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Foreword

In now 35 years of existence after its foundation in 1983, the Master´s Program Infrastructure Planning (MIP) has qualified more than 500 alumni who are now helping in various ways in more than 89 developing and emerging countries all over the world. There have been successes, setbacks and challenges but through it all a formidable force of intellectuals and professionals had been brought up from this interdisciplinary program. One big success factor is without doubt the multicultural background of the alumni and the present students.

In the past, there have been alumni meetings as singular events on the 10th and 20th anniversary of the MIP study program. However, the idea behind the "MIPALCON" (MIP AL*umni* CON*ference*) is to establish a regular sequence of alumni conferences every four years in order to foster the exchange of knowledge and experience between the members of the MIP network.

MIPALCON 2010 and 2014 each brought together ideas, challenges and best practices from various professionals who have already gone through the MIP studies. In September 2018, during the third conference of this series, fortunately again supported by the DAAD and selected by review of the Scientific Advisory Committee, 15 alumni presented their current work related to the topic "Resilient and Smart Cities", discussing their ideas with current MIP students, lecturers and experts from the field of infrastructure planning. This publication contains their contributions presented at the conference.

On behalf of the Master's Program Infrastructure Planning and the University of Stuttgart, I hope you will find the MIPALCON 2018 proceedings both informative and inspiring.

Prof. Dr.-Ing. Markus Friedrich
Master's Program Infrastructure Planning
University of Stuttgart

Session 1

Methodological Aspects of Resilience and Smart Cities

Using Openly Available Data to Analyze Urban Systems and Support Municipal Decision Making

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After graduating from MIP, he worked as a graduate teaching and research assistant at Virginia Tech and completed a second Master degree civil engineering. He is currently a graduate assistant at the University of British Columbia and working on his Ph.D.. He feels that the MIP program is unique due to the breadth and depth of topics covered. Taking multidisciplinary courses has helped him gain a broad understanding in a wide range of topics in the area of infrastructure planning. Apart from gaining a holistic view, this was crucial in identifying his area of interest to pursue for his Ph.D. studies.

Abstract: Since urban infrastructure planning and management involves complex decision-making processes, reliable data is essential for analysis to support authorities in adopting effective policies. However, data availability presents a big challenge in the municipal decision-making process. Reliable data is even more scarce in developing countries where there is a lack of resource to collect and compile data. Therefore, available open data sources can be used to support planners and researchers making an initial analysis. Open data is freely available to everyone to use, analyse and republish without restrictions. Technological advancements and the increasing availability of fast and universal internet has made it less expensive and instant to obtain such data. This data can come from any source with different formats and it can cover a wide range of topics and geographic locations. This paper shows how open data is used to investigate the impact of urbanization on pluvial flooding in the City of Toronto, Canada. The methodology and procedures can easily be implemented in developing countries. The study shows that freely available data can be used to drive valuable information and provide preliminary direction for policy makers.

Key Words: Open Data, Decision Making, GIS, Flooding, Urban Systems

1 Introduction

Building inclusive and resilient cities are key to ending extreme poverty and promoting equity across the globe. Today, more than half of the world's population lives in urban areas. According to a UN report [1], this is expected to approach 70 percent by mid-century and most of the growth will be concentrated in developing countries. Consequently, managing urban areas has become a fundamental development challenge. Cities must plan to accommodate the unprecedented population growth, as

well as maintain existing infrastructures. Economic activity that is connected by infrastructure and further intensified in cities can unlock the growth potential of developing countries. However, infrastructure investment and urbanization do not automatically lead to inclusive and sustainable economic development. To realize these benefits, well managed connective infrastructure and effective planning are needed.

At present, infrastructure deterioration, increasing service demand, and climate change (CC) are the main planning challenges facing cities across Canada. More and more municipalities are turning to open data and Location Intelligence to tackle the problems and optimize infrastructure services. This is one characteristic of the smart city concept. A smart city utilizes different types of electronic data collection methods that can be analysed to support decision makers effectively manage municipal infrastructures [2]. Data can be collected from citizens, sensors, satellites and other devices that is processed to monitor and manage various urban infrastructure services, such as transportation systems, power plants, water supply networks, waste management.

Open data is freely available to everyone to use, analyse and republish without restrictions. Technological advancements and the increasing availability of fast and universal internet has made it less expensive and instant to obtain such data. This data can come from any source with different formats and it can cover a wide range of topics and geographic locations. For example, The European Commission's Urban Data Platform [3] provides an access point to exchange information on the status and trends of European cities and regions. It provides access to numerous socioeconomic, urban development, infrastructure, environment and climate related spatial indicators. The government of Canada [4] also has an open data platform facilitating data sharing and research in various topics across the country. Many cities across Canada also provide open data access on the current state of their infrastructure.

Additionally, there are dozens of websites from agencies around the world that provide high quality satellite imagery, freely available for download, covering diverse topics. One popular platform is United States Geological Survey's (USGS) National Centre for Earth Resources Observation and Science that provides access to Landsat and other satellite data. Images from the Landsat satellites are one of the most widely used sources of data to analyse land cover changes including urban growth, deforestation, agriculture expansion and intensification, and wetland loss [5], [6]. Landsat is the longest continuously acquired collection of space satellite based medium-resolution land remote sensing imagery [7]. It is a joint mission between USGS and NASA, the data collected by the program can be used free of charge by educational research communities, government, commercial, industrial, civilian and military operations throughout North America and worldwide [7]. Another example for open data provider is the International Soil Reference and Information Center (ISRIC), which is an independent, scientific foundation for world soil Information established in 1966 [7].

Such open data sources can be used as starting point to analyse and solve various issues facing urban areas. Acquiring reliable data is very expensive in developing countries due to the lack of resource to collect and compile data. Therefore, freely available data can be used to drive valuable information and provide preliminary direction for policy makers to address the concerns of residents. This paper shows how

open data is used to investigate the impact of urbanization on pluvial flooding in the City of Toronto, Canada. The study attempts to diagnose the reason behind the variations in the number of reported basement flooding in different parts of the City of Toronto, and recommend potential mitigation strategies. The proposed methodology can be adapted in any urban area, based on its characteristics and data availability, to support strategic to operational level decision making. The case study is discussed in detail in the next section.

2 Case Study

Toronto (boundary shown in Figure 1a) is the fourth most populous city in North America and the largest city in Canada with about 2.8 million inhabitants [8]. Basement flooding is a major concern and the City is continuously working to improve its drainage system. Studies show that Toronto is experiencing shorter return periods for severe storm events that have stressed existing drainage infrastructures. Furthermore, Most of the drainage network in older neighborhoods are combined sewer systems without any provision for overland flow routes, which can increases the likelihood of basement flooding [9].

The city of Toronto - open data catalog contains basement flood events reported by districts and wards from January 2013 to June 2015 [10]. According to the data, in 2013, property owners reported more than fourteen thousand basement flooding. Figure 1c shows the sum of all service requests received between January 2013 and June 2015 for water or sewage entering a basement due to a blocked drain, sewer backing up, or surface flooding from storm events. Wards located in the western part of the city reported the highest number of basement flooding compared to the eastern parts. To reduce basement flooding, the City has an ongoing Basement Flooding Protection Program (BFPP) that aims to improvement drainage infrastructures by conducting an assessment in flood prone areas and constructing recommended infrastructure improvements on a priority basis. Furthermore, the BFSPP provides up to $3,400 support for homeowners to make important improvements to reduce the risk of basement flooding [11]. Figure 1d shows the number of approved applications for the City's BFSPP to assist homeowners to install flood protection devices including a backwater valve, a sump pump, and pipe severance and capping off the home's storm sewer or external weeping tile connection [10]. Wards located in Etobicoke York district received the highest number of approvals for BFSPP while Scarborough district received the lowest.

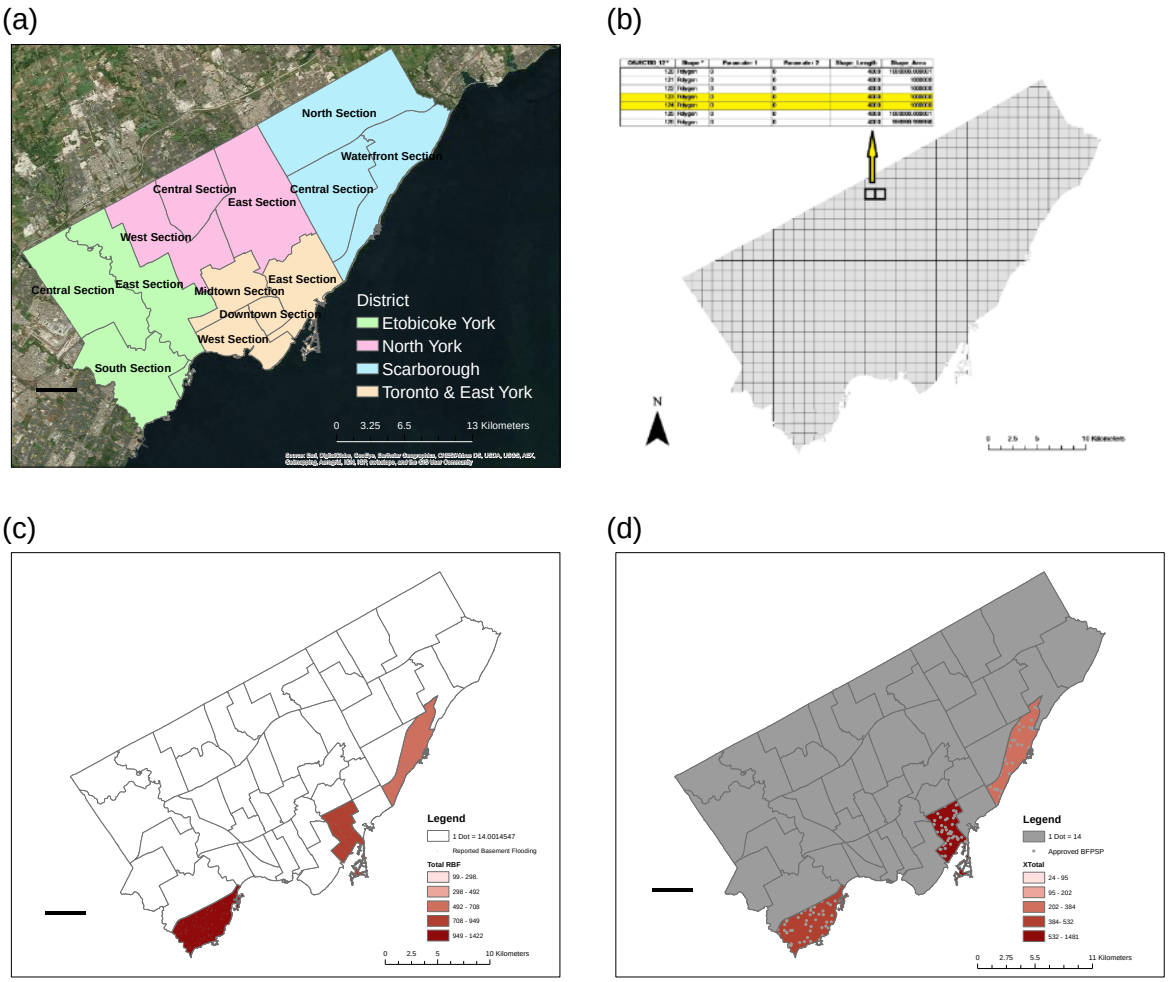

Fig. 1 Data collection and processing: (a) city boundary (b) analysis grid (c) Reported basement flooding (d) approved Basement Flooding Subsidy Protection Program BFSPP approved

2.1 Data Collection and Preparation

The purpose of this study is to assess the reason for the varying trends in basement flooding in different parts of the city of Toronto. Therefore, we have identified major factors that can contribute to pluvial flooding in a given area. Pluvial Flooding is usually associated with short duration high-intensity rainfall but can also occur with lower intensity rainfall over longer periods or melting snow [12]. In addition to rainfall intensity, pluvial flooding processes are affected by topography, drainage infrastructure capacity, soil permeability and antecedent soil conditions (wetness and frozen ground). For this study we have considered topographic, climatologic, soil, infrastructure, and watershed related parameters. The study area is classified into 760 small grid cells (Figure 1b) and data regarding the different parameters considered for the study are collected for each grid cell. Except for zones near the city's boundary, all grid cells have an area of 1 km^2. The grid cell size was determined based on data availability. The data is organized in the ArcMap attribute table, where the raw size is the same as the number of grid cells and the columns are equal to the number of parameters considered in the study. Each grid cell has its own unique data showing the casual relationships between the parameters considered and basement flooding.

Data obtained from the city's open data catalogue is used to analyse the forest and land cover of the study area [10]. Of particular interest for our case study are the relative proportion of vegetation cover (green areas) and paved surfaces (built up areas). The dataset has eight land cover classes as shown in figure 4. From these, we have estimated the total area of vegetation cover, paved surface, pervious areas and impervious areas for each grid cell in the study area. Vegetation cover is calculated as the sum areas for tree canopy, grass/shrub, and agriculture areas, whereas paved surfaces constitute buildings, roads, and other paved surfaces. Soil drainage class data from Land Information Ontario (LIO) was used to extract soil drainage class data [13]. According to the National Soil Data Base (NSDB), there are seven classes ranging from very rapidly drained to very poorly drained soils. The Canadian Digital Elevation Model (CDEM) prepared by Natural Resources Canada is used to calculate the average slope in each study grid cells [14]. Unlike the Canadian Digital Surface Model (CDSM), that captures elevations at the top of buildings and other objects, the CDEM elevations represent either ground or reflective surface elevations. Soil drainage class data from Land Information Ontario (LIO) was used to extract soil drainage class data [13]. According to the National Soil DataBase (NSDB), there are seven classes ranging from very rapidly drained to very poorly drained soils. Since most of the city is a built-up area, soil type data is only available for some zones. In order to have a statistically significant analysis, as shown in Figure 2b, areas in near proximity (1km radius) from available data points are assumed to have the same drainage class. Engineering Climate Datasets, published by Environment and Natural Resources Canada, is used to calculate the IDF values for the study area. There are 12 IDF stations in and around the city of Toronto. Based on these stations, the IDF values for all part of the city is calculated using Inverse Distance Weighted (IDW) approach, which interpolation based on proximity with the assumption that areas near to one another are more alike than those that are farther apart. The processed data for the different parameters considered in the case study are summarized in the figures 2, 3 and 4 below.

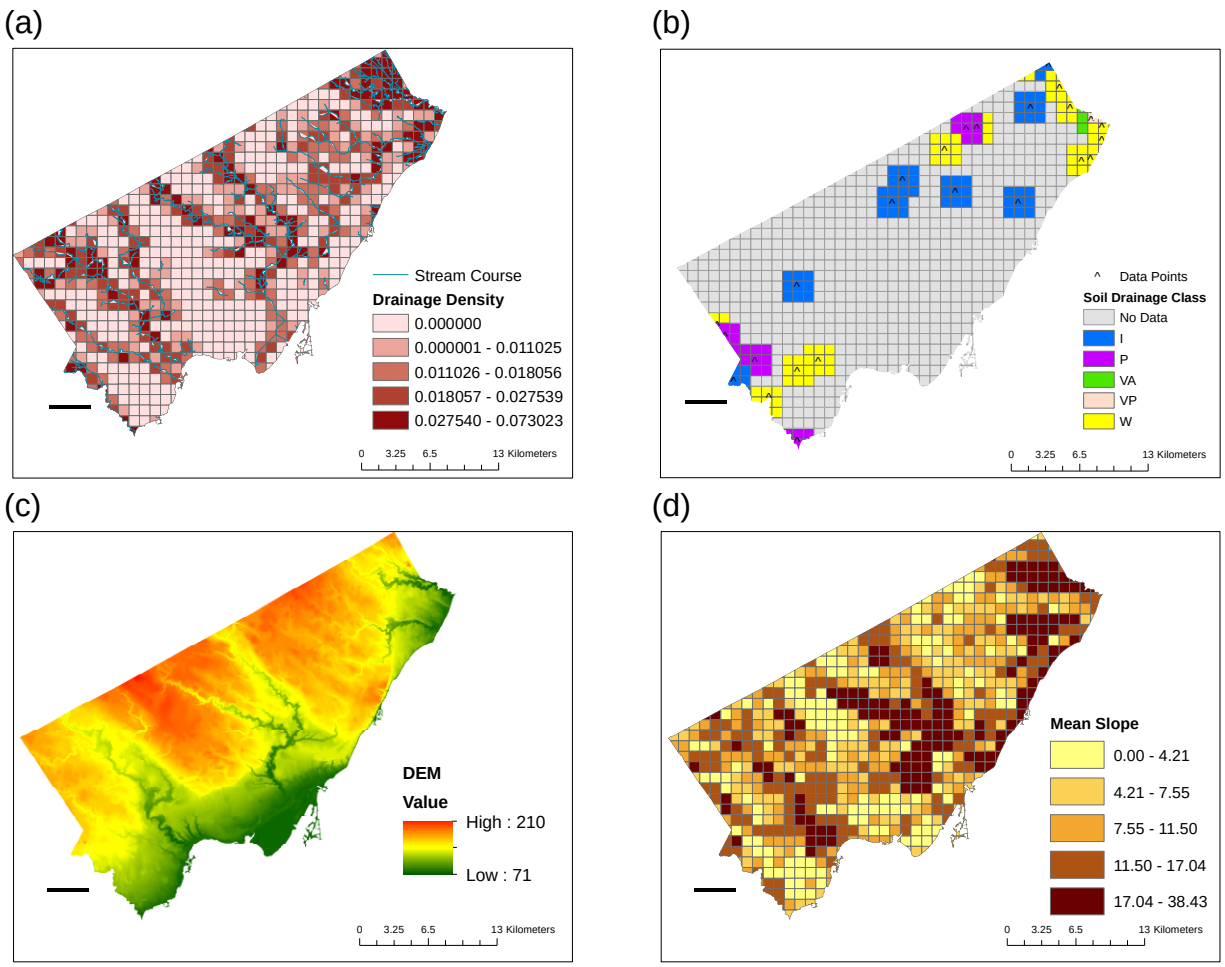

Fig. 2 data collection and processing: (a) river and stream network (b) soil drainage class (c) DEM (d) mean slope

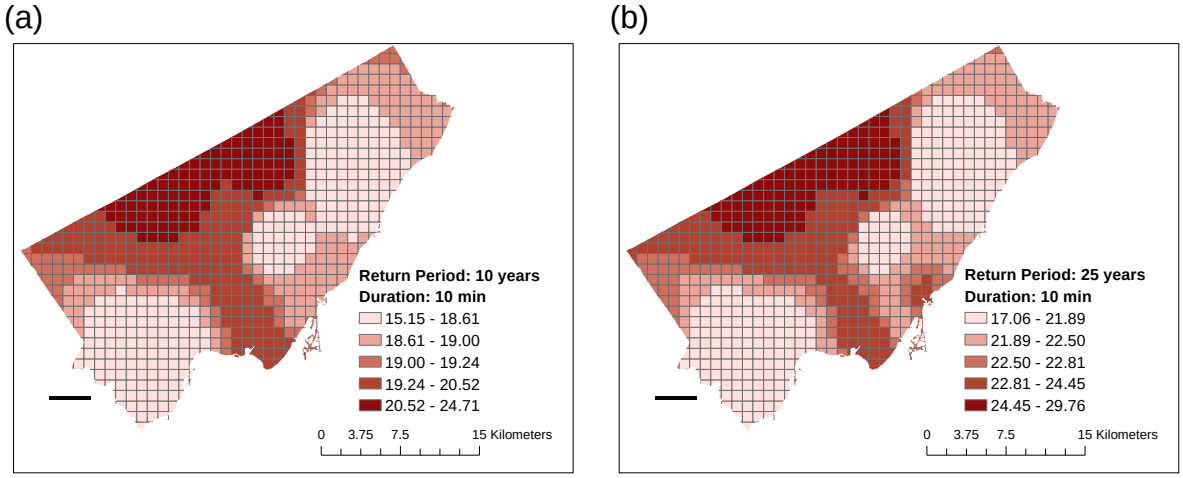

Fig. 3 Data collection and processing: Average IDF for duration = 10 min and return period (a) T = 10 (b) T = 25

