to decrease the unit cost of a MB produced, and at long last, the selling price of the data services offered to customers.

CHAPTER VI

CONCLUSION

My role throughout this report is that of a consultant who is studying the feasibility of deploying smart cities in Lebanon, considering that Touch telecom operator has to be the leader and a major contributor in this project. The Feasibility Study Consulting Practice that I did is primarily addressed to Touch mobile operator, which will eventually take the outcomes of my analysis and present them to the MoT seeking approval to launch the project. Given that the role of Touch in this project is to essentially ensure the provision of the bulk of the ICT requirements, and considering the importance of having an advanced ICT infrastructure as a crucial requirement for the deployment of smart cities, a big part of my analysis was accorded to the ICT resourcing activity that is to be performed by Touch in this respect, bearing in mind the context of Lebanon as a developing country, where the government actually owns the mobile networks.

In consideration of the above, and in particular the developing nature of the country, the various building blocks of the smart ecosystem were in fact explained and benchmarked with global practices from the literature review section, in order to derive the following outcomes which were specifically tuned to conform with the context of Lebanon and the prevailing conditions in the country:

- The motives underpinning the project;
- The scope of the project and the stakeholders involved;

- The role, contribution, and categorization of each participating stakeholder, whereby the role of a stakeholder is to either provide the necessary empowerment for the initiative, or the resources needed for execution. And as you know by now, the activities of providing the required resources, from capitals to labor to ICT to city infrastructure, are at the heart of the value chain process, which was incorporated within the framework of stakeholders' categorization and the business model that were tailored for our project. As I have mentioned before, the ICT resourcing activity occupied a separate section of my report, and represented the major finding of my feasibility analysis for the reasons stipulated above.
- The business model to be espoused for the implementation of the change initiative in Lebanon, whereby the dynamics of the relationships among the participants were considered with respect to the context of the country to come up with the most practical, if we don't want to say optimal, stakeholder engagement model; and last of all
- The technical exploration pertaining to the ICT requirements in smart cities, and the competences of Touch mobile operator in this regard.

Briefly said, the essential motive for the conception of smart cities is to provide advanced applications and services to the community through a cutting edge and revolutionary ICT technology, thus, delivering a better way of living for the citizens by making the services available to everyone anywhere and at any time, in addition to promoting ecological sustainability and economic development. In reality, every smart city project is built upon various building blocks correlated with each other. The value chain comprises mainly the stakeholders' activities to provide the resources necessary for the execution of a smart city project, including the capitals, the human labor, the ICT infrastructure, and the inherent city infrastructure; whilst the participants and the dynamics of the relationships among them constitute the business model that primarily defines the engagement level of every contributor to the smart project.

As it was depicted in the literature review, almost all smart cities were instated in the developed countries, with only few implementations in developing countries provided that their government has enough money to undertake the project. Ordinarily, the leadership of the project can be held by the public or the private sector, which is the case actually in developed countries; whereas we noticed that smart initiatives realized in the so-called developing nations, such as Qatar, Dubai, and China for instance, were exclusively held by the government, and sometimes solely executed by the leader. In fact, the availability of funds in industrialized countries facilitates the project execution, whether the capitals are afforded by the local or national authorities or by the ICT companies involved. Moreover, the ICT infrastructure in these countries is technologically advanced, likewise the city infrastructure, and do not require large investments to become fit for smart city services and community life.

Since the provision of resources pertaining to the value chain process is generally less complex in developed nations compared with developing countries, and the pool of potential stakeholders is more extensive, the realization of smart cities is clearly easier and faster. The key success factor is to have the same motives and agree on a shared vision for the city; so whenever this is seized and understood by the prospective economic actors, their degree of contribution as well as the project scope and leadership will directly ensue.

Indeed, I have recognized during the course of reading that the real-life deployed smart cities in developed countries were implemented using a multitude of business models, where the engagement level of the stakeholders and specifically the leadership of the projects varied from one initiative to the other. Conversely, the smart city projects that were executed in some of the developing nations were all led by the government, because usually in the less developed countries, the power and the resource, if obtainable, are controlled and extended by the authorities in command.