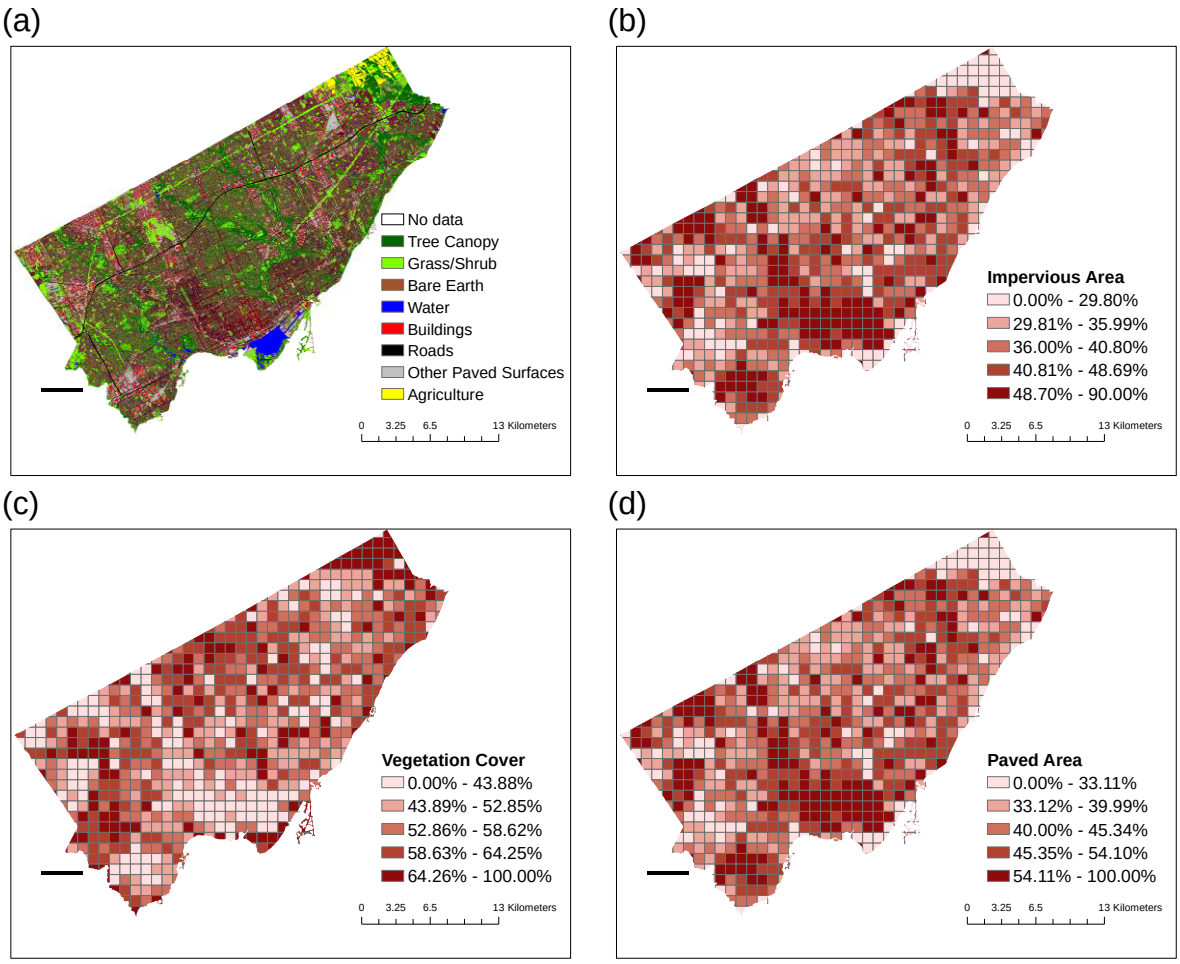

Fig. 4 Data collection and processing: Land cover (a) land cover classification (b) percent of impervious area (c) percent of vegetation cover (d) percent of paved area

2.2 Data analysis

The casual relationship between the different parameters considered and basement flooding is modelled in a Bayesian Belief Network (BBN) model, proposed on Abebe et al [15]. BBN model is supported by a graphical network representing cause and effect relationships between different factors considered in a study [16]. The qualitative component of a BBN is a directed acyclic graph, where nodes and directed links signify variables of interest or system variables and the causal dependencies or conditional relationships among the variables [16] - [18]. The BBNs are flexible enough to perform bottom-up inference or diagnostic analysis and top-down inference or predictive analysis (Cockburn and Tesfamariam 2012; Nielsen and Jensen 2007; Thomsen et al. 2016). The quantitative component of a BBN model is presented with a set of conditional probabilities or probability distributions for each child node given its parent nodes in the network [16], [19]. Details on the analysis can be found on Abebe et al. [15].

The analysis result reveals that population density is the most influential factor affecting the number of reported basement flooding. Densely populated areas near downtown Toronto recorded a higher number of basement flooding in the past four years. Land cover related parameters and slope are the second groups of most influential factors affecting the number of RBF. Areas with a high proportion of vegetation cover

and pervious area reported a lower number of basement flooding while built up areas near downtown Toronto recorded a higher number of basement flooding. Rainfall intensity and soil drainage class are the least influential parameters. Although there is a clear variation in rainfall intensity in different parts of the city, the impact it has on the reported number of basement flooding is very low.

3 Conclusion

Reliable data is essential to model, understand and effectively plan and manage critical urban infrastructures. Data availability presents a big challenge in the municipal decision-making process. Reliable data is even more scares in developing countries where there is a lack of resource to collect and compile data. Therefore, available open data sources can be used to support planners and researchers making an initial analysis. Open data is freely available to everyone to use, analyse and republish without restrictions. Technological advancements and the increasing availability of fast and universal internet has made it less expensive and instant to obtain such data. This data can come from any source with different formats and it can cover a wide range of topics and geographic locations. Moreover, there are dozens of websites from agencies around the world that provide high quality satellite imagery, freely available for download, covering diverse topics. Such open data sources can be used as starting point to analyse and solve various issues facing urban areas. Data availability presents a big challenge in the municipal decision-making process. This paper shows how open data is used to investigate the reason for the variation in the number of basement flooding in different parts of the City of Toronto, Canada. The methodology and procedures can easily be implemented in developing countries. The study shows that freely available data can be used to drive valuable information and provide preliminary direction for policy makers.

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Housing Policies for Smart & Resilient Cities

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Next to Master's Program Infrastructure Planning, he completed his studies in Ph.D. Urban and Housing Policies at the Habitat Unit at Technical University of Berlin, Germany, between 2000 and 2004. Afterwards, he worked as advisor and consultant in Chile, Ecuador, Mexico and Argentina in topics such as public policies evaluation, housing policies, strategic planning for social prevention and security, and technological innovation. In addition, between 2006 and 2010, he was the Executive Director of NGO Cordillera. Since 2017, he has worked as housing policies analyst at the Ministry of Housing and Urban Development, Chile. He highlights from the MIP the holistic thinking because it allowed him having enough criteria for comprehensive analysis of urban policies and regional development. In addition, it was valuable for him the human experience of meeting people from diverse countries and background as an invaluable contribution for his career, particularly on interpersonal skills and multicultural team working.

Abstract: Adequate housing represents a crucial aspect of urban resilience as much as an undeniable requirement for smart cities. Global swift urbanisation, sophisticated technology, climatic adaptation and risks exposure, particularly to those most disadvantaged and affected people, are relatable phenomena: planning decisions and comprehensive thinking are key factors for resilient cities and inclusive societies.

Protecting the most vulnerable living in substandard shelter is a priority and Innovative and affordable housing schemes are urgent. After almost three decades of massive construction, Chilean housing policies are shifting from subsidising low-standard-cheap-housing proprietaries towards well located, good quality and affordable rental housing, conducing to urban regeneration and social inclusion.

In developing countries, formal rental housing is a novelty. Chilean Ministry of Housing and Urbanism (MINVU from now) is building an empirical model which is already showing its potential to correlate Information and Communications Technology (ICT) and housing policies to build a new market of adequate and affordable dwellings capable to face social and environmental risks.

This paper is presented in 3 sections. First section, briefly explores and defines a working concept about smart and resilient cities. Second, and within the same conceptual framework, it highlights urbanisation trends and the crucial role of adequately housing for most vulnerable people. In the third section, Chilean paradigmatic shifts and its relation between rental housing policies and ICTs are explained. Finally, the fourth section summarises future expectations towards planning for smart and resilient cities.

Key Words: Smart and Resilient Cities, Housing Policies, Information and Communications Technology, ICT.

1 Smart and Resilient Cities (SRC)

A brief theoretical approach seems pertinent, particularly regarding debatable terms such as smart and resilience, both related to qualitative features of people or things but used as adjectives to define cities in a paradigmatic mode.

Smart city as a concept has no single or an unequivocal definition. While some confine smartness to the connections between information technology and cities operation and functioning -mainly regarding infrastructure-, others expand the term to focus in its possible or desirable outcomes, particularly directed to people´s wellbeing.

Resilient cities, on the other hand, allows no much room for interpretation: is always related either to the ability or capacity to recover -or to return to- a former or original shape, situation, condition, etc. However, applying this notion of resilience to cities implies to clarify whose resilience and whose city.

Rapid urbanisation represents opportunities and risks. Cities are engines of economic growth and social prosperity, but its benefits do not reach everybody. Moreover, cities worldwide have been evolving towards social and spatial inequalities, segregating informed and connected winners of global trends who build their protected enclaves as far away as possible from the ghettos where the losers are con-fined and exposed to manifold risks.

This paper stands for widespread and transparent information as an influential vehicle towards more equitable, democratic and safer urban development. Nowadays, decision-makers and general population claim for opportune and reliable information, and there is no doubt that real-time streamed data (big data), as well as the spreading out of computers and sensors, are powerful means contributing to man-age rapid urbanisation and avoiding predictable hazards. Assuming the amplitude of smartness and resilience multifactorial concepts, this paper summarises and assembles both conceptualisations in the following working definition:

> A smart and resilient city is the one where its planners, authorities and wide-ranging residents intensively use information and ICTs as a mean to achieve their socioeconomical wellbeing, improving preparedness to face and recover from natural and human risks, as well as preserving cultural and environmental societal values.

2 Urbanisation and Housing Crucial Role

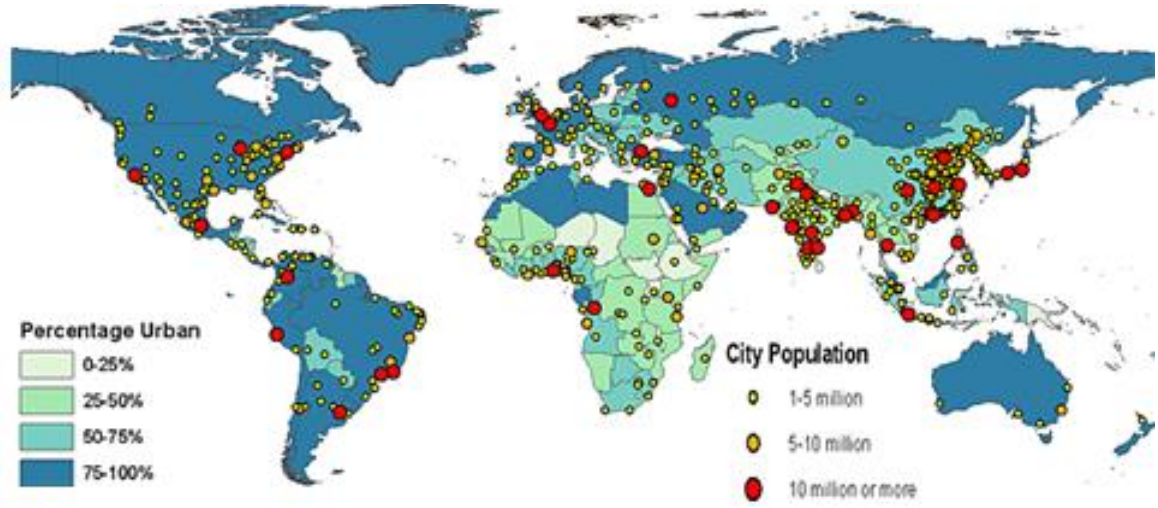

Fig. 1 Urban population and agglomerations by class size, 2025 (UN, 2012) [1].

Cities are under pressure. To be smart and resilient, they must express economic feasibility, social cohesion and environmental sustainability. They must be strong facing adversity and flexible to recover after natural disasters. But these events do not affect all urban residents alike: low-income people suffer the most.

According to the United Nations Development Program, rapid uncontrolled urbanisation is creating new disasters risks, many of them associated to poverty concentrations, lack of adequate housing, and underdeveloped warning information systems, among other factors (UNDP, 2012, [2]). The same report stated a differential impact of natural hazards: while just 11% of people exposed live in poor countries, those nations suffer 53% of total deaths.

The World Bank gives also evidence about the impact of floods, earthquakes, tsunamis and other extreme natural disasters, events that not only push 26 million people into poverty each year, but also cost the global economy more than half a trillion dollars in lost consumption (WB, 2016 [3]).

Swift urbanisation accompanied by rising informal and/or inadequate housing can be recognised as risk drivers. Most urban newcomers settle in cheap, dangerous located land, such as sloppy soil or river banks vulnerable to natural disasters. In addition, unplanned, irregular or low standard housing represents an extra risk for people affected by hazards and natural disasters: housing not only reliefs after but also kills in between.

Experts estimate that more than 1 billion people live in housing that is below minimum standards of sanitation and habitability, number which will need to be triplicated by 2030 (UNDP, 2016) [4]. Consequently, providing secure, safe, affordable, and habitable housing represents an unavoidable mission for smart and resilient cities. When informal settlements expand faster than public or private capacity to supply basic infrastructure and adequate, environmental risk might swiftly accumulate.

While considerable efforts to reduce infrastructural deficit have been done in most of the countries, adequate housing for low-income households has follow a narrow per-

spective: enabling markets to provide subsidised home ownership, mainly located at low-cost land, at the outskirts and with poor quality standards, resulting in exclusion through housing public policies (Jimenez-Cavieres, 2008, [5])

Correctly built and adequately located housing can make the difference between smart and resilient versus risky and unsustainable. Protecting the most vulnerable living in substandard shelter is a priority and innovative and affordable housing schemes are urgent. The world needs a shift on housing policies as a milestone in the path towards resilience: safe and affordable housing rather than minimum standard shelter for low-income families.

3 Chilean Paradigmatic Shifts

After more than three decades of massive construction, Chilean housing policies are shifting from subsidising low-standard-cheap-ownership-housing towards well located, good quality and affordable rental housing, conducing to urban regeneration and social inclusion.

Formal rental housing is a novelty in developing countries, and a counteracting tendency before either enabling markets approaches or estate absolute involvement. As a matter of fact, rental housing policies in developing countries could combine subsides and promotion to handle demand and to improve supply with proper quality and location, not requiring huge investments but strategical partnerships.

3.1 Housing policies in Chile: a short overview

Chile has a long tradition of social housing policies. since the early “hygienical” interventions in the second half of the nineteenth century to today’s organised subsidiary system, most Chilean governments of the last 120 years have not only tried to cope with housing needs but have also pursued to institutionalise these efforts. During this historical process, many different housing schemes were developed.

In a land historically habituated to droughts, floods, forest fires, volcanic eruption, earthquakes and tsunamis, learning from disasters have been a relevant issue, resulting in continuous renovation of engineering norms and building codes in the aftermath. Nowadays, it is possible to assert that Chile has made important progress in developing resilient infrastructure.

However, the pattern of subsidiary housing policies developed by MINVU has been not that auspicious. Last four decades have witnessed more coverage at minimal standards, more ownership and broader spatial segregation, concentrating low-income people at last resort locations.

Fig. 2 Subsidised estates over a dump site, now in demolition. Puente Alto, Santiago de Chile (Photo by the author ®)

As far as land-markets are deregulated housing location is defined exclusively by affordability and does not follows any other social or economic concerns, neither environmental cautions. Furthermore, standards for social housing are minimum, not only in terms of the dwellings' area and the type of construction materials, but also in relation to infrastructure and social facilities.

The result is evident: considerable part of social housing developments financed by public subsidies have been built in risky areas, such as over former dumpsites, near to landslides-prone areas, close to flooded zones, adjacent to slums or simply at the periphery, lacking many services and apart from urban opportunities. In this context, thinking about well-located, good quality and affordable rental housing focused on low-income families' accommodation needs, appears as a promising innovation.

In a paradigmatic shift, in 2014 MINVU launched a *Programa de Arriendo (Rental Housing Programme),* aimed at making rental housing more affordable to low- and moderate-income families. The programme consists of a flat-rate, time-limited subsidy that offers a completely online system of operation. In four years, the Programme has been increasingly accepted and demand has doubled, reaching today more than ten thousand beneficiaries with currently effective rents contracts. So far, most of the supply come from individual landlords, whose personal and housing data are already part of the model.

3.2 Rental Housing and ICTs

The *Programa de Arriendo* introduced many innovations, not only related to its aims and expected outcomes, but also by broadening the use of ICTs in its operation. Besides information systems present since long within the subsidies application´s mechanism, the *Programa de Arriendo* advances on the road to further develop-

ments, particularly those focused on meeting demand and supply according to people´s needs and interests.

Digital government have simplified several administrative tasks included within the application and selection procedure, automatically connecting data about applicants from diverse public agencies, i.e.: socioeconomical score from the Ministry of Social Development; tax and income data from the Internal Revenue agency, and family information from the Civil Registration Office, just to mention some of them.

Apart from appropriate targeting, the use of information systems within the *Programa de Arriendo* facilities opportune monitoring and evaluation of the entire process: since a potential applicant connect MINVU, during its monthly rent payments and until the voucher expires, information data is processed. Early contacts, by phone, mail or personal are registered into the system called *MINVU CONECTA*, paving the way towards orienting and satisfying social housing demand.

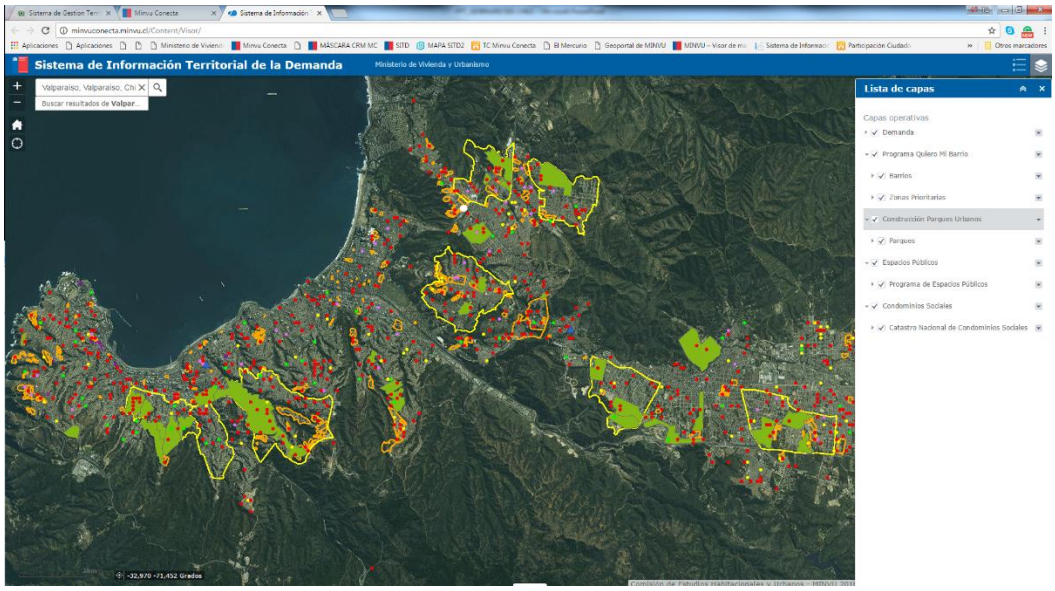

Fig. 3 Mapping housing demand and public programmes on progress (MINVU, 2018 [6])

MINVU CONECTA is quite a new territorial information system, launched in 2016, seeking to strengthen the link with citizens through delivering personalised information on the subsidy programs that best suit the needs of people who are looking for a housing solution (buying, building, leasing or improving a dwelling).