The government leadership was also validated through the business case that I developed particularly for Lebanon, in which case the approach was to instigate a Brownfield smart transportation project that is led by the leading Lebanese mobile operator Touch working for the ministry of telecommunications. Considering that Lebanon is a developing country where the public budgetary conditions are tight, still the government involvement in any proposed change initiative remains a must, I decided to follow the Brownfield approach through transforming one industry sector at a time. As to which business segment to modernize, I based my choice on the motives of Touch behind the idea of developing smart cities in Lebanon. The transportation sector was not relevant to me at first, whereby I had to really dig into previous initiatives undertaken by Touch trying to understand whether the motivator for deploying smart cities was economic, social, or related to the eco-sustainability aspect of urban living. It turned out that the biggest campaigns Touch has initiated were about the safety on roads and spreading awareness among drivers, which validates the social motivator; whereas other initiatives, promoting the "Go Green" slogan such as selling to customers eco-friendly scratch and SIM cards, endorse the ecological motivator. Moreover, Touch has started, few years back, its entry into the high-tech world of smart digital devices and M2M connections, and into the world of selling e-services to customers; however, the financial returns and achievements made weren't that influential. If this transition into being the main ICT provider for the smart city initiative in Lebanon were to happen, Touch will be able to generate an additional significant source of revenue, confirming thus the economic motivator for leading the drive for change. In my opinion, the major driver for Touch in this initiative is to make its business more profitable and money-making, especially that the company has been waiting for this opportunity for so long. In fact, it is about time that Touch leverages and improves its ICT competences to the standards implemented in the developed wireless mobile networks around the world, as a way to ensure the sustainability of its business. By leading the change initiative in Lebanon and providing the bulk of the ICT requirements, Touch would have to at least expend around $40M to add 300 new LTE cell sites, swap the outdated ODUs, IF Boards and some of the RTN equipment, and operationalize the fiber cables from Touch backbone network to Ogero central offices. However, although the recommended approach does not implicate a shared responsibility to lessen the risk of failure, Touch should be confident that the investment gains will compare favorably to the investment costs, considering the potential sources of revenue that it might be able to generate from the data captured by smart city solutions. Touch mobile operator needs to eventually assume longer-term and more strategic business models than they are accustomed to, in which case the business model refers to the revenue generation formula or proprietary method to attract, acquire, and profit from clients.

Now before analyzing the various building blocks of smart cities, my role as a consultant, was to interpret the implied business needs of the Telco and map them to a concrete scope of work for the initiative. Accordingly, bearing in mind the motives explained above and the economic status of the country, I was able to infer that the most practical approach is to pursue a small-scale project targeting the transportation industry in Lebanon. Even though the Lebanese republic does not have the resources, nor the empowerment needed to pursue the project alone, I came to realize that the optimal way to carry out the initiative is to use the business model where the government is the prime participant in order to give governance and credibility to the change initiative, and a higher chance of it being actually implemented. Touch mobile operator, working under the supervision of the Ministry of Telecommunications, will be the project manager, but will certainly demand the contribution of other stakeholders coming from the private or public sector, as well as from the civil society. Those include the municipalities of the major cities covered by the project scope; the IT companies, namely the software developers and manufacturers of sensors; the city services companies comprising the transport and delivery firms; the Central Bank of Lebanon which is a government entity or other potential private financial institutions; NGOs such as YASA for the safety of roads; and eventually the citizens representing the end users for whom the smart initiative is started in the first place. The remaining partakers, other than the public Telco leader, will have a primary or secondary active role depending on the scope of the project, its drivers and goals, as well as the capabilities of the stakeholders to provide either the power or the money or both. Citizens, on the other hand, might be among the beneficiaries and passive defenders of the capitalist society, who no longer can depend on what used to be one of their mainstays, but will find themselves affected by and in need of the begotten smart technologies. The same applies for the private research and academic bodies, namely AUB, which might be also passive supporters of the initiative without actually promoting it to the civil society or other potential partakers. And lastly, private city services companies might be passive opponents of the initiative if they are not willing to invest their money for the sake of implementing the smart technologies.

The above combined will not ensure, however, the accomplishment of the project, but is considered to be most feasible alternative if the country really intends to make the transition to a modernized urban life where the infrastructure and the services offered to citizens are developed and advanced enough to guarantee a better quality of life. The considered project would definitely require large capitals to revamp the city and ICT infrastructures which are behind the global standards upon which the smart cities in developed countries are founded.

For that reason, I focused for the most part of my analysis on the provision of ICT that is to be conveyed by Touch. The ICT capabilities of Touch telecom operator, and particularly with regard to the ICT network layer considered the major among the four ICT layers, were assessed and benchmarked against the desired ICT capabilities of the mature network operators, and the gap analysis concerning the two requirements that fall under the ICT network layer category was used to forecast the additional competences that Touch has to acquire in order to properly contribute to the project as a leader and main provider of ICT. In line with the results of my technical analysis on the status of Touch ICT network capabilities, the company will need to primarily address the following inconsistencies if it were to provide a robust ICT infrastructure, considered to be a binding and unavoidable requirement in the deployment of smart cities.

- The LTE coverage, which spans only 2% of the Lebanese territory, needs to be expanded to cover at least the cities defined within the scope of our smart transportation project. Moreover, the corresponding network load capacity, which is about 19% of the total data users who can connect to the LTE network concurrently, needs also to be increased to at least 50%. This will ensure higher LTE penetration rates, considering that LTE compatible devices are available in the Lebanese market at fairly affordable prices. The LTE expansion consisting of 300 additional LTE sites was assessed from both technical and financial perspectives, and turned out to be capable of improving the load capacity to around 48% of total potential data customers, as well as the LTE network coverage, provided that these additional sites will be mounted in the crowded cities set forth in our project. As to the financial viability of this expansion, it is deemed to be profitable with a positive NPV and IRR of 23.4%.
- The current LTE data throughputs at air interface are reasonably acceptable, benchmarked with the average data speeds that can be reached in the advanced and developed networks. However, for the sake of our smart transport initiative, these data rates need to be further enhanced so as to provide a better user experience for the citizens using the new services and technologies, as soon as they become available in the to-be-deployed Lebanese smart cities. In view of that, it is required that Touch works on improving the capacities of the microwave transmission links through swapping some of the legacy equipment or using the newly commercialized highest frequency band, which will in turn,