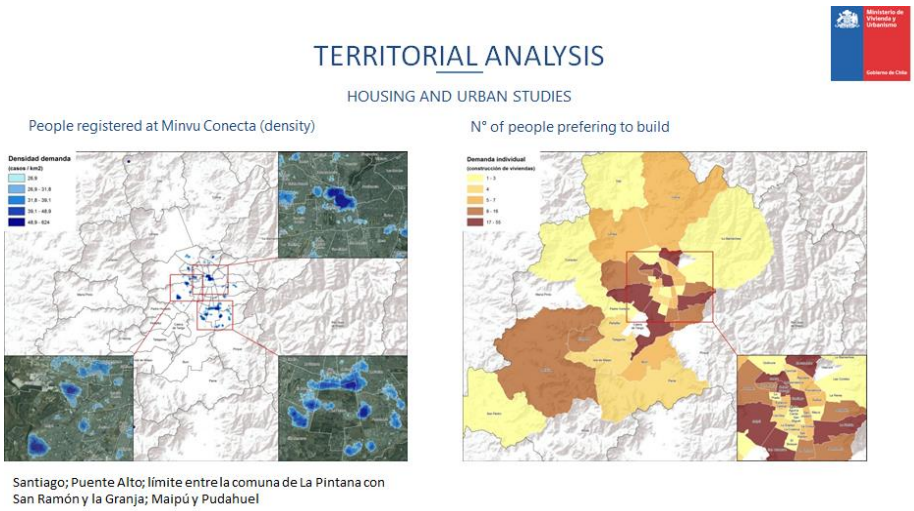

Fig. 4 Territorial analysis for housing and urban studies (MINVU, 2018)

On one side, MINVU obtains better information about demand, usable to correlate it with current plans and programmes. Data collected is very useful to characterise demand, but also to distribute resources regionally and nationally. In addition, is a powerful tool to evaluate territories and localities where greater needs are generated, according to the socioeconomic characteristics of the families.

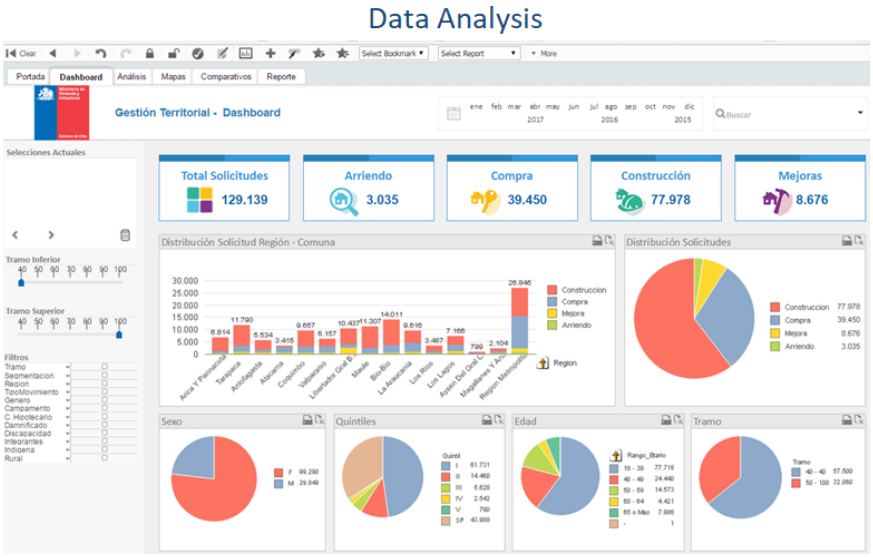

Fig. 5 Data analysis for territorial and budgetary management (MINVU, 2018)

On the other hand, people received guidance about to what subsidy to apply, the necessary steps to follow and potential market offer receiving vouchers, everything at their computer or mobile app.

Fig. 6 MINVU Conecta APP (MINVU, 2018)

4 Future Expectations

Since 2017, and in addition to totally digitalised rental housing allowances, MINVU began to implement different mechanisms to promote supply. Above and beyond normative and administrative matters, the focus is towards defining priority locations and housing typologies where vouchers holders could rent a dwelling. In this direction, MINVU is gathering and processing big data about housing markets, unused or sub-utilised buildings that can be regenerated and transformed as rental units.

Big data, informing about current availability of land, real estate -public and private- situation, as well as information derived from the work of diverse private platforms, devoted to collect and aggregate territorial data about properties markets, both are considered strategic partners to match ICTs planning connections and housing policies, focused on building a new market of adequate and affordable dwellings capable to face social and environmental risks.

Guiding smart urban planning and implementing appropriate measures for resilience requires big data processing and the encouragement of diverse stakeholders committed to share information and to work for a better future for all. The future of cities, I our own destiny.

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Indonesia Taking Steps towards New Urban Agenda Implementation: Strengthening Cities Resilience through Integrated Infrastructure Plans and Programs

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Abstract: Indonesian cities are growing fast at a rate of 4.1% per year, and it is estimated that the country will have 68% of people living in cities by 2025 (World Bank, 2016). Consequently, with a high rate of urbanization, the population becomes a burden to the existing infrastructure and environment. Besides, inadequate infrastructure in Indonesia has hampered growth and poverty reduction and posed significant problems to cities resilience. In line with New Urban Agenda (NUA) that has been declared in Quito 2016, one of the agreements is “strengthening the resilience of cities and human settlements, including through the development of quality infrastructure and spatial planning, by adopting and implementing integrated, age- and gender responsive policies and plans and ecosystem-based approaches” (United Nations, 2017, p. 21).

That point of declaration is in line with an approach applied by the Indonesian government since 2015 to develop public works and housing infrastructure (road construction, water resources, human settlements infrastructure, and housing) based on an integrated infrastructure development plan and program. The paper takes a look at how the strategies of the Indonesian government to develop regional and urban infrastructure in accordance with the development of strategic areas designated in the spatial plans. The Ministry of Public Works and Housing has been using a tool to prioritize public works and housing infrastructure in those strategic areas called as Strategic Development Region. The concept itself combines regional development with markets and considers the environmental carrying capacity in order to accelerate the economic growth and to minimize the regional disparity.

The paper also describes how to translate an integrated infrastructure development plan in one strategic area into synchronized infrastructure programs based on function, location, time, magnitude, and budget. With an integrated plan and program that

refers to the spatial plans, cities can be managed to address increasingly complex problems and to accelerate poverty alleviation, which in turn will strengthen their resilience.

Key Words: Integrated Infrastructure, Spatial Plan, Synchronized Programs, Resilience

1 Infrastructure Development Issues in New Urban Agenda

Indonesia is roughly fifty percent urbanized and it is estimated to have 68% of people living in cities by 2025 (World Bank, 2016). The country's cities are growing rapidly, at a rate of 4.1% per year. It is not only caused by natural population growth, but also by a high rate of urbanization due to urban-rural migration and reclassification of urban areas (Mulyana, 2012). The rapid urbanization rate is triggered by uneven distribution of development activities throughout Indonesia. Western Indonesia, especially Java and Bali, are significantly more developed than other islands. Consequently, the cities' population in those two areas becomes a burden to the existing infrastructure and environment. It will specifically increase vulnerability and bring impact to cities and people in utmost inhabited places.

Moreover, there are still long-lived development problems in Indonesia driven by inadequate infrastructure services and qualities. As published by the country's statistics agency, *BPS* (2018), the development disparities are shown by an inequality index of Gini Ratio with around 0.391 in September 2017; a quite high proportion of poor people stated by the census in 2017 at around 7.26% in urban areas and 13.47% in rural areas; and a relatively high unemployment rate of 2017 at about 5.5% (BPS, 2017). Those problems have hampered growth and poverty reduction and posed significant problems to cities resilience.

In addition, the climate change phenomena in Indonesia have been affecting livelihoods and cities including their infrastructure. Many cities are particularly vulnerable to the effects of climate change, predominantly because of the number of islands at 17,504 and approximately 65% of the population living in and around coastal areas (Sukardjo, 2002). The other factor is due to the most concentration of economic activities and infrastructure assets in urban areas. The government has released that Indonesia is one of the exposed countries to sea level rise, shown by about 405,000 hectares of coastal areas will be flooded with an estimated sea level rise of one meter (Ministry of Environment, Republic of Indonesia, 2007).

As a response to the infrastructure development issues as well as the sustainable urban development, Indonesia contributed to the preparation of New Urban Agenda (NUA). The country played an active role from the beginning of the NUA formulation, including hosting the Preparatory Committee Meeting III in Surabaya, Indonesia in July 2016, which was attended by 142 countries and resulted in the Surabaya Draft before the NUA was declared. The United Nations Conference for Housing and Sustainable Urban Development (Habitat III) held in Quito, Ecuador in October 2016 was crucial to Indonesia in influencing the strategic direction and the global agenda for the next 20 years which are presented in the NUA. The NUA also delivers

guidance for achieving the Sustainable Development Goals (SDGs) and provides the groundwork for actions to address climate change (Setiawan, 2017).

The NUA declaration in October 2016 accommodated the infrastructure issues in the context of urban development in Indonesia, such as access to clean water and sanitation, eradication of urban slums and poverty, housing development, as well as integrated urban and territorial planning and management. The NUA also calls for the integration of infrastructure and spatial planning development. It commits states and cities to implement an agreement of "strengthening the resilience of cities and human settlements, including through the development of quality infrastructure and spatial planning, by adopting and implementing integrated, age- and gender responsive policies and plans and ecosystem-based approaches" (United Nations, 2017, p. 21). That point is in accordance with Indonesian priorities development agenda under the 2015-2019 National Mid-Term Development Plan or *RPJMN* (*Rencana Pembangunan Jangka Menengah*).

Moreover, in Indonesia's urban management policy, the stated paragraphs in the NUA are actually not new since many NUA concepts have been considered in formulating development plans (Hartoyo, 2018). They have been also considered in planning and programming arena of infrastructure development by the Ministry of Public Works and Housing based on integrated plans and programs.

2 Indonesian Government Strategies to Develop Regional and Urban Infrastructure

The Indonesian President Jokowi has a national development agenda called *Nawa Cita* that comprise nine national development priorities. They were then translated into the 2015-2019 National Mid-Term Development Plan (*RPJMN*). This on-going *RPJMN* represents the third-year stage of the 20-year National Long-Term Development Plan (*RPJPN*). *RPJPN* expresses determined plans for a well-established infrastructure development by 2025. In the medium term of five-year national development agendas, the Ministry of Public Works and Housing created Strategic Plan 2015-2019 that consists of infrastructure development objectives and targets. Indonesian public works and housing sectors cover road construction, water resources, human settlements infrastructure, and housing.

2.1 The National Development Priorities of Public Works and Housing Infrastructure

The *Nawa Cita*, the *RPJPN*, the *RPJMN*, and the Public Works and Housing Strategic Plan from 2015 to 2019 have aligned with the global agenda to realize such inclusive and sustainable development. It should underline the relevance and interdependence between the implementation of the NUA with the highest international commitments in the 2030 Agenda for Sustainable Development or SDGs, Addis Ababa Action Agenda, Sendai Framework for Disaster Risk Reduction, and the Paris Agreement (Hadimuljono, 2016). It is particularly related to the SDGs for goal 11, which is to build cities and communities that are inclusive, safe, resilient, and sustainable.

The Indonesian government has designed the national priorities considering issues of resilient infrastructure as well as sustainable development. The national goals related to infrastructure development within 5-year period (2015-2019) are covered in the four agendas of the *Nawa Cita* that include: 1) to build Indonesia from its periphery; to strengthen rural areas within framework of a unitary state of Indonesia; 2) to enhance quality of Indonesians by improving education and training, and by increasing Indonesia's social welfare and health; to encourage land reform and land ownership for the people in Indonesia by 2019; 3) to improve people's productivity and competitiveness in the international market hence Indonesia can move forward and stand up with other Asian nations; and 4) to achieve economic independence by accelerating strategic sectors to domestic economy.

These four objectives have several challenges in developing infrastructure, focusing particularly on the need to support water resilience, food, and energy sovereignty, connectivity for national competitiveness, and basic services to improve the quality of life. The four challenges are as follows:

1. The need to develop infrastructure towards balanced regional development,
2. Resource utilization and development for added value to achieve water resilience, food, and, energy sovereignty towards sustainable economic growth,
3. Improving connectivity within regions and between land and sea to increase the national competitiveness, and
4. Developing infrastructure to address high urbanization and to improve the quality of life in urban and rural areas.

Therefore, the Ministry of Public Works and Housing has 4 (four) strategic targets as stated in the Strategic Plan of the Ministry of Public Works and Housing from 2015 to 2019 as follows: 1) increasing integration of public works and housing infrastructure development between regions, between sectors, and between government levels 2) increasing support for food and energy security; 3) increasing connectivity support for enhancing competitiveness; and 4) increasing support for basic infrastructure services of settlements and housing.

2.2 Regional Approach to Infrastructure Development

The first target of integrated infrastructure development in the Strategic Plan was generated since the issue of adequate provision of infrastructure, from both access and quality perspective, adversely affects the country's competitiveness and attractiveness to investors. Given the limited capacity of government to deliver all the needed infrastructure, prioritization of public works and housing sector development in strategic areas is indispensable. A tool that has been used by the Ministry of Public Works and Housing is called as Strategic Development Region (SDR). The concept itself combines regional development with markets and considers the environmental carrying capacity in order to accelerate the economic growth and to minimize the regional disparity (see Figure 1).

Fig. 1 The Concept of Strategic Development Region for Prioritizing Infrastructure Development (Source: RIDA, Ministry of Public Works and Housing, 2017)

The concept has also delivered regional development strategies with an approach of physical development (infrastructure and land use), which also developed and implemented in various countries. In Indonesia, the idea of a regional approach to infrastructure development is not new but has been introduced since the 1970s by Sutami who expressed that rapid, simultaneous, and consistent infrastructure development would be able to develop the region. After the spatial reforms indicated by the Law of the Republic of Indonesia Number 26 Year 2007 on Spatial Planning, the integrated development between regional infrastructure and strategic areas is strengthened from the implementation and controlling perspectives, such as the determination of at least 30% of green open spaces, the mechanism of incentives and disincentives, as well as sanctions.

The regional approach to infrastructure development is applied to integrate the public works and housing infrastructure with the national priorities, namely 17 industrial priority areas and 10 special economic zones, 10 national tourism strategic locations, 10 metropolitan areas, 40 rural priority areas, 13 food barn provinces, national border in Kalimantan, East Nusa Tenggara, and Papua, and multimodal connectivity (ports, fishing ports, ferry crossing, airports, and railways) (RIDA, Ministry of Public Works and Housing, Republic of Indonesia, 2017).

2.3 Integrated Public Works and Housing Infrastructure Plans and Programs

The government of Indonesia has evaluated the approach of infrastructure development since the objective is not only for accelerating regional growth, but also to solve the problems of income disparity, poverty alleviation, and environmental degradation. Therefore, the government has taken steps to ensure that provision of regional and urban infrastructure can eliminate the aforementioned problems as well as enhance

the regional competitiveness in the production and service sectors more equally throughout Indonesia.

The development of regional and urban infrastructure is carried out by considering the territorial planning at the national, provincial, and regency/municipality levels. At the national level, the government maintains the regional infrastructure systems that are synchronized with the local networks; so that they can ensure that the movement of people and logistics between cities and within cities works efficiently. The integrated infrastructure development also plays an important role in national infrastructure delivery, particularly in strategic areas, which are expected to synergize in producing the output and the outcome at the greatest leverage. At the urban context, the government has assigned the Government Regulation of the Republic of Indonesia Number 14 Year 2016 on Organization of Housing and Settlement Areas. It mandates the arrangement of settlement plan including integrated infrastructure and utilities.

The National government has created a master plan of integrated regional and urban infrastructure in strategic areas, that belong to the authority of the central government. The infrastructure master plan is developed in accordance with their spatial plans, including for urban areas such as metropolitan areas and new town development. The arrangement of the master plan has brought the respective stakeholders into the discussions, ranging from Ministry/Institution at the national level (e.g. Ministry of National Development Planning, Coordinating Ministry for Economic Affairs, Coordinating Ministry for Maritime Affairs, Ministry of Transportation, Ministry of Land and Spatial Planning), local government and communities. The master plan of infrastructure development has compromised the National Mid-Term Development Plan, the President's directives, the Ministry's Strategic Plan from 2015-2019, spatial plans at the national, regional, and local level, sectoral master plan (e.g. road network development, drainage system, port development) as well as strategic plans or mid-term development plans at the regional and local level.

The master plans then were translated into infrastructure programs that are prepared to be constructed according to a set of readiness criteria. The readiness criteria involve land availability, Pre-Feasibility Study or Feasibility Study, Detailed Designed Engineering (DED), environmental assessment and other requirements. In terms of providing the readiness criteria which is the responsibility of the province/regency/municipality, it is important to highlight that the strong commitment from the local government is necessary. For instance, the regency or municipality level has to ensure the land readiness before the construction begins.

Besides examining the readiness measures, the programs were subsequently synchronized based on function, location, time, magnitude, and budget. The infrastructure programs are set into five-year programs, three-year programs, and annual programs. Each program has to be designed in a specific location with a certain function and funded by specified financial resources whether from the national budget or other resources. For instance, building a regional drinking water system in one particular area designated in the spatial plan will be constructed in a year. When it is first started developing the program, the water system should be identified for predetermined functions, such as to support residential or industrial zones. The financial capacity delimits the magnitude of the detailed program according to the time span of con-

struction. An integrated master plan ensures that the water supply for drinking water system is already provided so that it can well function to support the cities and the people. As if the raw water has not existed yet, the government has to provide it before the drinking water system is programmed.

3 Infrastructure Development Plan and Programs in Strengthening Cities Resilience (The Case of Greater Jakarta)

The integrated approach to infrastructure development is closely linked to the NUA principles that are the social inclusion or leave no one behind, sustainable and inclusive urban economies and environmental sustainability. In paragraph 34, it is clearly stated that the NUA has a purpose “to promoting equitable and affordable access to sustainable basic physical and social infrastructure for all, without discrimination…” (United Nations, 2017, p. 12). In addition, the integrated infrastructure plans will promote sustainable and inclusive strategic areas development and foster an enabling environment for investors as well as livelihoods, which in turn will achieve resilient cities and infrastructure.

USAID defines resilience as “the ability of people, households, communities, countries and systems to mitigate, adapt to and recover from shocks and stresses in a manner that reduces chronic vulnerability and facilitates inclusive growth” (USAID, 2012). Many infrastructure programs in Indonesia have been developed to increase the capacity of cities to function; therefore, people living in cities, particularly the poor and vulnerable, can survive and thrive from the stresses. The integrated approach to infrastructure development can strengthen cities resilience since it has benefits in increasing growth in regional and inter-cities scale as well as urban-rural linkages and ensuring the access and quality of basic infrastructure.

The infrastructure development plans and programs are created for strategic areas in Indonesia, such as for the Greater Jakarta Metropolitan Area known as *Jabodetabekpunjur*. The area covers the capital Jakarta and its surrounding, such as Bogor, Depok, Tangerang, Bekasi, Puncak, and Cianjur. The infrastructure master plan was arranged to make that metropolitan be a liveable and qualified area as well as a sustainable and competitive place for people to live. Therefore, the development concept of each growth center has applied the following principles, namely a) self-contained; b) mixed-use; c) integrated commuting transit system (TOD); d) the regional infrastructure supporting the main function of the strategic areas, settlements, and housing to serve the population; and e) maintain the carrying capacity of the environment. With that idea of development, it will increase the capacity of the cities and the people in the Greater Jakarta Metropolitan Area to withstand perturbations and other stressors as well as can improve their welfare.

In the master plan of infrastructure provision in the Greater Jakarta, the metropolitan has three stages of development from 2016 to 2025. It began with the establishment of the function and role of the surrounding urban areas of Jakarta to be independent and complete to each other function as a metropolitan. At the urban scale, improving settlements and housing infrastructure is required in order to increase the ability of people to survive from inadequate access and services to basic infrastructure. Thus,

several main infrastructure programs have set up in the development plan of infrastructure development in the Greater Jakarta (see Figure 2).