tolerate the implementation of new configuration rules and advanced technologies such as higher-order modulation and wider channel spacing to boost the performance of the links. This is in addition to the possibility of substituting the incumbent coaxial cables used to go up the site to the antennae, and the microwave links used to enable the connectivity between sites with fiber optics. However, the latter will not be considered a priority until the previous improvements are successfully executed.

- The connections from Touch EPC (core) network to Ogero ISP, which are currently through E1 lines having a very low bandwidth of 2 Mbit/s each, need to be urgently swapped with fiber links. According to the MoT, the project of deploying fiber cables on the Lebanese territory was initiated years back; still, we haven't seen any outcome yet nor heard any news about the estimated date of completion. This point specifically will be given top priority while discussing with the MoT the ICT network related requirements of the smart transportation project that is to be led by Touch. As I have mentioned previously, the MoT is monopolizing the internet provision that is deemed inevitable for the operations of Touch mobile operator. And if Touch were to embark on the change initiative under consideration, Ogero, i.e. the MoT, will definitely have to find a solution for this problem by providing a connectivity medium to the backbone network of Touch that is up to the standards sought after in smart cities.

- And lastly, the connectivity from the access network to the backbone network of Touch, as well as the connectivity within the backbone network, which are at present a mixture of electrical and fiber links having considerably a high bandwidth, need to be made up entirely of fiber cables to ensure improved capacities at long distances. However, this is not considered a major requirement at the time being, whereby the upgrading of the formerly identified discrepancies is accorded the highest priority for the successful implementation of the smart transportation project in hand.

In addition to the gap analysis that I have done with respect to the ICT network layer requirements, the other three fundamental building blocks of the ICT infrastructure, namely the sensory, analytics, and applications layers, were also analyzed and leveled out with the prevailing know-hows of Touch telecom operator, and the resulting dissimilarities were highlighted throughout my report. In fact, the smart transportation project envisioned required from me to conduct this exhaustive technical analysis, particularly since having an advanced ICT infrastructure in place is the utmost requirement to deploy sustainable smart cities. Not to mention that my major role here is to offer consultancy advice to the founder of this project, Touch telecom operator, on how to remain viable in the long-term, as well as achieve and meet the goals of the project that it intends to carry out. The main purpose from this technical analysis is to understand the vital and intangible ICT requirements and be able to translate them accordingly into palpable business needs that will eventually help better assess the global requirements vis-à-vis the successful deployment of smart cities.

The former derivatives I have deduced, except for those pertaining to the provision of the necessary ICT infrastructure, are directly addressing the business side of the project. Whereas the detailed technical assessment and the subsequent findings, challenges, solutions, and justifications require more efforts from me as a consultant so as to convert them into the common business language which is understood by all end users and potential investors in similar projects, irrespective of their area of expertise. If I say that the transmission capacities of the microwave links on the LTE RAN side are limited and need to be improved; only few will understand this statement. But if I say that the user is experiencing very slow connection while he is using the internet in a LTE area, and the connection speed needs to be improved; then the majority if not all of us will understand this statement. The correlation between the two statements, i.e. translating the technical finding into a market requirement is what I have tried to do, as a consultant for this project, all over the in-depth technical analysis I have conducted.

The comprehensive feasibility analysis done evaluates the economic, environmental, technical, and quality of life aspects of the proposed business idea, which will ultimately let Touch and the MoT decision-maker to have the accurate and relevant information needed to make knowledgeable choices. As a summary of the lessons learned from running this consultancy job for my client, Touch mobile operator, I recognized that before one dives head long into the shoes of a consultant, he/she should know that this job calls for a lot of patience and perseverance, whereby a consultant has to explore a lot of alternatives before he/she chooses to focus on the issues that could influence the success of the project he/she is assessing. The process includes dealing with a lot of people coming from different backgrounds, collecting a large amount of data, pertinently analyzing the data considering the time given to perform this task, narrowing down the data to concentrate on the most relevant info gathered, identifying loopholes, and coming up with plausible and practical solutions and recommendations to make the project a success. The business analyst needs to understand very well all the aspects of the business idea under liberation; in which case many of them might be out of the scope of his/her expertise, in order to be able to evaluate their ability to meet the set objectives, describe a recommended solution if needed, and offer a justification for this selection. This is in addition to the fact that the areas the consultant engages him/herself in, and the recommendations he/she offers, might not always be the right decisions that he/she should have made. In my case, irrespective of my success or failure in assessing the project under deliberation from all its angles, I have to admit that I have learned a lot on the technical, business-related, as well as personal sides; all of which will hopefully support me in my next career bound to the world of consultancy.