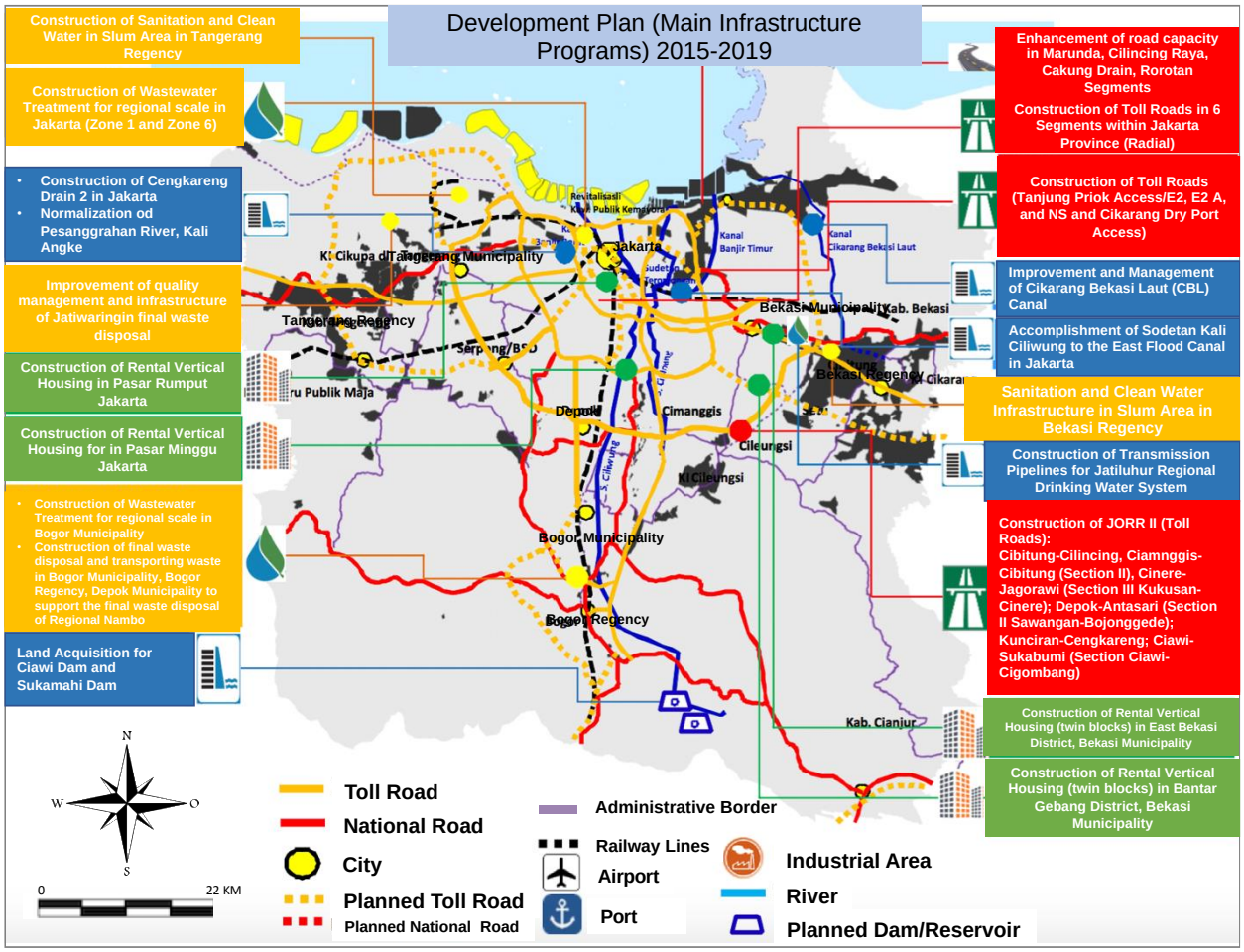

Fig. 2 Main Infrastructure Programs in the Greater Jakarta Metropolitan Area (Source: RIDA, Ministry of Public Works and Housing, 2016)

The urban infrastructure programs in Indonesia have considered the NUA components. In addressing the problems of access and services to basic infrastructure, the National government has addressed the target of 100-0-100 program, which is to realize 100% clean water service, 0% slum area, and 100% of sanitation service. According to the achievement progress this year, the progress is 72.58% access to clean water, slum upgrading of 5,848 Ha (around 25% accomplishment), and 78.04% access to sanitation (RIDA, Ministry of Public Works and Housing, Republic of Indonesia, 2018).

To alleviate urban slums, Indonesia has a programme called Cities Without Slum (*Kota Tanpa Kumuh*/*KOTAKU*). It is a collaborative program for slum upgrading interventions between ministries, as well as enable local governments to lead design and implementation in their respective cities. The program is carried out through policy, strategy, and institutional preparation, capacity building for local government and communities as well as prevention and improvement of the quality of slum area of 23,656 Ha in 269 cities across the country (Hadimuljono, 2017). From the data, it is indicated that the government still has a huge task to upgrade the slums. Therefore, without high participation from the local communities, the 100-0-100 target would not be achieved completely.

In case of the Greater Jakarta, the main programs within five years are constructing sanitation system and providing clean water in slum areas in Tangerang and Bekasi Regency. The distribution pattern of slums in the two regencies is mainly in coastal and industrial areas. In fact, the access to clean water in Tangerang Regency was 30% in 2017, while 70% people were not accessible due to limited raw water, mostly live in coastal areas (Kompas, 2007). The water supply in Tangerang only depends on Cisadane River and it is exaggerated by the polluted river condition in the northern part. The development plan in Jakarta Metropolitan Area is created to ensure that the basic infrastructure is well-developed and integrated. To overcome the problem, Karian Dam has been constructing since 2015 and it will be operated in 2019 with the capacity of 314.7 million m^3 and supply of 9.1 m^3/second (Ministry of Public Works and Housing, 2017). The dam has not the only function for water supply, but also for irrigation and electricity generation.

Since the slums inhabit the coastal areas in the Greater Jakarta, they also occupy the land in the northern part of the capital city. North coast of Java, including coastal areas in North Jakarta, is one of the places which might have severe impacts of the climate extreme (Subandono, 2002). The risk of coastal flooding in Jakarta is increased by land subsidence, largely due to excessive extraction of groundwater with a high volume of abstraction from the middle and lower aquifers (Ward et al., 2011). To protect the capital city from high tides and land subsidence as well as to overcome the slums, the National government has a responsibility to construct the 20-kilometer North Coast Jakarta seawall as part of the effort to protect the capital city from high tides and land subsidence.

Besides, the National government is responsible for providing a clean water facility of 3,500 liters per second to reduce groundwater consumption. The provision of drinking water facility systems (*SPAM*) will also be built, namely the Jatiluhur *SPAM* I with a capacity of 4,000 liters/second, the Jatiluhur *SPAM* II with 5,000 liters/second, and the Karian Dam *SPAM* of 3,200 liters/second (KPPIP, 2017). Meanwhile, to reduce the groundwater and river pollution, the National government in collaboration with the Jakarta government is realizing the Communal Waste Water Management Installation (*IPAL*) and the community-based sanitation programs. The Jakarta sewerage system is planned to be constructed within five years in North Jakarta (Zone 1 & Zone 6). By following the integrated plans and programs, each of urban infrastructure will function to serve the people and the cities. The marginalized inhabitants who live in poor condition will have easier access and better quality of basic infrastructure that lead to improving their livelihood.

4 Future Challenges

The acceleration of urbanization and the persisting development problems in Indonesia has resulted in growing infrastructure demand. Due to an inadequate financial capacity of the National government to spend its budget on infrastructure, the social and economic problems continue to occur. In some cases, it contributes to increasing disaster risk in urban areas and negative environmental and climate change impacts. The financial ability of the cities to spend enough the own budget on infrastructure is still a major problem. Consequently, it is necessary to develop infrastructure financial innovations by emphasizing on cities self-sufficiency and collaborating with the pri-

vate sectors to gather the capital investment. Therefore, the National government can focus on developing infrastructure on regional and strategic areas scale.

In case of slums alleviation target into 0%, the government still has to put much effort into slum upgrading until 2019. The slums are significantly affected by the climate change impacts, especially for those who live in hazardous areas. Huq et al. (2017) expressed that the development of informal settlements, including slums in flood-prone areas is one of the exposure's drivers of risk. Most of them do not have enough resources to cope or recover from the impacts. Consequently, it is significant to have active actions from cities governments to upgrade their livelihood. Furthermore, since the main constraint to meet the slum upgrading target is the national budget, it is very required to have more concern from the local government through its own budget, companies by doing Corporate Social Responsibility (CSR), and self-help communities. Therefore, it is very required to improve the capacity of local government to strengthen their resilience.

Another challenge is to measure the impact of infrastructure development not merely within a five-year period, but also in the long run. A huge spending budget on infrastructure development should give enormous benefits to society's welfare. Therefore, the government has to carefully design indicators and methodology in order to value the impact of infrastructure development on economic growth, poverty alleviation, and ecological balance. It is important to ensure how a strong commitment from the government to build infrastructure is positively correlated with the national economic growth and the cities resilience.

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Session 2:

Case Studies of Resilience - Oriented Planning and Smart City Concepts

Hybrid Rural-Urban Development Pattern in Western-nonthaburi in Bangkok and its Relation to Resilience

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Abstract: This paper studies relationships between spatial development patterns and their effects on resilience enhancement. Various types of hybrid rural-urban development patterns have been observed in the Bangkok Metropolitan Region. The only pattern emphasised in this paper is the hybrid rural-urban development pattern developed based on specific characteristics of small landholdings, which was a result of land policy launched in third phase of the modernisation period. The spatial analysis is focused to the area called 'Western-nonthaburi'. The study shows that the hybrid rural-urban development pattern in Western-nonthaburi is likely to bring positive impacts regarding resilience enhancement to the urban system. This is because it tends to generate an environment that enhances the capability of the urban system to absorb disturbances and to retain essential conditions while undergoing changes, as well as to learn and to adapt to the changes.

Key Words: Hybrid Rural-Urban Development Pattern, Resilience Enhancement, Western-nonthaburi, Bangkok Metropolitan Region

1 Introduction

The concept of resilience has recently been the focus of various disciplines, including spatial planning. It is considered an essential quality for urban systems for coping with recent territorial development challenges in a world of rapid transformations. The term 'resilience' in this context refers to the capacity of an urban system to absorb and deal with undesired disturbances and reorganise while undergoing change so as to still retain essentially the same functions, structure, identity and feedbacks (Folke

et al., 2005). Folke *et al.* (2002) argue that a fundamental quality necessary to create resilience is the diversity of species, human opportunity and economic options that maintains and encourages both adaptation and learning processes.

The term 'hybrid rural-urban development pattern' in this context refers to the spatial pattern of *desakota* as defined by McGee (1991). It expresses the blend of country (*desa*) and city (*kota*), where agricultural and non-agricultural activities coexist in close proximity to large urban centres. In other words, it refers to regions that have undergone intense processes of mixed urbanisation, with agricultural, industrial and residential functions side by side. During this process, the countryside is urbanised without the hinterland population necessarily moving into a major city. McGee (1991) argued that it is not just the visual expression of a transitional stage of urbanisation, but a unique landscape that characterises Southeast Asian cities. It is the result of specific social systems in the fringe of mega-cities, which is distinct from that experienced by western countries during their urbanisation processes. This hybrid rural-urban development patterns take place also in the Bangkok Metropolitan Region, yet with distinctive characteristics in different parts of the region.

The focus of this paper is to investigate relations between a specific hybrid rural-urban development pattern associated with the specific characteristic of small landholdings on resilience enhancement. This specific pattern is a result of land policy applied in the region during the second phase of the modernisation period of land development (1880s-1900s). Western-nonthaburi is used as a case study area, as the area was reclaimed since the 1930s and has been continuously developed. The development of the area has been underpinned by the specific characteristics of the area associated with small landholdings. Three parameters are employed to assess the degree of resilience. They are (i) absorbability and retaining capability - relating to diversity of the system, (ii) learning capacity - relating to human-nature interaction and independency and (iii) adaptive capacity - relating to speed of change and diversity of the system.

2 Development of Land Policy and Spatial Development Outcomes in the Bangkok Metropolitan Region

2.1 Three phases of land policy during the modernisation period (1855-1970s)

The land policy in operation in Thailand is a result of significant shifts created in three different periods of development. They are (i) the pre-modernisation period (before 1855), to which development was based on subsistence economy with customary land policy; (ii) the modernisation period (1855-1970s), to which modernised land policies driven by economic growth promotion were the emphasis; and (iii) the reorientation period (1980s-present), of which the modernised approach has slowly given way to the reintegration of territorial management with the more customary approach, driven by sustainable development discourses and the societal changes in the region.

During the modernisation period, the Thai society experienced major shifts in land policy. One of the significant shifts was the change in the system of land tenure, from the occupancy-by-use model to the title deeds system in 1902. This was underpinned

by the liberalised trade agreements (starting in 1855 with the United Kingdom and followed by agreements with several other countries) that significantly changed the economic structure of the country, along with the abolition of the *nai-prai* system[1] (starting in 1874) that considerably changed the social structure. The shift from a subsistence to an export-oriented agricultural economy and the new peasants who were just free from the *nai-prai* system generated a dramatically increased demand for land for cultivation. Demand for land for building construction also increased to accommodate emerged trades and services. Various land reclamation projects took place in the area that corresponds to the present Bangkok Metropolitan Region to accommodate these increased demand for land for development. As the demand for land to support agricultural export was dramatically increased, the state launched new development policies aiming to promote farming in unoccupied areas. Different development policies were applied to different reclamation projects through canal excavation in three phases.

During the first phase (1850s-1870s), land policy promoting largeholdings was introduced and replaced the customary land policy that promoted smallholdings. Canal excavation in this period was mainly for irrigation purposes and to improve transport of various kinds of goods from the west of the Chaophraya River to Bangkok. Excavation was conducted by the state, and land adjacent on both sides to the newly excavated canals was given to the aristocracy (Jarupongsakul and Kaida, 2000). This land policy resulted in land development based on largeholdings. This occurred, however, to a relatively small area as compared to what occurred in the second phase.

The new land policy introduced in the second phase (1880s-1900s) strengthened landlordism to a large extent. According to the new land policy in this phase, concessionaires were responsible for all the cost of development. In return, the state granted ownership 1,600 metres of land on both sides of the main canal and 1,000 metres of the secondary canals to concessionaires, subject to whether or not the land was already utilised and claimed (Molle, 2005). This policy was driven by the demand for rice for exporting to Britain's colonies (Peleggi, 2007).

The government was thereafter aware of potentially negative impacts created by the new land policy that promoted landlordism. This led to the reorientation of the land policy in the third phase of modernisation period. In order to abate landlordism and promote small-scale concession to peasants, the Ministry of Agriculture entrusted the reclamation projects to the Department of Canals (which became the Royal Irrigation Department in 1914) in 1902 (Kitahara, 2000), instead of giving concession to privates; in 1936, the state fixed the limit of land ownership at 50 *rai* (8 ha) per household, which was considered sufficient to make a reasonable living for a household in that time (Peleggi, 2007).

[1] Before the gradual process of slave and *nai-prai* system abolition (1874-1905), the Thai society comprised of four main social classes: (i) the king - referred as the state in this context; (ii) *nai* - nobility (including all members of the royal family and the high-ranked government officials appointed by the king no matter of his nationality or social class); (iii) *prai* - commoner (including the ethnic groups), who has either to work for the state or his *nai* as appointed by the king for two months a year or to pay to the state with a certain amount of money or goods and (iv) *dasa* (slave) (Chitchang, 2006).

2.2 Spatial development outcomes during the modernisation period

In the pre-modernisation period of development in the Bangkok Metropolitan Region, settlements were concentrated on the west of the Chaophraya River, where land was suitable for cultivation, mainly on the natural levees along the banks of the river and the water networks. Residential units were mixed with agricultural fields with trading communities concentrated at the main water junctions (Wallipodom, 2000). Swampy lowlands, mostly on the east of the river, were left unattended.

Settlements in swampy lowlands started taking place in the 1880s to serve increasing demand of rice for export. These areas were maintained for the agricultural functions with rural environment until the beginning of the 1970s when enormous and rapid urban expansion took place, underpinned by the shift of the Thai export-oriented economy towards manufacturing production. The urban expansion included also development of housing estates, which was driven mainly by the rise of middle class with a high purchasing power, changing life styles of urban families and the influx of rural immigrants drawn by economic development in Bangkok (Askew, 2002; Molle, 2005).

Urban expansion had, however, affected each part of the region differently. In the areas to which the revised version of land reclamation policy launched in 1936 was the main triggering factor for reclamation were developed in the way that the reclamation project was executed by the state with an intention to abate large-scale concession of land. Land was distributed to peasants, who became landowners with small-scale concessions (Peleggi, 2007). The landholding size was limited to 50 *rai* (8 ha) per household. The size was even progressively reduced overtime due to subdivision of the plot through family inheritance over generations (Kitahara, 2000; Peleggi, 2007). Rice fields in the area were soon converted into orchards since the profit earned from orchards is considerably larger than that earned by cultivating rice (Askew, 2000).

3 Hybrid Rural-Urban Development Pattern and Its Effects on Resilience Enhancement

This paper uses Western-nonthaburi as an example for analysis of spatial development outcomes underpinned by development based on the revised version of land reclamation policy launched during the third phase of the modernisation period. It is argued here that this specific characteristic of small landholdings promoted by this specific land policy is one of the key factors contributing to resilience enhancement of the area.

3.1 Hybrid rural-urban development pattern in Western-nonthaburi

The land in Western-nonthaburi was mostly occupied by individual households, primarily for agricultural and residential purposes (Askew, 2000). The landholding size was progressively reduced from the original size when the land was reclaimed, then limited to 50 *rai* (8 ha), to between 2 - 4 *rai* (0.32-0.64 ha) (Askew, 2000). This was due to subdivision of the plot through family inheritance over generations (Askew, 2000). Due to its smallholding characteristic, land was developed generally on the basis of small projects. Small-scale orchards mixing with residential uses were com-

mon here. Share of industrial uses was rather minor. Smallholding characteristic makes the transformation process of agricultural areas to accommodate industrial and residential functions happened quite slowly. This is because incorporation of plots for development or industrial uses is likely to be slowed down by owner-by-owner negotiations, resistance of owners to sell and slower legal procedures to incorporate a large number of plots.

After World-War II, Thailand experienced rapid economic growth with the shift from an export-agricultural-oriented economy towards a more service and manufacturing-oriented economy. The rapid economic growth increased the monetisation of the peasant economy and led to an enormous urban expansion in the Bangkok Metropolitan Region, including in Western-nonthaburi. As the economic structural changes made a number of households in Western-nonthaburi more attached to non-agricultural works, land use here started changing slowly. Generally, only a small part of the land within a single plot was maintained for agricultural uses; the rest was parcelled for residential uses, either for the heirs of the plot or for selling to new arrivals or developers (Askew, 2000). The logic that explains a landholder selling only part of his plot is based on a strategy of maximisation of assets, with an aim to preserve parts of the land as legacy to the heirs or to retain still-productive land for agricultural activities as a supplementary source of income (Askew, 2000). This led to an even smaller landholding size in Western-nonthaburi.

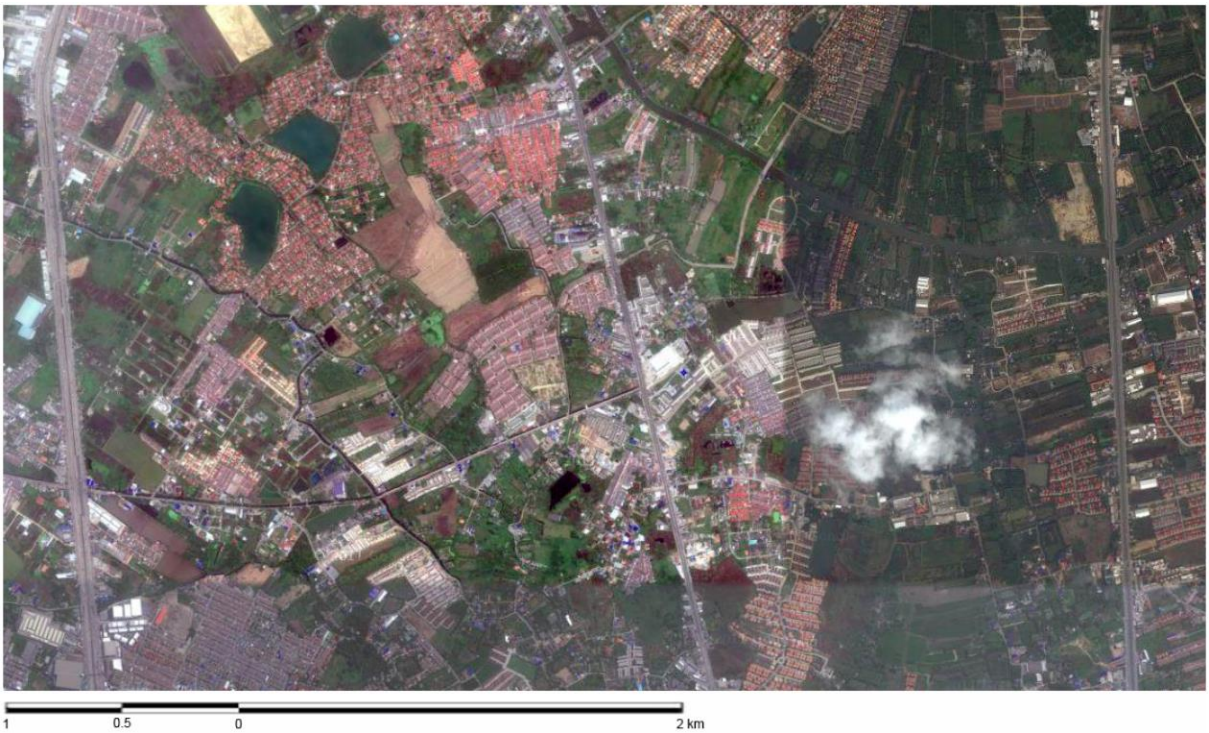

Fig. 1 Aerial maps showing examples of development patterns in Western-nonthaburi (Source: https://www.google.com/maps)

3.2 Effects of the hybrid rural-urban development pattern on resilience enhancement

The degree of resilience enhancement is assessed using three qualities of the area. They are explained below.