On a final note, I would like to direct my plea, and not my recommendation, to all the Lebanese politicians to gather the powers given off by their political parties for the sake of a more contended civic life in Lebanon. This will guarantee sufficient empowerment and enablement from the government to pursue the change initiative, as well as generate harmony among the different stakeholders to form and fulfill all the claimed requirements. In view of that, what really matters is not the selection of the stakeholders involved in this project, but their interactions with each other and the segregation of duties between them in a way that every participant knows its rights and obligations towards the project planning and execution; all of which ultimately contributes to the completion of the smart city value chain process. The engagement model was specifically premeditated for the deployment of a small-scale smart project in Lebanon under the leadership of the public telecommunications company Touch, whereby the manner in which the role and contribution of the stakeholders partaking in this project were explained, illustrates the case in point of an developing country where the government lacks the resources and the authority needed to carry out such an initiative on its own, while its primary contribution and leadership are compulsory likewise all developing countries. The business model that was proposed to be embraced by the leader of the smart transport initiative in Lebanon gives an idea about how sustainable smart initiatives are supposed to be handled in general in the emerging nations. However, can this explanatory pattern constitute the pillar upon which the selection of stakeholders, their extent of contribution to the project, and the dynamics of their relationships are shaped? And accordingly, can it be considered the basis for every smart city that is intended to be put up in any of the developing countries?

APPENDIX I

FIRST DATA SET

These are sample questions I have asked to Mr. Hussein Helmi Jalloul from the Research & Development Team in the technical department. I will not be able to add all the questions since I have sat with him for more than ten times and some information were gathered through emails, or phone calls.

1. What are some of the challenges of Touch Lebanon LTE networks, and what might be some of the future work in mind?

   - Touch has started deploying LTE on 800 MHz as it provides the best indoor penetration; however, 800 MHz DL & UL speeds are highly deteriorated due to multiple sources of interferences (Radio & TV stations), and there is also a lack of LTE devices that work on 800 MHz band.
   - Radio Frequency planning will have to be reviewed since the coverage of 1800 MHz is different from 800 MHz in order to avoid any coverage gaps.
   - Existing antennae do not support the LTE bands, and have to be upgraded.
   - Available power systems are not sufficient to cater for 2G, 3G & 4G, so an upgrade to the battery system should be implemented.

2. What is the current status of the LTE networks in Lebanon in relation to the network map, DL& UL on peak and average rates…?

- Number of sites on air: 200 LTE sites whereby 100 LTE sites are provided by ZTE and covers Bir Hassan area, Beirut suburban region, and another 100 LTE sites provided by Huawei covering Beirut and the north cost. Mainly we can draw a horizontal line on the map with corner point of Ras Beirut as the starting point, all sites below this line (i.e. to the south of this line) correspond to ZTE area, all sites above or to the north of this point correspond to Huawei area.
- Currently the LTE sites are operating on 1800 MHz or band 3 with 20 MHz spectrum
    - UL used frequency: 1765 to 1785
    - DL used frequency: 1860 to 1880
- Theoretical speeds:
    - DL: Max or peak speed per sector is 150 Mbit/s. (3 sectors in one cell on avg.)
    - UL: Max or peak speed per sector is 75 Mbit/s.
- Practical Average speeds:
    - DL: 25 ↔ 35 Mbit/s
    - UL: 5 ↔ 10 Mbit/s
- LTE uses 2x2 MIMO (Multiple Input Multiple Output) Antenna.

3. Can you explain the different terms and nominations used to describe the network elements of the LTE Radio and Core networks?

- The LTE Radio is named eUTRAN (evolved UMTS Terrestrial Radio Access Network).
- The LTE EPC (evolved packet core) is provided by Huawei. The EPC comprises the MME which the Mobility Management Entity similar to SGSN in 3G, the S-GW (Serving Gateway) and P-GW (Packet Gateway) are on a Box called U-GW as per Huawei equipment and is similar to the GGS in 3G. The HSS similar to HLR in 3G is provided by Nokia.

4. Please state the problems related to the fact that channels/frequencies are being fully used and what solutions are proposed for this matter?

- First Problem: Radio links / Air interface capacity problem: To start with Radio links that are approaching theoretical limits while data is growing exponentially, you need to check the "Mobile Traffic Explosion" presentation which provides figures on how much traffic is increasing, as well as to check the "Technology Roadmap 3" presentation which explains clearly the problem and provide solutions for which some are valid, and some others not applicable (these two presentations and others are available upon request). The solution for the first problem is to:
    - Go for LTE, and add more sites
    - Offload traffic through Wi-Fi

- Use higher order MIMO is effective; however, it needs huge Capex as antennae need to be swapped and new RRUs need to be bought. Moreover there is a lack of devices supporting 4x4 MIMO.

- Second Problem: Microwave links
    - Transmission infrastructure is not mature (fiber is not ready)
    - MW frequencies are being fully utilized by telecom and other entities (military, TV), there is no room to use free channel.
    - For some sites, ODU type used is old (Standard Power ODU from Huawei) and cannot support wider channel spacing, and it requires Capex to be able to swap them.