(i) Absorbability and retaining capability

The hybrid rural-urban development pattern in Western-nonthaburi based on smallholdings is associated with fine degree of mixed-use with high degree of ecological diversity, as explained earlier. The owner planted a variety of fruit crops which ripen throughout the year to ensure a continuous income for the family. The area is diverse not only ecologically, but also socially. This is because land belongs to diverse owners who own small piece of land. These qualities allow more chance that some attributes or actors can absorb or cope with the undesired disturbances, which helps the system not to be drastically affected by or collapse due to a rapid change. In other words, these diversity characteristics of the area help enhancing resilience of the urban system by promoting absorbability and retaining capability of the systems to deal with disturbances and imminent shifts.

(ii) Learning capacity

The hybrid rural-urban development patterns in Western-nonthaburi, based on family subsistence with smallholdings mixing with agricultural practices with a variety of plants, are likely to encourage learning capacity. As the agricultural products from the land contributed to part of the family income, farmers commonly chose to plant a variety of fruit crops as explained above. This helps not only ensuring a continuous income throughout the year, but also suit the family-based labour system (Askew, 2000). The variety of plants requires regular interaction and attendance from the farmers throughout the year. This, as a result, creates human-nature interaction and independency. The human-nature interaction and independency characteristic helps strengthening learning capacity, which is one of the fundamental qualities necessary for resilience enhancement (Folke *et al.*, 2002). The human-nature interaction and independency characteristic provides early warning signals for loss of the system's resilience. Imminent shifts to less desirable states can be better perceived through such interaction processes. In other words, human-nature interaction and independency characteristic resulted by specific development patterns in Western-nonthaburi is likely to provide early awareness that enables the urban system to gradually reorganise itself to changes. This, thus, helps enhancing resilience of the urban system.

(iii) Adaptive capacity

In Western-nonthaburi, a high degree of diversity is observed. This regards to both ecological and social dimensions of diversity. Diversity of the area is clearly presented in Fig. 1. The area shows mix of land use on the basis of small plot size, dominated by residential uses mixing with orchards. Small portion of land is occupied by industrial uses. Various types of fruits planted in orchards make the area being ecological diverse. Small landholdings resulted in collective actions that involve diverse actors, with different social and economic attributes. This social diversity led to a slow spatial transformation process. In short, the hybrid rural-urban development pattern in Western-nonthaburi, which is associated with ecological and social diversity of the urban system, allows changes to take place with slower pace than the more monotonous ones. It allows more chance that some attributes or actors can be either safe from or adaptable to the disturbance. Additionally, some attributes/actors may response to changes immediately, whereas some may take longer to respond. Thus, the diversity characteristic in Western-nonthaburi is argued to offer more chance and

time for some attributes or actors in the urban system to prepare and to adapt to the change gradually. It helps the system to still retain its essential conditions, such as functions and structure, and thus enhances resilience of the system.

4 Conclusions and Remarks

The study shows that the role of land policy on shaping the spatial development patterns is evident. Land development in Western-nonthaburi is a results of land tenure based on smallholdings for family subsistence. The diverse and fine degree of mixed-use in this area creates an environment for the urban system to cope with the change. This is because the diverse urban system presents various attributes that are associated with different degrees of resistance or adaptability to changes. The diversity also results in a low speed of change, and thus an opportunity of the urban system to recover from changes. In addition, small-scale of agricultural practices mixing with residential units are likely to enhance human-nature interaction and independency. This is because the small-scale mixing patterns are more likely to enable learning and adaptation of the urban system by providing early warning signals for loss of ecosystem resilience and for imminent shifts to less desirable ecological states.

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Climate Change Vulnerability and Adaptation of Infrastructure in Cities in Ghana

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Abstract: The majority of climate change research in Ghana has focused on agriculture and forestry. This is understandable given that there was a need to attain the United Nations Millennium Development Goals by 2015. However, the impacts of

climate change will have far-reaching effects on sustainable development, especially on critical infrastructure, in rapidly developing cities in Ghana.

Examining how Ghana's critical infrastructure is affected by climate change in the major cities like Accra, Kumasi and Takoradi provides a solid basis for adopting best practices or improving existing adaptation approaches. This paper focuses on the documented and projected climate change impacts on key infrastructure (transport, housing, energy, water supply, waste facilities and telecommunication). It introduces the various adaptation approaches for infrastructure by planners and policy makers in Ghana and compares them to international practices. It then examines the impacts, which have already happened due to changes in temperature, rainfall and sea level rise, and compares them with what could happen in the future. The report card approach is used to rank the impacts based on a level of confidence. The juxtaposition of the results from this approach with current adaptation approaches for infrastructure in Ghana and international approaches provides new insights on how different methods can be applied in helping Ghanaian cities develop resilient infrastructure in light of increasing climate change impacts.

Key Words: Climate Change, Critical Infrastructure, Vulnerability, Adaptation and Resilient Cities.

1 Introduction

Cities are complex systems, which weave together thousands of economic, social, institutional, and environmental threads that affect individual and societal well-being [1]. Modern cities rely heavily on infrastructure. This is because infrastructure installations and networks embody and connect to critical sectors of the economy. Indeed, integrated infrastructure networks have been central to urban growth allowing cities to expand and support increasing populations [2].

For this study, the emphasis is on physical built critical infrastructures that make urban space and facilitate urban routine. Such infrastructures include urban buildings and spaces, energy systems, transportation systems, water systems, wastewater and drainage systems, communication systems, and other products of human design and construction intended to deliver services in support of human quality of life [3]. Experience over the past decade shows vividly how vulnerable such infrastructures can be to the types of extreme weather events projected to be more intense and/or more frequent with future climate change. Vulnerabilities and risks are associated with changes in average temperature and temperature extremes, including heat and/or cold waves; changes in amounts and patterns of precipitation, including extreme rainfall events and flooding; and sea-level rise [3].

Recent studies show that developing countries like Ghana are the most vulnerable to climate change impacts because they have fewer resources to adapt: socially, technologically and financially [4] [5]. There is a broad recognition that climate change is a significant development challenge in Ghana. Ghana's National Sectoral Climate

Change Vulnerability and Adaptation Assessments, 2008 revealed the substantial impact of climate change on the national economy [6] [7].

This paper examines the vulnerability of critical infrastructure in cities in Ghana and looks at adaptation approaches. It addresses the following key questions:

- What are the identified vulnerabilities and documented climate change impacts on critical infrastructure in cities in Ghana?
- What are the current adaptation approaches juxtaposed against international best practices?
- How can planners and developers in cities in Ghana develop resilient infrastructure to adapt to current and future climate change effects?

The key contribution of this paper is two fold. Firstly, it identifies and examines existing and possible vulnerabilities of critical infrastructure to climate change impacts and risks. Secondly, it examines current adaptation approaches and proposes possible means to ensure resilience of infrastructure to the changing climate in Ghana. This is because current and future vulnerabilities of critical infrastructure in cities in Ghana will depend on the type of developmental path pursued. This is relevant because formulating climate change adaptation based on identified current and future vulnerabilities and hazards helps planners and policy makers make the appropriate adjustments and changes in cities concerning critical infrastructure development.

2 Ghana's Infrastructure Development amidst Climate Change

The manifestation of climate change shown in rising temperatures, declining rainfall totals and increased variability, rising sea levels and high incidence of weather extremes and disasters are becoming prevalent in Ghana [8]. The impacts of these changes will adversely affect infrastructure especially in Ghana's rapidly developing cities. Ghana's key infrastructure base, as found in the rapidly developing cities, includes but is not limited to transport infrastructure, housing development, energy infrastructure, and water and sanitation systems. Although Ghana's infrastructure base has improved considerably over the last few years, it still falls considerably short of the requirements of a middle-income country [9].

Clustered in the south are most of Ghana's cities, and subsequently the majority of infrastructure, especially in the 200 km triangle between Accra, Kumasi and Sekondi/Takoradi (See Figure 1) [10]. The distribution of Ghana's infrastructure networks generally reflects the spatial distribution of economic activity and demographics. Population of the major cities have increased and so has their infrastructure. Ghana's infrastructure therefore broadly follows the north/south pattern with major transport, power and communication infrastructure networks in the south and southwest [11].

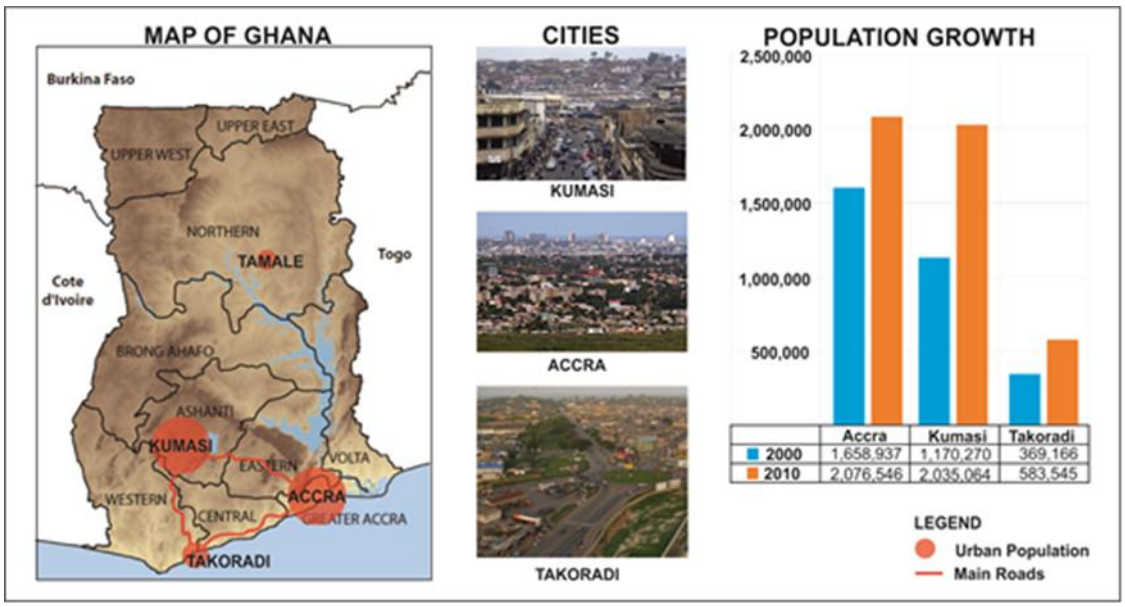

Figure 1: Location of Ghana's cities (Source: 2010 Population and Housing Census).

Over the years, provision of infrastructure in Ghana have not taken into consideration additional climate-risk especially at the design stage. The ultimate effect is that in times of intense climatic impacts such as flooding, infrastructure facilities are not able to withstand the shocks [12]. Coastal erosion aided by rising sea levels has engulfed a substantial portion of the east coast, carrying along millions of dollars of investments in infrastructure. Heavy downpours have affected the road network, and flooding has also affected public infrastructure [13].

The challenge, therefore, is to ensure that infrastructure is 'climate-proof', meaning that it will keep working to support economic growth, whatever the future weather conditions may be [14].

2.1 Critical Infrastructure in Ghanaian Cities

Critical infrastructure consists of those physical and information technology facilities, networks, services and assets, which, if disrupted or destroyed, have a serious impact on the health, safety, security or economic well-being of citizens or the effective functioning of governments [15]. This includes networks and facilities associated with energy and water supply, sewage and waste removal and treatment, and telecommunications. For example, increased flooding is one of the most significant risks, which affects virtually all types of infrastructure. Flooding of electricity substations may leave large areas without electric power, while inundation of water treatment or sewage treatment plants can cause pollution of water and have serious epidemiological implications [3] [16].

Ghana's critical infrastructure in cities consists mainly of water storage and treatment, waste management and landfill sites, energy (mostly electrical), communication hubs and masts, transport network and housing [17] [18] (See Figure 2).

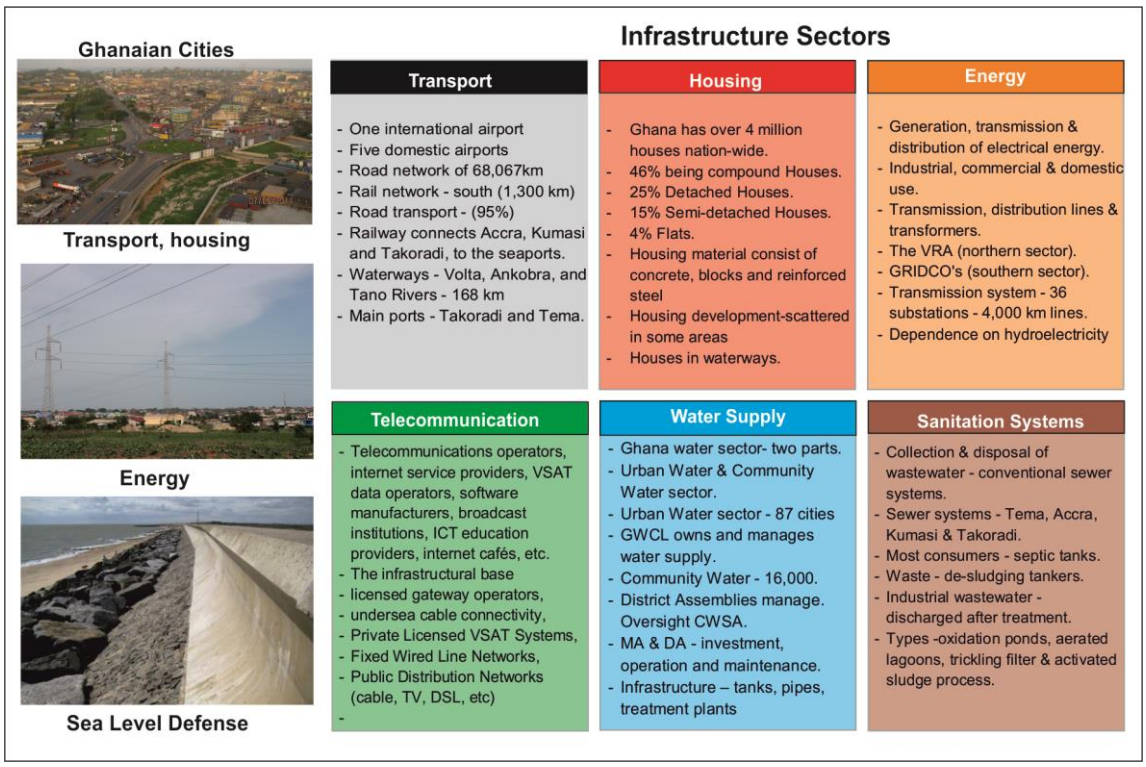

Figure 2: Critical Infrastructure in cities in Ghana (Source: NCCC, 2010).

2.2 Vulnerability and Climate Change Impacts on Ghana's Infrastructure

Over the years, Accra, Kumasi and Takoradi have experienced climate change impacts such as floods, rainstorms and strong winds affecting infrastructure such as roads, dams, power distribution lines, homes, and drains. A close look at the impacts shows the need for adaptation. Disasters are becoming more frequent than before. This means the focus of research on infrastructure development and capacity building to combat climate change hazards is relevant, especially in cities [19].

To understand the vulnerability of infrastructure in Ghanaian cities, there is a need to examine what has already happened and what is likely to happen in the future.

2.3 What has happened to date

Over the years, Ghanaian cities have experienced the impacts of climate change, which have destroyed critical infrastructure and thereby affected the function of the cities. The impacts include flooding of roadways, energy and telecommunication infrastructure [20] [21]. Sea level rise inundating sanitation systems and causing the corrosion of water conveyance infrastructure [22] as shown in Figure 3.

Figure 3: Documented impacts of climate change. (a) Flooding of houses in Accra (b) erosion of road due to sea level rise, Teshie (Source: Asamoah, 2012).

2.4 What could happen in the future

Ghana's location is in one of the world's most complex climate regions, affected by tropical storms, and the climatic influence of the Sahel. As in many other countries, there is debate on likely climate change scenarios, and various models and projections. Their conclusions vary enormously, creating real uncertainty about the future scale and impact of climate change, and there is a pressing need for more reliable and current data. Nevertheless, they show clear signs of climate change, and confirm Ghana's vulnerability. While their precise conclusions vary, they agree on two key issues. Clear signals of warming and sea level rise in all models [12]. The main areas at risk, observed through modelled climate change, which affects infrastructure, includes temperature, rainfall and sea level rise [23] [24] [25].

3 Climate Change Adaptation Approaches: Critical Infrastructure

Due to factors including expanding populations, and urban landscapes, cities face a particularly strong adaptation imperative. Current weather extremes and the threat of further rapid climate change should force sustained contemplation of what this means for planning cities today and for the future [26].

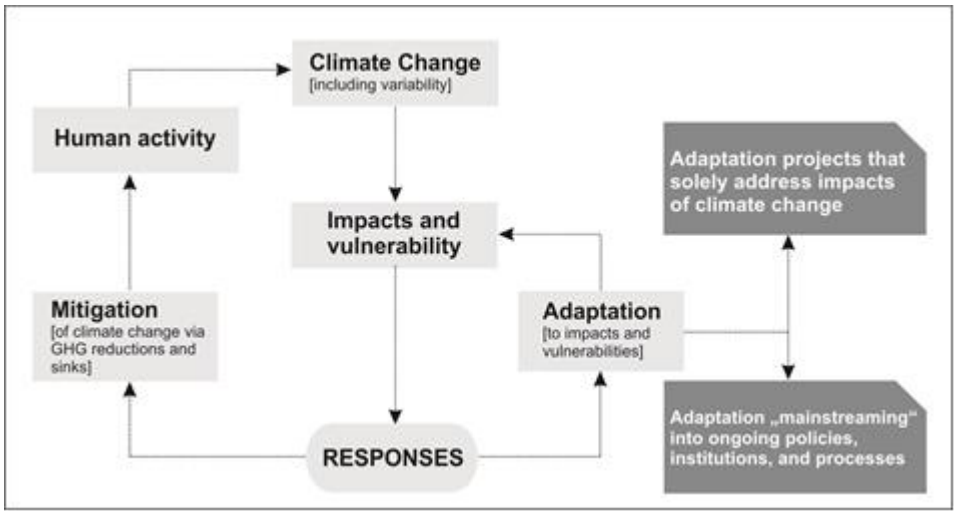

Figure 4: Climate change adaptation (Source: Adapted from Lemmen et al. 2008).

Figure 4 shows that to understand the what, how and when to adapt, identification of the vulnerabilities and impacts caused by climate change is necessary. Adaptation is a process through which societies make themselves better able to cope with an uncertain future. Adaptation for critical infrastructure ranges from technological options such as increased sea defences or flood-proof houses on stilts, early warning systems for extreme events, better water management and improved risk management [5]. The goal is to reduce our vulnerability to the harmful effects of climate.

3.1 International Best Practices and Local Approaches

Though research on the impact of climate change on infrastructure in Ghana is not substantial, there is a number of international research done [27] [28] [29] [30]. These provide general ideas and recommendations for policy makers and developers in the developing cities in Ghana. Table 1 provides some international best practices for critical infrastructure drawn from research from Mexico, Canada, UK and Indonesia.