The table below was sent to me in a separate email:

Item	***Description***		
	High Power ODU RTN XMC ODUs	***High Power ODU RTN 600 ODUs***	***Standard Power ODU RTN 600 ODUs***
ODU Type	XMC-2	HP, HPA	SP, SPA
Frequency Band	6/7/8/10/10.5/11/13/15/18/23/26/28/32/38/42 GHz	6/7/8/10/10.5/11/13/15/18/23/26/28/32/38 GHz (HP ODU) 6/7/8/11/13/15/18/23 GHz (HPA ODU)	7/8/11/13/15/18/23/26/38 GHz (SP ODU) 6/7/8/11/13/15/18/23 GHz (SPA ODU)
Highest Order Modulation	2048QAM (13/15/18/23/38 GHz, 7/8 GHz XMC-2E) 1024QAM (6/10/10.5/11/26/28/32/42GHz) 256QAM (7/8 GHz Normal)	256QAM	256QAM
Channel Spacing	3.5/7/14/28/40/50/56 MHz	7/14/28/40/56 MHz (6/7/8/10/11/13/15/18/23/26/28/32/38	3.5/7/14/28 MHz

	NOTE The 10.5 GHz frequency band does not support 40/50/56 MHz channel spacing.	GHz) 7/14/28 MHz (10.5 GHz)	

Table 9 – ODU Types and Related Parameters

The solution for the second problem is as follows:

- Layering fiber which provides very high capacity
- Swap the old ODU in the sites where capacity is needed. New ODU such as XMC-3 supports Higher Order Modulation (up to 4096 QAM) and wider channel spacing (112 MHz channel spacing).
- Use features on MW RTN in order to compress traffic (L2+L3 Header compression + payload compression)
- Use CCDP (co channel dual polarization) and XPIC feature in order to reduce interference form dual polarization transmission
- Use new emerging high frequency bands: E-band (operating at 80-90 GHz), whereby we can buy new product from Huawei RTN 380 R2 E-band for that purpose.

5. What are the maximum capacities of the current MW links used at Touch?

   R: Below figures are the maximum capacities over a single MW link. With the help of N+1, LAG, PLA, header compression and payload compression, larger air interface capacities are supported between Microwave sites:

IF board	Microwave link	Maximum Air Interface Capacity		
		TDM services	Ethernet Throughput at Air Interfaces (Mbit/s)[a]	XPIC Configuration
IFU2	Integrated IP radio	75xE1	360 to 420	Not supported
IFX2	Integrated IP radio	75xE1	360 to 410	Supported
ISU2	Integrated IP radio	75xE1 or 1xSTM-1	360 to 456	Not supported
ISX2	Integrated IP radio	75xE1 or 1xSTM-1	360 to 456	Supported
ISV3	Integrated IP radio	75xE1 or 1xSTM-1	504 to 636 (none-XPIC) 450 to 575 (XPIC)	Supported
ISM6	Integrated IP radio	75xE1 or 1xSTM-1	504 to 636 (none-XPIC) 450 to 575 (XPIC, IS3 mode)	Supported

Table 10 – IF Board Types and Related Parameters

6. How do you plan for the transmission capacity over a single MW link?

   R: When we want to plan the transmission capacity needed to cater for such air interface capacity, we use the peak of one sector since the three sectors cannot peak at the same time. Therefore we shall plan for 150 Mbit/s for LTE only without 3G or 2G. The 150 Mbit/s is not available now. Touch is working on the MW level in order to upgrade the link capacity assuming that fiber will not be ready in the coming 2 years.

APPENDIX II

SECOND DATA SET

Here is an email that I have exchanged with Mr. Houssam Mansour from the Service Quality Technical Department to get the number of data customers at the end of June 2015 (the below includes both postpaid and prepaid customers):

1. Total number of voice and data subscribers: Voice = 2241k and Data = 1383k
2. Total number of data subscribers (attached to the network and detached) = 1383k
3. Total number of LTE subscribers = 18k LTE maximum attached subscribers
4. Is 30% of 4G population out of the total number of subscribers or out of the total number of data subscribers? R: Out of Total population, i.e. total number of subscribers.

APPENDIX III

THIRD DATA SET

Here is a sample of another interview with Mr. Elie Moukhaiber from the Radio Network Planning & Optimization Technical Department to clarify some of the information that I failed to fully grasp during my interviews with people from the Research & Development Team in the technical department:

1. For the Huawei MW links' capacities, I saw that it differs with every type of ODU. For example, for those using SP ODU, the throughput at air interface is on average 180 Mbit/s. Is this per sector or per cell site? When we say that the LTE sector peak data rate is 150 Mbit/s so it is 450 for a cell with 3 sectors; but how is this related to the MW link? I.e. do we have a link for every sector or for the whole cell site? If the latter is the case then the 180 for this link will be divided among the 3 sectors assuming the 3 of them have active users?

   R: It is true that the MW links capacities are restricted by the ODU type capabilities. Also correct, Huawei MW links for those using SP ODU have a maximum air interface throughput of 180 Mbit/s. This is not related to cell or sector. We have a link for the whole 3 sectors of the cell because from the eNodeB you have a single connection to the transmission equipment; therefore all 3 sectors use the same MW link. I am referring here to a transmission link, in this case it is a point to point link (MW) between two sites (i.e. in site A, I have a MW equipment and in site B (facing site A) I have a MW equipment, and there is a Line of Sight between them and the capacity of the air interface on this link is dependent on the ODU type, frequency used and channel spacing or BW. When we say that the LTE sector peak data rare is 150 Mbit/s we refer to one sector of the cell whereby the cell has 3 sectors and the total throughput of the cell is 3x150 = 450 Mbit/s. This is not related to the MW link however, this affect the planning of the MW link. That is if you have a MW link of 50 Mbit/s you cannot have an LTE site with 450 Mbit/s. So in brief the radio air interface depicts or puts rules for the design and planning of the MW links.

Usually the planning goes as follows for a site that has 3 active modes GSM, UMTS, LTE. We take the peak of one sector of each technology (i.e. 150 Mbit/s for LTE, 21 Mbit/s for 3G and 2 Mbit/s for 2G) ~ 175 Mbit/s. This figure is needed for the access for each site. Then when you consider a hub MW site then you need to add the capacity of each of the converged link. This is in fact the worst case scenario which is not usually used, since in this case we are assuming that those converged sites (all of them) are peaking at the same time, all the time which is never the case. Another approach is to use a statistical multiplexing approach; there is a formula to be used which I can provide you with later on. This approach is more realistic.

2. Please give me the type of MW links along with their full capacity and average data rate at air interface. I may have this info but it is scattered and I am not able to compare between types of links because the links were specified using different

criteria in every case. And please specify if this link refers to one cell or covers one site.

- Below are the ODU type used in Touch:
  - Links using SP ODUs
  - Links using HP ODUs
  - Links using XMC-2 ODUs
  - Links using XMC-2H ODUs
- 56 MHz and below BW is used as a channel spacing. We have lots of links running with 28 MHz channel spacing.
- Fixed Modulation is used which varies from QPSK up to 512 QAM depending on link design.
- Below are the IF Boards and related modulation schemas:
  - IFU2 Board/IFX2:

    Channel spacing + HOM → Native Ethernet Throughput (untagged)

    @28 MHz + 128 QAM → 160 ↔ 180 Mbit/s

    @56 MHz + 128 QAM → 310 ↔ 360 Mbit/s

    @28 MHz + 256 QAM → 180 ↔ 210 Mbit/s

    @56 MHz + 256 QAM → 360 ↔ 420 Mbit/s
  - ISV3 Board:

    Channel spacing + HOM → without compression, with L2 + L3 compression

    @28 MHz + 1024 QAM → 217 ↔ 275 Mbit/s; 222 ↔ 520 Mbit/s

@28 MHz + 2048 QAM → 245 ↔ 306 Mbit/s; 250 ↔ 585 Mbit/s

@56 MHz + 1024 QAM → 447 ↔ 567 Mbit/s; 456 ↔ 1000 Mbit/s

@56 MHz + 2048 QAM → 504 ↔ 636 Mbit/s; 512 ↔ 1000 Mbit/s

3. As to the improvements on the MW links, can you briefly update me on that? It was mentioned to me that since fiber will not be available in the coming 2 years we are leveraging the capacity of our links. How is this being done? Is it related to this XPIC thing? Do we have XPIC now? XPIC refers to the antenna type like 2x2 MIMO or is it something else? What is its added value? And how much more capacity we will have after upgrades on the links?

   R: We are leveraging the capacity of our links indeed. First option is to swap the old ODUs (SP and HP) that cannot cater for high capacity and get the new ODU (XMC-3). Second option is to use wider channel spacing 56 MHz and 112 MHz. Third option is to use higher order modulation (this require new IF boards (ISV3), such as 2048 QAM and 4096 QAM. Fourth option is to use new features on the RTN level such as header and payload compression to compress the traffic. Fifth option is to use CCDP + XPIC that can double the capacity (CCDP stands for Co-Channel Dual Polarization and XPIC stands for Cross Polarization Interference Cancellation).

4. What is Quality of Service (QoS) in LTE? Is it implemented at Touch?

   R: There are premium subscribers who always want to have better user experience on their 4G LTE device. These users are willing to pay more for high bandwidth and better network access on their devices. Not only the subscribers but some services itself need better priority handling in the network (e.g. VoIP call). To be able to fulfill this, QoS plays the key role. QOS defines priorities for certain customers / services during the time of high congestion in the network. We don't have QoS now, but it is being tested.