Key Sectors	Planning, Policy Changes & Project Development	Construction, Operation, Maintenance & Program Activities
Transport	- Develop Redundant services - Planning (coastal roadway/events) - Update design standards	- Financial/Technical resources - Relocate - Improved Asphalt
Housing	- Integrate climate projections - Reconsider zoning & planning regulations - Update/amend design standards	- Insurance/regular maintenance - Reinforced material - Retrofit - Relocate
Energy	- Plan for redundancy - Integrate sea level rise projections - Update design standards	- Install backup systems - Incorporate structural improvements - Relocate infrastructure
Water supply	- Develop a coastal aquifer protection strategy - Develop water conservation programs - Evaluate options to relocate water treatment infrastructure	- Install new or improved water storage options - Build and operate upgraded water treatment facilities - Relocate at-risk facilities out of flood-prone areas
Sanitation System	- Properly site landfills away from floodplains - Update design standards - Plan for extreme event evacuation	- Prevent erosion of landfill slopes - Frequent maintenance and repairs - Develop new sites in more secure locations
Telecommunication	- Develop Redundant services - Planning (coastal infrastructure relocation) - Update design standards	- Move cables below ground - Protective barriers - Relocate or reroute

Table 1: International Best Practices for Adapting Critical Infrastructure to Climate Change

Compared to international best practices, Ghana's National Climate Change Adaptation Strategy (NCCAS) utilizes a participatory approach and incorporates sectoral vulnerability and adaptation assessments carried out by national experts to develop priority adaptation programs. The long-term goal of Ghana's adaptation strategy is to increase climate resilience and decrease vulnerability for enhanced sustainable development. Some of the current adaptation programs includes the Climate Resilient Strategic Infrastructure Program and the Ghana Urban Transport Project.
Despite these efforts, a number of adaptation needs remain in Ghana. These include developing sector-specific solutions and local-level planning.

3.2 Methodology (Report Card Approach)

The Report Card method assesses scientific evidence regarding the relationship between climate impacts and infrastructure using a level of confidence. The results, juxtaposed with the assessments in Sections 2.3 and 2.4 of this paper provides a clear picture of climate change impacts on infrastructure in Ghanaian cities. The relative significance of the impacts is not considered. This would require analysis of social, economic and environmental implications.

In developing the card, a key objective was to be clear about the level of confidence in the various statements made about the impacts of climate change on Ghana's infrastructure in cities (see Figure 5). Attributed to each assessment is a confidence level (high, medium or low). The assigned levels reflects the degree of scientific agreement in each case as well as the amount of information available. For example, there is a low confidence level, in a conclusion drawn from a few studies, which disagreed with each other. Even though it has high confidence in cases where many separate investigations reached the same conclusion [31] [32] [33] [34] [35] [36] [37] [38] [39] [40] [41] [42].

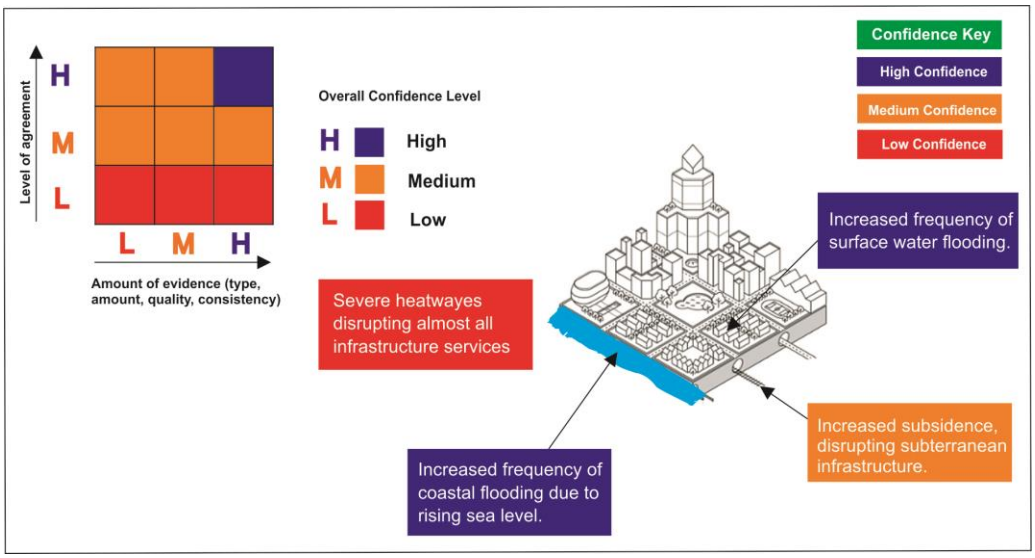

Figure 5: Report Card Approach (Source: Infrastructure Climate Change Impacts, 2015).

3.3 Findings

Table 2 presents the main findings of the Report Card assessment. The first column highlights some existing trends and sensitivities relevant to the relationship between infrastructure and climate in Ghana's cities (Accra, Kumasi, and Takoradi). The second column summarises what may happen over the rest of the 21st century.

Risks	Current trends and sensitivities	What could happen
Temperature	1. Sagging of overhead power and communication lines during hot days. **H** 2. Buckling of railway track, rutting, and melting of road during hot weather. **L**	1. Increase in temperatures and severe heatwaves disrupting almost all infrastructure services. **H** 2. Increase in subsidence affecting infrastructure foundations. **M**
Rainfall	1. Location of infrastructure in areas	1. Increase in frequency of drainage ca-

	susceptible to flooding. **H** 2. Service disruptions and impacts far beyond the flooded area. **L** 3. Increase in impermeable surfaces disrupting natural processes and increasing the risk of flooding. **L**	pacity being exceeded, hence flooding. **H** 2. Increase in incidence of disruption to earthworks. **M** 3. Lower overall rainfall but higher frequency of destructive flash floods disrupting infrastructure. **M**
Sea Level Rise	1. Infrastructure assets, located in the coastal zone. **L** 2. Breach of coastal defences on a number of occasions. **M**	1. Increased likelihood of extreme weather events disrupting coastal infrastructure. **M** 2. Increased rates of erosion and reduced protection from natural barriers. **M**

Table 2: Summary of potential climate impacts on infrastructure in Ghanaian cities.

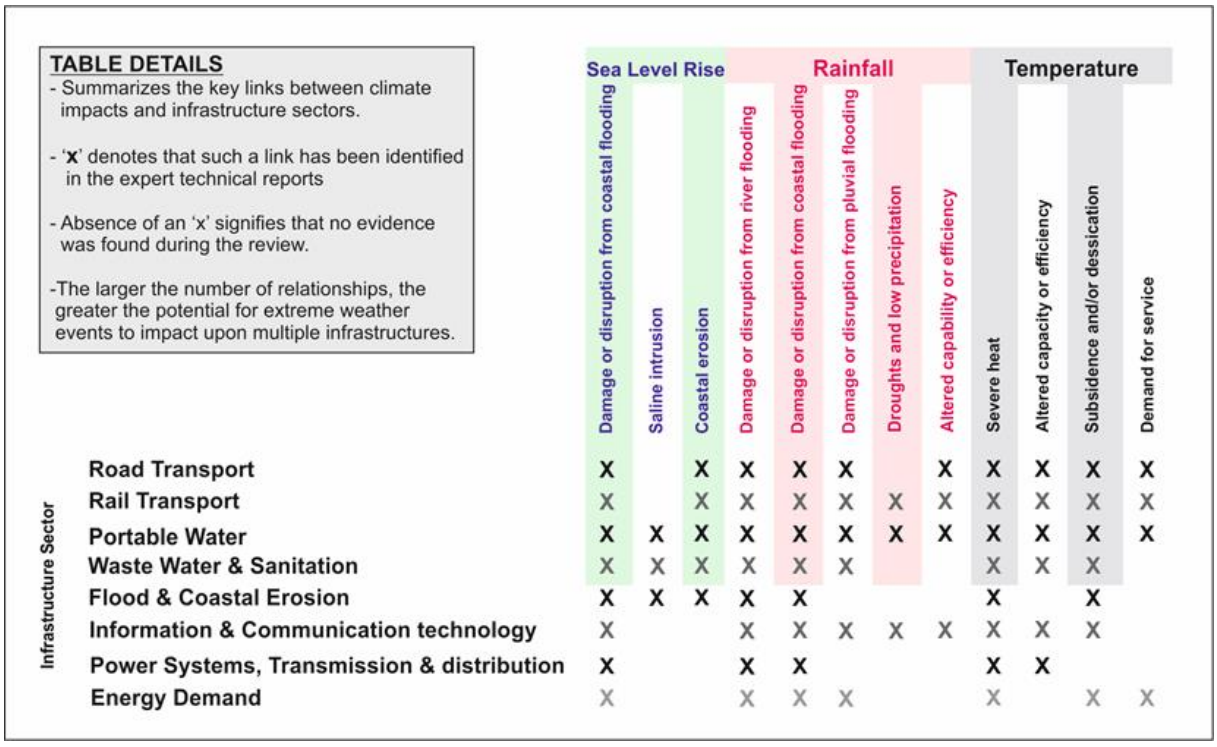

Figure 6: Key Links between climate impacts and infrastructure sectors in Ghanaian Cities.

4 Discussion and Conclusions

Findings from the report card assessment showed that across all infrastructure sectors in cities in Ghana, infrastructure are vulnerable to climate change impacts especially concerning rising temperatures, precipitation changes and sea level rise.

Compared to international best practices, Ghana's current adaptation approaches needs to be mainstreamed and included in regulation and codes. Ghana's National Climate Change and Adaptation Strategies (NCCAS), published in summer 2013 [7], sets out the roles of government, municipal and district assemblies and others in meeting the challenge of climate change, including the Government's adaptation policies and actions. These should be expedited.

The Government of Ghana invests over GHS 2.624 million yearly on infrastructure, most of which are sited in cities. In order to adapt to long-term impacts due to climate change, it is essential that these investments consider adaptation in the context of the potential impacts highlighted in this paper.

Although there is still uncertainty about the nature and extent of future climate change impacts, Ghana should aim at developing resilient cities by incorporating 'climate-proof' infrastructure.

Suggested, therefore, are the following recommendations in **Table 3**.

Sectors	**Recommendations**
Engineering recommendations	• Retrofitting existing infrastructure to be more resilient to impacts. • Building in flexibility to allow modification of infrastructure assets.
Operational recommendations	• Maintaining detailed historical records of damages during extreme events for all critical facilities and city-owned infrastructure. • Monitoring city coasts regularly to check their sea defense systems due to the projected high sea level rises.
Policy recommendations	• Incorporating best practices for infrastructure planning. • Improving data collection, data documentation and data dissemination procedures for cities in Ghana. • Ensuring city planners and developers have the necessary skills and capacity to implement adaptation measures. • Considering future regulations to include impacts of climate change.

Table 3: Recommendations for adaptation of infrastructure to climate change impacts.

5 Future Research

This study revealed that there is a limitation in the research regarding climate change impacts on infrastructure in Ghana. Future research should therefore consider both the risk to infrastructure in cities and social vulnerability when addressing climate change adaptation and planning strategies. Since most rural and peri-urban communities in Ghana are developing rapidly, research into developing comprehensive vulnerability and adaptation frameworks for assessing climate change impacts on infrastructure also requires attention.

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Naya Raipur - India's First Green Field Smart City, An Opportunity for Sustainable & Inclusive City

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Abstract: This paper aims to understand the planning and implementation of the first ultramodern 'Green and Smart City', equipped with all sorts of modern amenities as well as bringing in social cohesion and local inclusiveness. Recognizing the growing demands for high-quality infrastructure in the state of Chhattisgarh, the government decided to develop a modern, hi-tech, eco-friendly capital city - "Naya Raipur", that will serve as the administrative capital of the state and also cater to the infrastructural needs of industry and trade in the region. With the fast pace of urbanisation in Indian cities, it is vital to understand interlinkages between various components of urbanization and provision of sustainable and resilient infrastructure which can be replicable and is sustainable. For planning and strategic development of this new capital city, Chhattisgarh Government constituted Naya Raipur Development Authority (NRDA).

The paper looks into various aspects of Naya Raipur Development Plan 2031[1] with an area of 237 sq.km and targeted population of 560,000 which suggests adopting constant drive and endurance to make Naya Raipur sustainable and the finest city in India. NRDA suggests adopting curative approach towards a feasible and realistic plan which works on making it more adaptable, sustainable, vibrant and resilient. The city managers chose to implement Transit Oriented Development (TOD) model for transport infrastructure. The infrastructure was envisioned as ICT friendly in the Master Plan and subsequently, when SMART city initiative was introduced by Govern-

[1] In India all the states have a separate Urban Planning or Town Planning Act. Some of the state Acts use the term Development Plan instead of Master Plan.

ment of India, the adaption of the same was easily materialized. The paper looks at the financial, social and environmental sustainability for the city with inclusive social planning done through provision of livelihood programmes and equitable access to education and health for all.

Key Words: Smart City, Naya Raipur, Sustainable Development, Infrastructure, Greenfield City, Resilient, Urban Planning

1 Introduction

The city of Naya Raipur came into existence after formation of the new state of Chhattisgarh on 1st November 2000. Initially, the largest city of the state Raipur was named its capital. Raipur has for many decades been a vibrant market place in central India. Yet, with an already burdened civic infrastructure, it was ill-equipped to take on its newfound role as the administrative capital of a rapidly growing state. After prolonged debates, discussions and public consultations a consensus on building a new greenfield capital city was concluded.

The new city was named ‘Naya Raipur’ and is now serving as the administrative capital of the State and catering to the infrastructural needs of industry and trade within the region. The planning and growth of the Naya Raipur city stands as a significant benchmark in rapidly urbanizing India. Naya Raipur has now developed into a world class city with state of the art infrastructure as well as bringing in social cohesion and local inclusiveness. Today, Naya Raipur serves as a role model for various emerging capital cities like Amaravati (of Andhra Pradesh state) and Ranchi the capital city of Jharkhand state (both under planning).

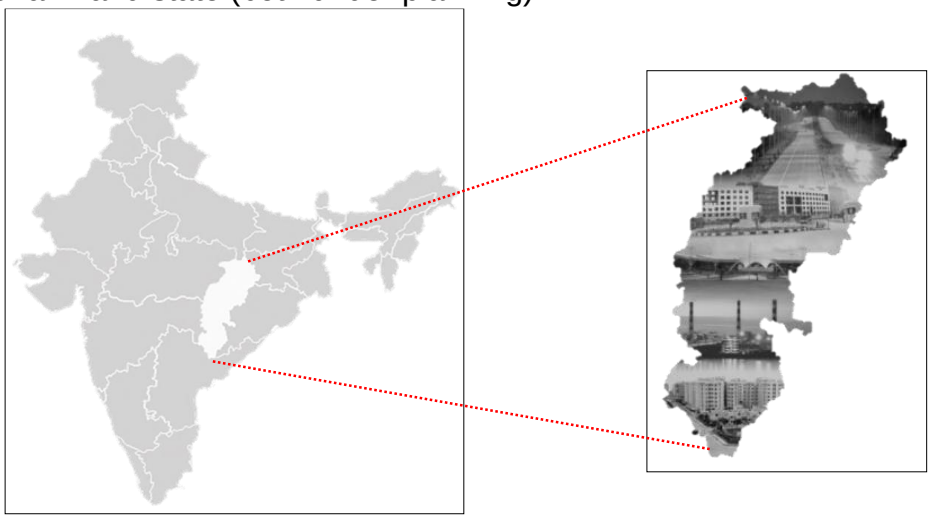


Fig. 1: Map of India highlighting the State of Chhattisgarh

Selection of the site for Naya Raipur was an important step towards making the new city since it involved social, economic, cultural, scientific and environmental considerations and political will. The site suitability and analysis for new city was done within a region of 50km radius. The governing parameters were availability of maximum

government land, land unsuitable for agriculture, minimum forest cover, easy drainage and easy availability of water.

Naya Raipur Development Plan 2031 was prepared with a vision to develop a Green and Smart City, equipped with modern amenities for its residents and visitors. The Development Plan covers a total area of 237.42sq.km, out of which the core area spreads over 95.22 sq.km. The targeted population for the city is 560,000 by 2031.

2 Planning & Development of Naya Raipur

Naya Raipur Development Authority was formed as a Special Area Development Authority to plan, implement and administer Naya Raipur under the provisions of Chhattisgarh State Town & Country Planning Act, 1973. The first Development Plan published was essentially a physical plan, depicting policy choices in all physical aspects of the city, i.e use of land, housing, commercial activities, leisure, transportation, communication, physical and social infrastructure etc. Later with the change in various national and state policies the state government was proactive in making modifications from time to time in the Development Plan with respect to introduction of concept of Transit Oriented Development (TOD) and planning for Smart Cities.

2.1 Development Plan of Naya Raipur

Development Plan 2031 was published in year 2008 encompassing 41 revenue villages. The Planning Area of Naya Raipur is distributed into three Layers, as mentioned below:

Layer	Area
Layer - I	95.22sq.km. (including 500m wide green belt)
Layer - II	130.28 sq.km (Peripheral Region)
Layer - III	11.92sq.km. (Airport Zone)
Total	**237.42sq.km**

Table 1: Planning Layers as per the Development Plan, Naya Raipur

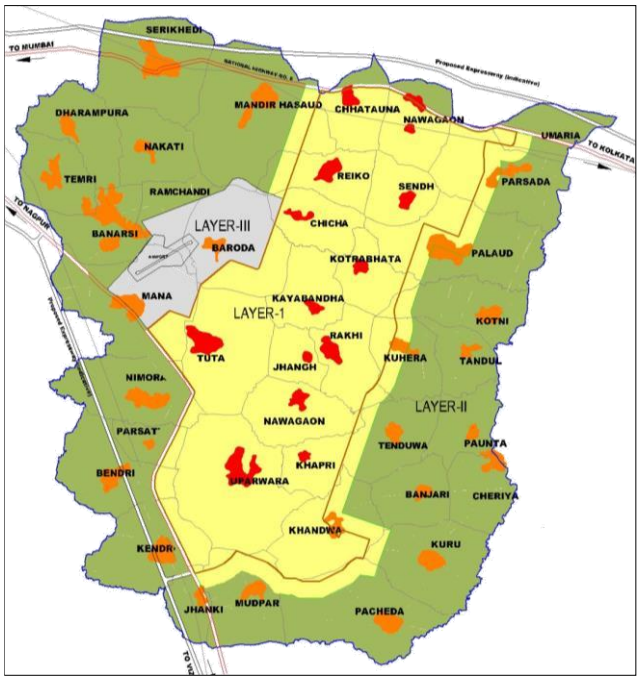


Fig. 2: Map of Development Plan (Master Plan) showing the development in three

2.2 Planning Concept

The planning of Naya Raipur was deliberately designed linear in shape to facilitate Mass Rapid Transit System (MRTS) movement and ease in planning of infrastructure and facilities. The city plan features the following:

- Two axial road corridors were proposed in a cruciform shape.
- The main road, running from transport hub in the north to meet the NH-30 at the southern end of the city, serves as a facility corridor.
- A grid of residential sectors was planned on these two forms.
- It also ensures walkability in the city when combined with MRTS.
- The second axial road acting as ceremonial axis running east west connects the software technology park to the capitol complex with Central Business District and recreational greens alongside.
- This pattern of city ensures rapid transportation, clean subdivision of plots and smooth expandability of city.