BIBLIOGRAPHY

5G: A Technology Vision, Huawei Technologies Co., Ltd., 2013. Retrieved from http://www.huawei.com/5gwhitepaper/

AVIAT NETWORKS: Official Wireless Transmission Blog, “8 Questions You Need Answered about Higher-Order QAM Usage” posted on February 22nd, 2013. Retrieved from http://blog.aviatnetworks.com/2013/02/22/8-questions-you-need-answered-about-higher order-qam-usage/

Ceragon Networks Ltd., White Paper: Microwave Backhaul – Capacity Matters by Tzvika Naveh, Director of Product Marketing, July 2013. Retrieved from https://www.ceragon.com/images/Reasource_Center/White_Papers/Ceragon_White_Paper Microwave_Backhaul_Capacity_Matters.pdf

Cisco Visual Networking Index (VNI), Global Mobile Data Traffic Forecast, 2011-2016, Research & Development Team, Technical Department, Touch

Crafting Smart Cities in the Gulf Region: a Comparison of Masdar and Lusail, by Evren Tok, Fatemah Al Mohammad, and Maha El Merekhi, June 2014. Retrieved from http://www.google.com.lb/url?url=http://eujournal.org/index.php/esj/article/download/3702/3555&rct=j&frm=1&q=&esrc=s&sa=U&ved=0CBkQFjABahUKEwjStLXuy9PHAhWBnnIKHQYcCq4&usg=AFQjCNHhNbEP3BumW0Y19op_ipKr1vW0tw

Deep dive: What is LTE? by Neal Gompa, an online article published in ExtremeTech Newsletter on April 1st, 2015. Retrieved from http://www.extremetech.com/mobile/110711-what-is-lte/3

Developing Countries’ List. Retrieved from http://www.isi-web.org/component/content/article/5-root/root/81-developing

EPC Overview, Huawei Technologies Co., Ltd. 2012

Enabling Smart Cities with Mobile Broadband, Sponsored by Huawei, October 2014, IDC #CEMA21562. Retrieved from http://www.google.com.lb/url?url=http://enterprise.huawei.com/ilink/enenterprise/download/HW_373080&rct=j&frm=1&q=&esrc=s&sa=U&ved=0CBkQFjABahUKEwiLvNeT99PHAhVEbj4KHTfcD0o&usg=AFQjCNFXG99mQ-C7ptHeDGwuLJG-64Rc3w

For Your Information, Fiber Optics vs. Copper Wire or Coaxial Cable. Retrieved from http://htcplus.net/fyi/fyi-fibervscoax.pdf

Getting Smart about Smart Cities – Recommendations for Smart City Stakeholders, Alcatel-Lucent, May 2012. Retrieved from http://www2.alcatel-lucent.com/knowledge-center/admin/mci-files-1a2c3f/ma/Smart_Cities_Market_opportunity_MarketAnalysis.pdf

Getting Smart about Smart Cities, Understanding the Market Opportunity in the Cities of Tomorrow, Alcatel-Lucent, February 2012. Retrieved from http://www.tmcnet.com/tmc/whitepapers/documents/whitepapers/2013/6765-getting-smart-smart-cities-executive-summary.pdf

Global Innovators: International Case Studies on Smart Cities, Arup, October 2013. Retrieved from https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/249397/bis-13-1216-global-innovators-international-smart-cities.pdf

GreenTechMedia (GTM online). Retrieved from http://www.greentechmedia.com/articles/read/who-are-the-top-ten-vendors-in-smart-grid

Guide to Smart Cities, The Opportunity for Mobile Operators, GSMA, February 2013. Retrieved from http://www.gsma.com/connectedliving/wp-content/uploads/2013/02/cl_sc_guide_wp_02_131.pdf

Hyperspectral Remote Sensing Technology and Applications in China, Qingxi TONG, Bing ZHANG, & Lanfen ZHENG, The Institute of Remote Sensing Applications, Chinese Academy of Sciences. Retrieved from http://earth.esa.int/workshops/chris_proba_04/papers/39_tong.pdf

ICT infrastructure as key enabler of Smart Cities, Alcatel-Lucent, May 2012. Retrieved from http://www.greentouch.org/uploads/documents/VanLandegem%20ICT%20Smart%20Cities%20FIA%20May2012.pdf

Information Marketplaces – The New Economics of Cities, the Climate Group, Arup, Accenture, and Horizon, 2011. Retrieved from http://www.google.com.lb/url?url=http://www.arup.com/~/media/Files/PDF/Publications/Research_and_whitepapers/information_marketplaces_29_11_11_v1.ashx&rct=j&frm=1&q=&esrc=s&sa=U&ved=0CBMQFjAAahUKEwi9sImv6IDHAhWCWxQKHXJbAi8&usg=AFQjCNHD0UCVCJNzS03e_GDhhwaBC1JXBg

Internet of Things for Smart Cities, by Andrea Zanella, Nicola Bui, Angelo Castellani, Lorenzo Vangelista, and Michele Zorzi, IEEE Internet of Things Journal, Vol. 1, No. 1, February 2014. Retrieved from http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=6740844