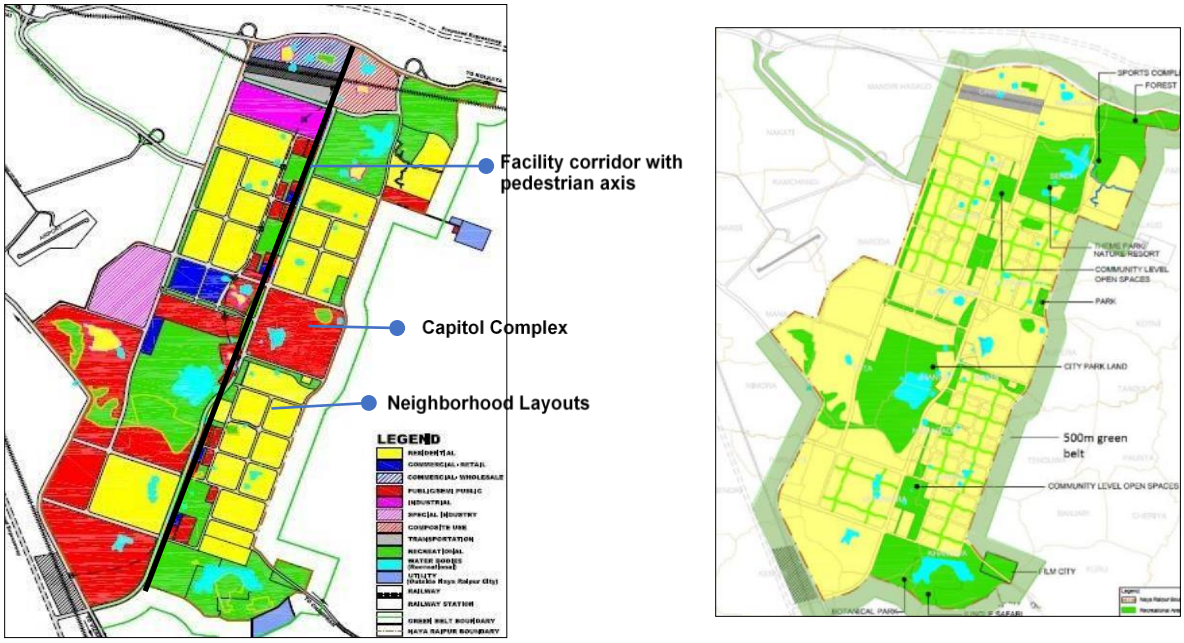
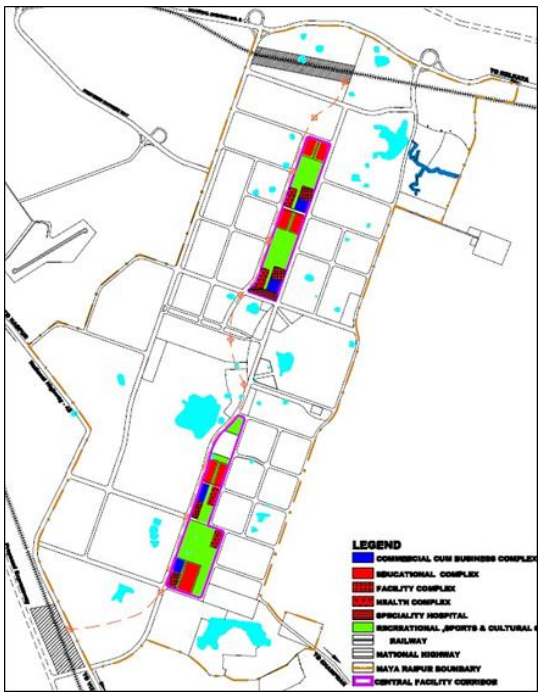


Fig. 3: Map of Planning Concept and Green belt proposed within the Development Plan

2.3 Green Finger Plan

Crisscross green walkways have been proposed and are connected from one end of the city to the other to promote pedestrian and NMT movement. The green belt of 500m width around Layer-I boundary acts as a natural buffer & air purifier for the city.

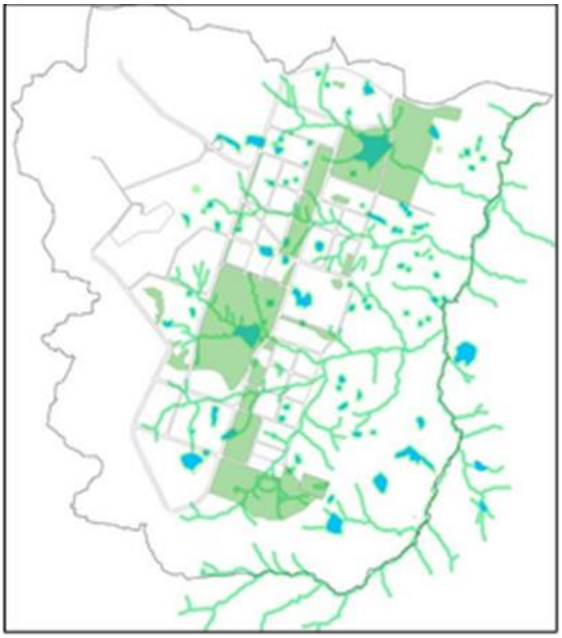
2.4 Planned City Core & Elongated Central Facility Corridor



The greatest problem our cities face worldwide is of managing growth. One of the solution is to leave scope for expansion of the city core. Therefore, provisions for future expansion of the central area viz., the Capitol Complex and CBD have been kept. The planned elongated facility corridor acts as the central spine of the city with independent development nodes to ease pressure as the city grows.

Fig. 4: Map of Facility Corridor within the Development Plan Naya Raipur (Layer 1)

2.5 Conservation of Water Bodies



All water bodies have been retained and even the smallest ones including natural streams, ponds and lakes have been provided with a buffer of 25m. Keeping the climatic conditions in mind, detailed natural drainage analysis based on Sustainable Urban Drainage System (SUDS) model was prepared to retain water in streams, ponds and lakes throughout the year and using the water front for urban activities.

Fig. 5: Map of Streams and open spaces

2.6 Inclusive City Development

a. Village Development Plans (VDPs)

The village settlements in Naya Raipur are declared as urban villages and Village Development Plans have been prepared. Layout plans for the villages have been prepared with provisions for basic infrastructure at par with city level. The same has been implemented with expenditure ranging from 60 million to 200 million INR per village.

Fig. 6: Rehabilitated village - Naya Rakhi, Naya Raipur

b. Housing for All

The planning of the city is contemplated to accommodate housing for EWS and LIG with 25% of area in the residential sectors reserved for the above economic classes.

Fig. 7: Construction of housing done in various sectors

3 SMART City

3.1 SMART City Flagship programme of the Government of India

In 2015 the Government of India launched its flagship programme for SMART CITIES in India. The mission is a bold, new initiative for the creation of such Smart Cities in India. In the approach to the Smart Cities Mission, the focus is on sustainable and inclusive development. The idea is to look at compact areas and create a replicable model that will act like a lighthouse to other aspiring cities.

3.2 SMART City - Naya Raipur

NRDA is implementing Smart City systems covering the following six sub-systems:

a. **Smart Governance (Application) including Common Portal -** Various GIS and IT based models and sub-models are being developed which will integrate data at various levels and facilitate provision of city portal and mobile applications.
b. **City Surveillance -** City Surveillance System will be integrated with the city command and control centre.
c. **Utility Management System -** SCADA (Supervisory control and data acquisition) system is being developed for various utility management services and shall be integrated with the Development Plan.
d. **Intelligent Transport Management System (ITMS) -** Equipment is being installed for detection of speed violations, automatic number plate recognitions.
e. **Command and Control Centers (CCC), Data Centers and Integrated Building Management System -** CCC is being developed for a central control and monitoring of all systems in one platform.
f. **Smart Network and other networking -**The last mile physical connectivity between all field level equipment & central control is being planned which include:
   - City guide map available through web browser and ITMS
   - Wi-Fi and touch screens around the city
   - Display boards across the city for real time information
   - Applications for emergency alert and crisis response systems

3.3 Sector Development

The Layer I of Naya Raipur city has been sub-divided into 40 sectors. Detailed planning of each sector has been undertaken adhering to the holistic needs of the city while maintaining its own identity.

Fig. 8: Implementation of Pilot project for SMART CITY network in Sector 27

3.4 Urban Design Elements

The Urban Design of Naya Raipur combines the traditional with a futuristic vision, lending elegance to its well-known/popular physical features, resulting in a soothing ambience to its inhabitants.

a. Visual corridor and Vistas

A 7.5km long corridor is envisioned as a seamless public walkable space offering a sense of linearity with landscaping on either side. In addition, the central boulevard is a 200 meters wide road located in the center of Naya Raipur running from west to east.

b. Pedestrianization

The North Block has been taken up as a model area to create a barrier free and boundary-less precinct for enhanced pedestrian walkability and promotion of NMT.

c. Façade

Draft guidelines for energy efficient and environment-friendly façade materials and colours of buildings in the city have been prepared for implementation.

4 Dynamic and Flexible Development Plan for Futuristic City

Following the constant drive and endurance to make Naya Raipur the finest city, the NRDA works on making it more adaptable, sustainable, vibrant and resilient. Though the original Development Plan envisioned MRTS, the real essence of success of mass transit was realized at the time of detailed planning and implementation of BRTS. After analyzing various options, NRDA selected the Transit Oriented Development (TOD) model for development just after four years of the publication of Development Plan. The modified Development Plan with inclusion of TOD was notified in 2015. Naya Raipur is the first greenfield city in India to implement the TOD**.**

4.1 Transit Oriented Development (TOD) and people friendly movement

The Development Control Regulation was revised to conform to the TOD guidelines.

- Multimodal transit station
- Interconnected streets
- Mixed use development
- Walkability
- Compact development & street facing buildings
- Urban place making and streetscape design
- Bicycle friendly streets / parking
- Urban parks & plazas and architectural variety
- Well-designed transit station
- Reduced parking standards
- Safety & security
- Market acceptance & successful implementation

Fig. 9: Proposed Transit Oriented Zones for Layer 1

4.2 Land procurement

The process of land procurement used is based on the mutual consent of land owners. Consensus was built through continuous stakeholder consultations. Change to Villagers' suggestions were considered in the preparation of the rehabilitation policy. A high-power committee was constituted to take decisions related to rehabilitation plans where it was decided to give 3 to 5 times of prevailing land rates. With this, NRDA has procured more than 90% of required land.

4.3 City level Infrastructure Development

The planning of infrastructure has been done utilizing state of the art technologies while conserving the natural resources. NRDA has envisaged the development of city on self-sustainable financing model. Various infrastructure projects like city level water supply, logistics hub and real estate projects like hotel, golf course, themed township, sports city, etc. are being developed. The infrastructure was envisioned as ICT friendly in the Development Plan itself and subsequently, when SMART city initiative was introduced by Government of India, the adaption to the same was easily materialized. For SMART city implementation, GIS mapping of all utilities and addition of SCADA system is being done.

4.4 Transportation System

The transportation network for NRDA was based on the concept of accessibility, affordability, equitable and safe mobility. 100km of four and six lane city level roads have already been constructed with 55km of LED street-lighting. There are dedicated utility ducts incorporated within the right of way of the road with green buffer, pedes-

trian and dedicated lanes for NMT & BRT. A 20m wide median has been proposed in most of the roads with a vision of future expansion.

A railway line has been planned and implemented connecting Naya Raipur to the main rail network within the country. Four railway stations within the planning boundary of NRDA will provide access to most of the sectors and villages. Other ongoing projects are Public Bike Sharing Scheme, Multimodal Logistics Hub and Last Mile Connectivity with e-IPT.

4.5 Power Supply

The focus is on provision of 24x7 power supply available, reduce transmission and distribution loss. NRDA intends to increase its renewable energy resources and continue to achieve more in this sector. Some of the key features of the smart energy system are to reduce redundancy, underground cable network, solar panels, wind powered street lights (pilot project), intelligent street light management system, smart meters, electrical charging stations.

4.6 Water Supply

A water treatment plant has been set up and treated water is supplied to the residents since year 2015. Existing system is being upgraded and SCADA system is being set up to increase the system efficiency by future provision of 24x7 fully pressurized Water Supply System, for real time monitoring, automatic meter reading and its integration with billing software.

4.7 Drainage and Sewerage System

Naya Raipur shall be covered with 100% piped domestic waste water collection and is in the process of becoming a Zero Discharge City. Storm water, sewerage, recycled waste water networks, decentralized STPs and sensors for monitoring these systems are under implementation. The recycled water will be consumed for flushing and gardening.

4.8 Communications

Naya Raipur is leading ahead of various cities in India with 75kms of fiber optic cables already laid within the city. It is planned to provide the city with various Wi-Fi hotspots for easy access to communication. Smart communication (wired & wireless) shall be the backbone of NRDA wherein all the government buildings as of today are Wi-Fi enabled.

4.9 Social Infrastructure

Residential sectors have been planned on neighborhood concept to provide world class education, health & recreational facilities through various financial models.

a. Education

NRDA is focusing on developing high class educational infrastructure which will serve the entire state. Special areas have been marked to setup schools and colleges. Some of the well-known education institutions like National Law University, IIM,

IIIT, IIMT, HMI and ITM University, AIIMS have already made their presence in Naya Raipur.

b. Health

NRDA is becoming the regional centre for provision of health facilities with a fully-functioning heart hospital. Other upcoming health facilities are AIIMS, Cancer hospital, nursing homes, dispensaries etc.

c. Recreation

All water bodies will be conserved in Naya Raipur including three major lake front developments which shall cater to provision of modern recreation spaces, sports tourism and nature tourism. Asia's largest man-made Jungle Safari is functional in 800 acres and Botanical garden is being developed. The central park and central boulevard are developed as modern, activity-oriented parks for all age groups. A heritage museum is developed in 170 acres and International Cricket Stadium with a capacity of 50,000.

5 Towards Sustainability

5.1 Economic and Financial

The development of infrastructure has been capital-intensive for which huge capital was required. The strategy was to develop state of the art infrastructure in place first prior to movement of the habitations. The initial investments came from various sources, majority through long-term loans. However, a detailed meticulously prepared business plan outlines the financial needs from time to time. Projects were identified for planning and implementation in phases. The identification process involved criteria like market demand, socio-economic needs of the city increased habitation and a financially sustainable city. To address the goal, it was important to bring in private investor participation. The city is moving towards financial sustainability with more than 8000 hectares of land in possession and an investment of INR 400 billion already made in world class infrastructure.

5.2 Environmental

Naya Raipur is developing as a unique example for reducing dependency on non-renewable resources. SMART city surveillance will further augment the optimal consumption of water and electricity. 38.3% of the area (Layer I with the 500 meters wide green belt around) is reserved for green spaces and plantations have already come up in these sites. Further, there is innovative use of open spaces through green-blue corridor. Green building concept is the key parameter for development of buildings in NRDA. All government buildings are being built on the Green Building concept. Development around the natural streams and drains connected to these lakes are being planned so that the water table is conserved and recharged. The NMT movement and ease in pedestrian movements planned across the city will reduce the carbon

footprints. Solar city, zero discharge water, charging points for e-vehicles, etc. (as discussed earlier) are under implementation.

5.3 Social

Naya Raipur is designed as a “City for All”. While planning the residential sectors, all sections of society have been provided housing where social inclusion has been a priority while implementing VDPs. Targeted training programmes have been imparted to the local populace and informal markets lead to alternate livelihood opportunities. Inclusive social planning has been done through provision of livelihood programmes and equitable access to education and health for all.

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Session 3

Mobility in Resilience - Oriented Planning and Smart City Concepts

An Agent-Based Modeling Approach for Shared-Use Mobility - A Proof of Concept Study

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Abstract: The rising demand for and fast growth in ride-sourcing and shared-use mobility services (4 billion rides in 2017 for Uber only) in the US and across the globe present a drastic change in the way modern societies move in transportation net-works. However, there is a lack of information about the impact such smart mobility services will have on the planning, operation and management of existing and future transportation networks. It is not yet made clear how the service units interact with one another, with service users, with other road users, and with the road networks itself. This lack of information can be seen as a stumbling block at the agency's stra-tegic planning level. It might either result in imposing hurdles on the promising mode (ride-sourcing), as seen in cases of the service banning or restrictions in several cit-ies (e.g. Berlin and London), or insufficient policies to regulate the service in a way to alleviate the additional burden on the cities' infrastructure. This research study aims to develop a performance evaluation tool that helps in understanding the impacts of the fast growing mode on the overall performance of the existing transportation net-

works. In order to achieve this goal, an agent based modelling and simulation (ABMS) approach is proposed.

The approach of multi-agent systems is commonly used to solve a wide range of transportation problems (e.g. equilibrium assignment on the macroscopic level). ABMS approach is selected to provide an extensive and granular computational framework at an acceptable cost. The proposed model will be tested in a microscopic network simulation (mixed fleet) environment. The network scale and level of microscopic granularity will be combined into a modelling framework to leverage the modern simulation and computation capabilities and to help the decision makers and planner better understand this new trend of mobility services. It is essential to understand this mobility trend patterns and interactions prior to the anticipated adoption of autonomous vehicles technology, which is under development by the auto-making, technology, and ride-share industry. The significance of this research can be better understood as a plan-ahead, and within the context of smart city decision making and policy planning. The key research question of this project can be summarized as follows: (1) what is the feasibility of incorporating this trend in a traffic microscopic simulation environment by means of ABMS?; (2) what are the impacts of several scenarios of modal shift(s) on the overall operational performance of the transportation networks under mixed fleet conditions and different set of key performance metrics?. The model will be presented in this paper, along with future directions for testing and calibrating the model.

Key Words: Shared-Use Mobility (SUM), Disruptive Technology, Performance Metrics and Agent-Based Modelling and Simulation (ABMS).

1 Introduction

SUM is an aspect of the globally growing trend of the sharing economy. The anything x-as-a-service (XAAS) business models adopted in sharing economy is the framework where consumers have an access to short-term-use or rent a specific good or service without the need to own it. These goods or services are offered by another owning consumer (in a peer-to-peer model), or offered by a business/ corporate to potential sharing users (in a business-to-consumer B2C model) [1]. These business models are mostly running seamlessly with online transactions, and powered by smart phone technology and web access. In the same regard, shared-use mobility (SUM) trend enables users to have an access to mobility-as-a-service model on “as-needed” basis [2]. Interestingly, the literature does consider the public transit within the SUM operational framework [3]. Thus, there is a technical necessity to classify the SUM services available in the literature with respect to their users’ serviceability. This classification will help later in investigating the impacts (SUM impacts) from networks planning, operations, and management perspectives. This operational classification, suggested in **Table 1**, categorizes the SUM services into three areas of users’ serviceability; namely, light (non-vehicular), medium, and massive SUM services.

Light (Non-vehicular) SUM Services (1 user)	Medium SUM Services (=< 4 users)	Massive SUM Services (> 4 users)
Bike-sharing ▪ Dock-based systems. ▪ Dockless or GPS-based systems. ▪ Low-cost or Tech-light systems. ▪ Peer-to-peer bike-sharing	Car-sharing ▪ Traditional or round-trip car-sharing ▪ One-way or point-to-point car-sharing ▪ Peer-to-peer (P2P) car-sharing ▪ Niche (Marketplace) car-sharing services	Microtransit ▪ "Company-employed drivers operate private shuttle services on dynamically generated routes." ▪ "Services often target employers (rather than individuals), who arrange service for groups of employees traveling between similar destinations."
E-bike	Ridesharing (medium): ▪ Carpooling ▪ Real-time or dynamic ridesharing	Ridesharing (Massive): ▪ Vanpooling: ▪ 7 to 15 persons
Scooter-sharing	Ride-sourcing TNCs (sequential travel; e.g. Uber, Lyft)	Ride-sourcing TNCs (concurrent travel or ride-splitting ; e.g. UberPOOL, Lyft line)
	Taxis and Limos (e-hail)	Public Transit

Table 1: SUM Operational Classification (extracted from [2] [3] [4] [5])

Although the bike-sharing market is globally growing rapidly, this study will tend to focus on the SUM services that were operationally classified as medium and massive, rather than the light ones. This is explained in terms of the level of impact and influence, in addition to the likeability of mode adoption in major trip types (work, school/ university, shopping and recreation), especially in big metropolitan cities, where SUM impacts on the network operational condition would be of significant interest. This typically applies to medium SUM like car-sharing and ridesharing, and of course ride-sourcing.

Traditional or round-trip car-sharing, where users have to return the shared borrowed vehicles to same point of trip start, was the most common model. However, the traditional one is overridden by a relatively new model, which is the one-way or point-to-point car-sharing that provides more flexibility in picking up and dropping off locations, placing it as the fastest growing car-sharing model. Another two models of car-sharing are present and operating in a modern way too; peer-to-peer (P2P) car-sharing and niche car-sharing services.

In ridesharing, the SUM service offered is basically adding passengers to a pre-existing trip, either in a static approach, or real-time basis. Pre-planned static approach is widely used for carpooling (and vanpooling on a larger scale), and often used for commuting to work. One important system feature is that, ridesharing driver is not hired, as will be seen later in ride-sourcing and TNCs. On the massive scale,

ridesharing is of interest in commuting to work trips, taking the form of vanpooling, similar to carpooling, but on a larger (massive) scale [3], serving between 7 and 15 users per trip. The most characterizing feature of vanpooling is that, the used vehicle is owned by a third party (rather than the driver and the riders), and the driver is often a volunteer co-worker [4].

Ride-sourcing, provided by companies like Uber and Lyft, known also as Transportation Network Companies (TNCs), is considered a revolutionary trend in mobility and traveling, involving high level of real-time computations and matching algorithms, equipped with seamless payment and surge-pricing, solving a good number of mobility and traveling problems (e.g. first and last trip mile). The service is offered via smartphone application that pairs riders and community drivers (in non-commercial vehicles) given their spatial (location) and temporal (time) constraints. The service is running seamlessly, with online transactions (e-payment), and surge-pricing scheme matching the supply with the demand [2]. The service is either offered in a form of sequential trips (medium SUM), or concurrently to several riders in a form of ride- and fare-splitting (massive SUM- Uber Pool and Lyft Line).