Large-Scale Mobile Sensing Enabled Internet-of-Things Test Bed for Smart City Services, a research article published in the International Journal of Distributed Sensor Networks, Hindawi Publishing Corporations, Volume 15, 2015. Retrieved from http://www.hindawi.com/journals/ijdsn/2015/785061/

LA to Become the First City with Smart Street Lighting, an online article published in Business Wire on April 9th, 2015. Retrieved from http://bwsmartcities.com/la-to-become-the-first-city-with-smart-street-lighting.html

Laser Motive, Comparison of Optical Fiber to Copper Wire, January 2013. Retrieved from http://lasermotive.com/wp-content/uploads/2012/12/Fiber_vs_Copper_summary2013Jan.pdf

LTE System Overview, Huawei Technologies Co., Ltd. 2010

Lebanon Economic Report, 2nd Quarter 2015, Bank Audi S.A.L., Group Research Department. Retrieved from http://www.bankaudigroup.com/GroupWebsite/openAudiFile.aspx?id=2715

Mobile Traffic Explosion, Presentation done by Research & Development Team, Technical Department, Touch

New Smart Cities, a Focus on Some Ongoing Projects, Cristina C. Amitrano, Annunziata Alfano, and Francesco Bifulco, Conference of Informatics and Management Sciences, March 24 – 28, 2014. Retrieved from http://www.google.com.lb/url?sa=t&rct=j&q=&esrc=s&frm=1&source=web&cd=1&cad=rja&uact=8&ved=0CCEQFjAAahUKEwiB5ZnzjIDHAhXln3IKHVaC6g&url=http%3A%2F%2Fictic.sk%2Farchive%2F%3Fvid%3D1%26aid%3D3%26kid%3D50301-62%26q%3Df1&ei=v6a4VcGJOuW_ygPftK7ACg&usg=AFQjCNETrBjs_Xj7x7CzmyBl2BDW9hRcow

Radio-Electronics.com, Resources and Analysis for Electronics Engineers, RF Topics, "What is QAM – All the Essentials", by Ian Poole. Retrieved from http://www.radio-electronics.com/info/rf-technology-design/quadrature-amplitude-modulation-qam/what-is-qam-tutorial.php

Setting the Stage for Stakeholders' Engagement in Smart Sustainable Cities, Telecommunication Standardization Sector of the International Telecommunication Union (ITU-T), March 2015. Retrieved from http://www.google.com.lb/url?url=http://www.itu.int/en/ITU-T/focusgroups/ssc/Documents/Finalized_Deliverables/fg-ssc-0113-r9-SSC-stakeholders.docx&rct=j&frm=1&q=&esrc=s&sa=U&ved=0CBMQFjAAahUKEwie1f6uhNTHAhWWjpIKHSKXAIc&usg=AFQjCNED40F7M-LcwpkwyaCvbRU4NG87XQ

Smart Cities in Southeast Asia – The Opportunities for Telcos, PWC, 2015. Retrieved from http://www.pwc.com/ph/en/consulting/assets/smart-cities-in-southeast-asia-report.pdf

Smart Cities in Southeast Asia: The opportunity for Telcos, PwC Consulting Services, 2015. Retrieved from http://www.pwc.com/my/en/publications/smart-cities-in-sea-2015.jhtml

Smart Sustainable Cities: An Analysis of Definitions, ITU-T Focus Group on Smart Sustainable Cities, November 2014. Retrieved from http://www.google.com.lb/url?url=http://www.itu.int/en/ITU-T/focusgroups/ssc/Documents/Approved_Deliverables/TR-Definitions.docx&rct=j&frm=1&q=&esrc=s&sa=U&ved=0CCsQFjAEahUKEwjwy7Xk-dPHAhUCDj4KHfg2ALY&usg=AFQjCNFSc_gNlakp0pnYZJEEFCiyPRy57w

Stanford University Website. Retrieved from https://itservices.stanford.edu/services

Streetline, Connecting the Real World, The Smart City Just Got Smarter. Retrieved from http://www.streetline.com/smart-city-solutions/

Technology Roadmap 3, Presentation done by Research & Development Team, Technical Department, Touch

Telecommunication Reforms in Developing Countries, Emmanuelle Auriol, ARQADE and IDEI, Université de Toulouse, Communications & Strategies, Special issue, November 2005. Retrieved from http://idei.fr/sites/default/files/medias/doc/by/auriol/telecom.pdf

The Urban and Regional Innovation Research Unit. Retrieved from http://www.urenio.org/

Visionary Innovation Leadership Award, Best-in-Class Smart City Integrator, Frost & Sullivan's Global Research Platform, 2014. Retrieved from http://www.ibm.com/smarterplanet/global/files/us__en_us__cities__FS_IBM_Award_Report.pdf

WETFEET, Industry Overview: Telecommunications, posted by the editors on December 3rd, 2012. Retrieved from http://www.wetfeet.com/articles/industry-overview-telecommunications

Wikipedia, the free encyclopedia: Business Intelligence. Retrieved from https://en.wikipedia.org/?title=Business_intelligence

Wikipedia Website. Retrieved from
www.wikipedia.org