2 Background and Research Rationale

SUM modes are not all newly introduced; however, they need to be further understood within the contemporary context of ubiquitous smart cities, in which, data (e.g. smart phone data) is the new oil. The common factors between these reviewed modes are the smart operation and the dynamic nature. This is particularly what constitutes the first rationale of this research, which proposes a modern modelling, and simulation tool rather than the classic ones to cope with potential impacts of these disruptive mobility services. The second rationale is the drastically increasing demand on SUM services, not only in the US, yet across the globe, which is expected also to aggravate these potential impacts if not modelled and well-planned ahead of extensive deployment.

2.1 Disruptive Mobility and Growing Demand

Disruption in transportation realm may not be observed as “one particular technology development” [6], rather, it is regarded as the advancement in the way the service is offered, given the available emerging technologies. Thus, SUM service identified as disruptive shall be, in a way or in another, running on a technology that is closely pertaining to one or more of the technological categories identified by McKinsey & Company team [7]. Categories that were found profoundly related to transportation and mobility, and SUM particularly are summarized here as following: (1) Mobile internet, (2) Automation of knowledge work, (3) Internet of things, (4) Cloud technology, and (5) Autonomous and near-autonomous vehicles [7]. In light of this brief definition of disruption in transportation, further elaboration of the exploiting of these enabling technologies will be sought while investigating their demand patterns.

As regards the SUM demand patterns, a brief review is conducted here to show the case. Earliest car-sharing program was introduced to the US in 1994, as for 2015; there were 23 car-sharing operators [2]. **Figure 1** depicts the growth in the demand expressed in the number of members in car-sharing programs. Interestingly, car-

sharing is among the key tools discussed for reducing vehicles miles travelled (VMT) and greenhouse gas (GHG) emissions in California [8]. Another insight from the California Transportation Plan 2014 (CTP) is the enhanced first- and last-mile connectivity provided by one-way car-sharing. These highlights and market insights signal the role expected to be assumed in the near future by car-sharing as a disruptive SUM candidate in the transportation realm. This role is ultimately associated with the emerging enabling technologies that would contribute to this SUM service deployment and leveraging.

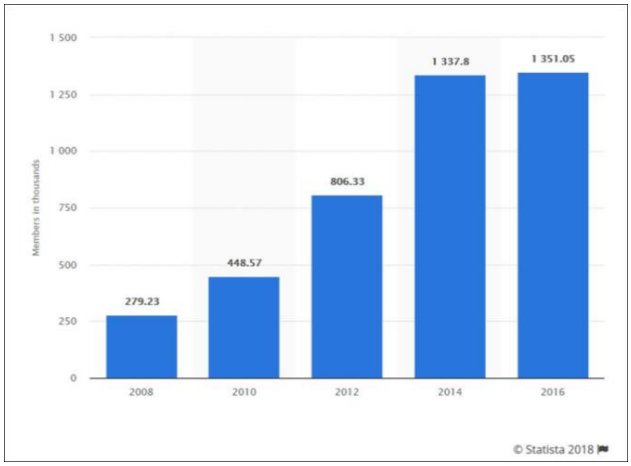

Figure 1: U.S. Car-sharing member growth from 2008 to 2016 (in 1,000s) - source: Statista [9]

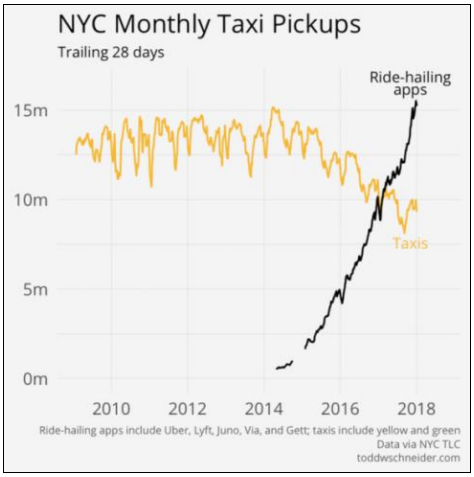

Figure 2: NYC Taxi vs Ride-hailing Apps. - Monthly Pick-ups- source: reddit [10]

As for ridesharing, although it witnessed a remarkable recession since the seventies until 2013 (from 20.4% to 9.3% among the American workers commuting to work), yet retains the second modal share in the U.S. after driving alone according to the U.S. Census Bureau, 2013. Again, the mode has been also highlighted in the California Transportation Plan 2014 (CTP), along with the car-sharing, as promising tools for reducing VMT and GHG. The service extensively relies on mobile internet (and GPS navigation devices) to match riders, and manage routes [11]. Social networking is also making it through contributing to establish accountability and eliminate any security or safety issues that may arise between users. However, it is suggested that connectivity and IoT will have a transformational impact on the way the service operates today. Moreover, it is believed that the autonomous vehicles technology (when deployed) is not far from the ridesharing marketplace [12].

In ride-sourcing, the demand patterns are remarkable. The relatively new SUM mode (known also as ride-hailing apps) surpassed the monthly taxi pick-ups in the city of New York in 2017 (see **Figure 2**), and its business profile is still witnessing an exponential growth. One can easily relate the emergence and the spread of ride-sourcing with the era of smartphones. Indeed, mobile internet, IoT, and cloud technology are all among the service key enabling technologies. Another highlight is noteworthy here; a Forbes article explains why Uber can't make money? The article assigns this to the competition in unregulated expanding market without adapting the business model to this market [13]. This might explain Uber's push toward autonomous vehicles, to replace this massive contracted fleet (and drivers) with robot-vehicles owned

by the company. Figure 3 summarizes qualitatively the enabling technologies level of influence for the three main investigated SUM mobility services.

SUM Mode	Mobile Internet	Automation of knowledge work	Internet of things	Cloud technology	Autonomous Vehicles
Carsharing					N.A.
Ridesharing					
Ridesourcing					

Figure 3: SUM Enabling Technologies- Level of Influence

2.2 SUM Potential Impacts Measures and Key Performance Metrics

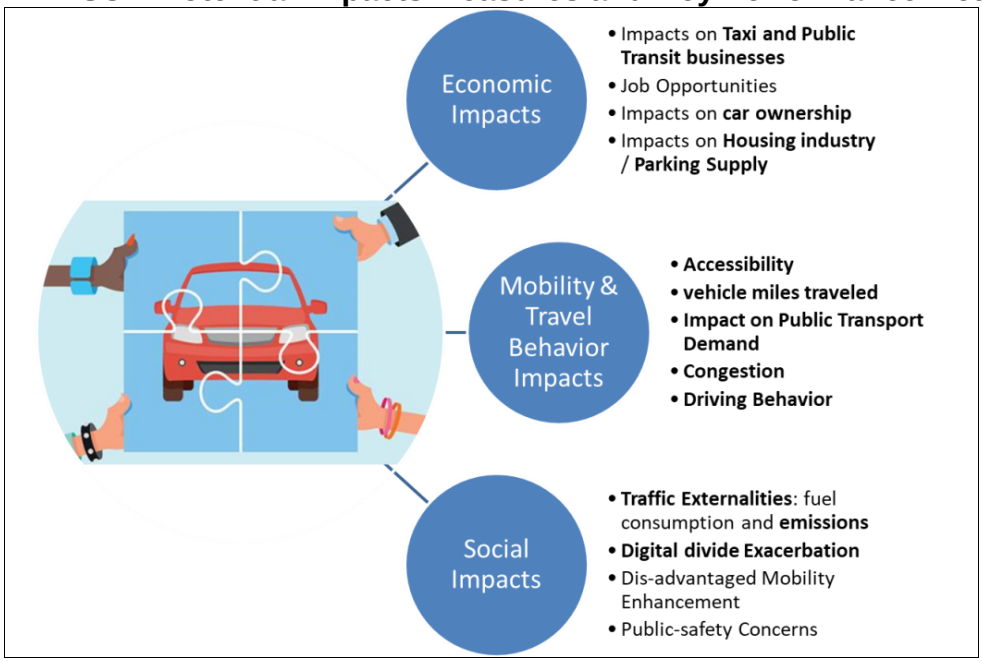

Figure 4: SUM Impact Domains

On one hand, the potential impacts can be categorized in three domains; the economy domain, the domain of mobility and travel behaviour, and the socioenvironmental domain (see **Figure 4**). There are very interesting findings in the literature on SUM impacts on car ownership, car dependency, and consequently traffic externalities. For instance, it was found that 9 to 13 vehicles are simply replaced by a car-sharing vehicle unit [14]. The same study concluded to remarkable figures on the VMT reduction (27 to 43 percent) and GHG emissions (34 to 41 percent) per participating household [2]. Here, the SUM impacts on mobility and travel behaviour will be tackled, as its performance metrics can be easily incorporated in the two other domains.

On the other hand, the literature often investigates the potential impacts of SUM by means of five key measures. These measures are: **accessibility**, **VMT**, **congestion**, **driving behaviour** (safety perspective) [15] and **public transport ridership**. There is no modelling and simulation framework, to the knowledge of the author, which is robust to quantify the impacts of SUM in terms of these measures. Moreover, these measures might not be feasibly integrated in one strategic modelling framework, since they are falling under different scopes (planning, management and operations).

It would be pragmatically beneficial to pursue network level performance metrics in mixed fleet conditions to assess the performance against several scenarios of SUM market penetration. These tactical performance metrics can be: **(1) *number of stopped cars***, **(2) *average speed of cars***, and **(3) *average wait times of cars***, during the study (modelling) horizon. Hence, the developing of a robust high-fidelity modelling and simulation framework for SUM in mixed traffic urban environment is indispensable. And this rationale recall the key research questions of this proof of concept study, first question is the feasibility of incorporating SUM in a microscopic traffic simulation environment, and the second is will this model be capable of tracing its impacts measured by the previously highlighted metrics.

3 SUM Modelling Framework- Literature Review

Early simulation endeavours were conducted in the context of dynamic ridesharing [16] and [17]. They were all pursuing system (ridesharing) advancement by means of using simulation analysis tools. However, the simulation environments overlooked the impacts on the network, and were limited to the one-time shared rides simulation problem. Martinez [18] pursued some endeavours to simulate a shared taxi service, however, the modelling agents and environment were very limited, and the model neglected the interaction with other agents, and the network performance under such circumstances. Further endeavours to investigate the shared-use mobility impacts on the network were conducted later by Levin, [19]. They studied the impacts of shared (and autonomous) vehicles in a traffic microscopic simulation environment using an event-based modelling approach (cell transmission model-based dynamic network loading simulator). This study introduced a heuristic approach for dynamic ridesharing to compare the impacts against different scenarios. They concluded recommending studying the impacts using a realistic traffic flow and congestion models.

Shaheen [20] introduced the agent based modelling and simulation (ABMS) as a realistic tool to model the shared-use mobility. However, the work done was limited to test the ABMS methodology against information symmetry and asymmetry and its impact on the riders, drivers, and service providers utility. Fiedler, D. et al. then investigated the potential impacts of the on-demand mobility on road network congestion and travelled distances by means of large scale multi-agent simulation of vehicular traffic [21], and the conclusion advised for more sophisticated congestion models. Throughout this brief review on the history of modelling SUM in microscopic environment, Agent-based Modelling and Simulation approach can be seen among the most promising approaches in terms of fidelity of results.

4 Agent-based Modelling and Simulation for SUM

In light of these modelling and simulation endeavours reviewed from the literature, a comprehensive realistic framework is needed to fill in the previous work gaps. This proposed framework should account for high-fidelity level of SUM operations, along with other operating modes' granularity and detail. This framework should be compatible with a traffic microscopic simulation environment, considering a mixed fleet in urban environment conditions, so that the shared-use mobility impacts can be better tracked within this context.

4.1 Introduction of ABMS

The ABMS is a relatively new modelling technique to model complex systems without compromising the heterogeneity of the systems' components. In ABMS, complex systems are broken down into candidate agents. In essence, these candidate agents are individual, autonomous, and interacting with each other, and with the system environment. Moreover, agents are modelled to have their own set of rules (responses and adaptation rules) [22] - see **Figure 5**. In other words, they are not statically respondent agents; rather, they are intelligently adapting and learning-from-experience agents. This point is pivotal in modelling complex systems that comprise human behaviour interaction.

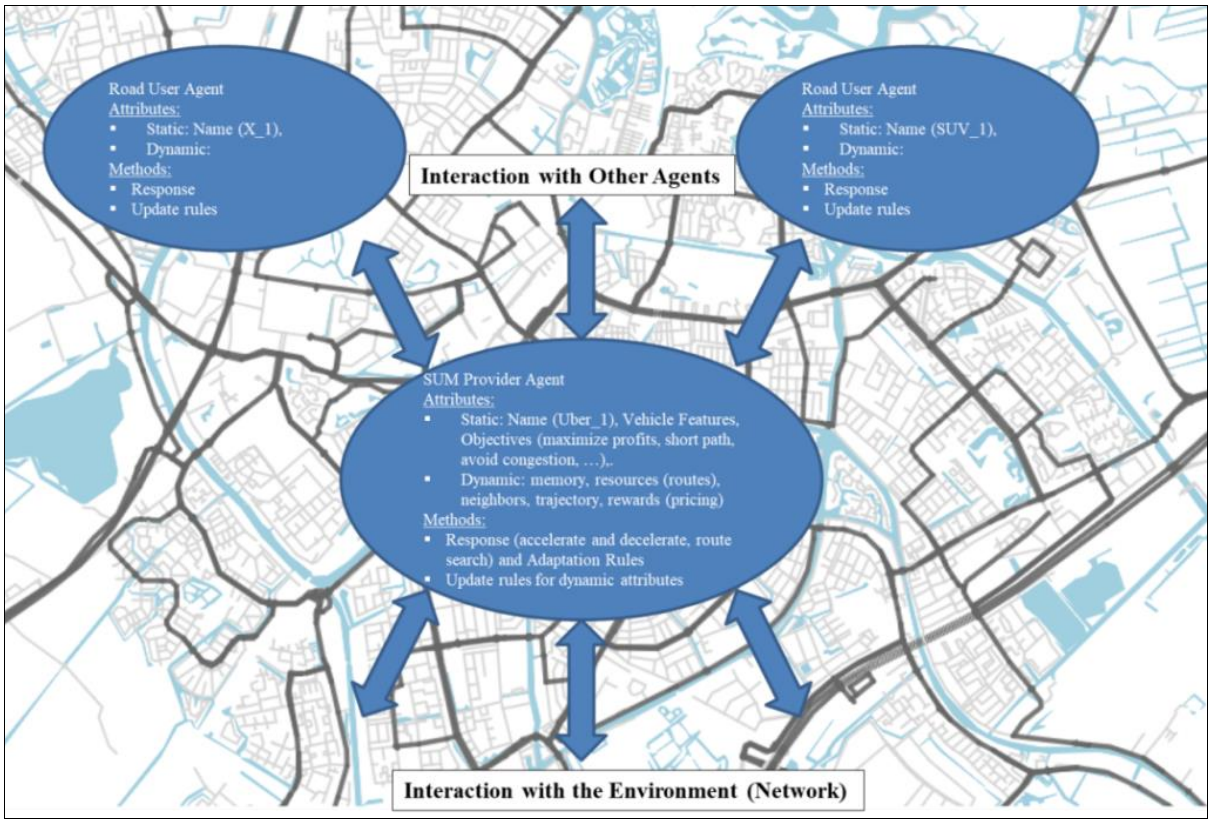

Figure 5: Conceptual Framework of SUM Agent-based Modeling Structure

The novelty of ABMS is that, it is built in a bottom-up approach, modelling agent-by-agent and interaction-by-interaction. This granularity and high fidelity modelling framework of agents, along with artificially-intelligent pre-defined set of rules, allow for observing *patterns*, *structures*, and *behaviours* that were not originally coded, "*but arise through the agent interactions*" [23]. Thus, the ABMS approach can be better understood as a multi-objective modelling framework that can be incorporated in different problem-solving analytics to address and resolve future relevant research problems in different domains. The incorporation of the complexity emerging from individuals' autonomic behaviour and interaction [22], along with the granularity of agents, promises for a high fidelity modelling framework. The structure of agent-based model comprises three main elements (see **Figure 5**):

(1) Set of Agents' **Attributes** and **Behavior**

(2) Set of agents **Relationships** and methods of **Interaction**

(3) The agents' **Environment**

4.2 Technical Merits of ABMS in SUM Context

Primer for Agent-Based Simulation and Modelling in Transportation Applications [24] further highlights the technical strengths of the ABMS approach in representing and analysing complex problems, given specific system attributes (e.g. population heterogeneity, complex agents interactions- nonlinear, or discrete) that is typically present in modelling SUM as a mode in a mixed traffic microscopic simulation environment. Moreover, the approach (ABMS) supports the notion of autonomy, and provides a unified perception of agents [25]; whether naturalistic human drivers, or autonomous vehicles. It promises a margin for introducing complex agents' behaviour, particularly, the ones involving learning and adaptation. This extends the modelling framework to include autonomous interacting agents (artificially intelligent), which would be of significant interest for a wide range of agencies interesting in an off-line testbed for unmanned SUM.

5 Methodology and Model Description

The methodology exploited here in this paper is building on the previous findings concluded earlier regarding one of the eminent SUM operating modes, particularly the ride-sourcing (ride-hailing and mobility services offered by TNCs). These findings were mostly related to its trip patterns that are dissimilar in their nature to other commuters, its real-time preferences update, and the potentially characterizing vehicles' dynamics (picking-up and dropping- related acceleration and deceleration). The tool used in this study is an open access multi-agent programmable modelling environment called "NetLogo" [26]. The model was built by introducing few modifications to one of NetLogo library models, namely, "Traffic Grid Goal" [27], in which; ride-sourcing agents were coded to reflect their characterizing nature.

An agent-based traffic model can be described with respect to the previously highlighted three key components; (1) transport network, (2) set of agents (commuters and ride-sourcers) attributes and behaviour (trip patterns and vehicles' dynamics), (3) set of agents relationships and methods of interaction, in addition to (4) the network key performance metrics. The case study transport network used in the model depicts five-by-seven blocks city-like network, in which SUM operators (shown in yellow colour) exist along with other commuters (in blue) to/from work/home (see **Figure 6** and **Figure 7**). Agents' methods of interaction were simply modelled in a way similar to the car-following model approach.

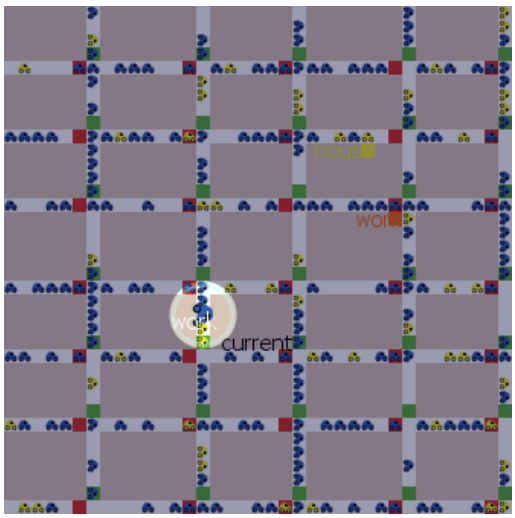

Figure 6: NetLogo Traffic Grid Goal Model

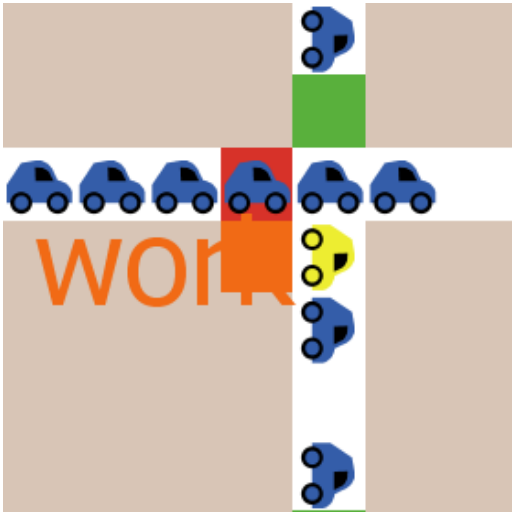

Figure 7: SUM Operator (in yellow) in Mixed Fleet Microscopic Environment

Another key aspect of the model network is the global variables, including speed limit, which is uniform for all candidate agents, and acceleration and deceleration variability, which differs from one agent to the other, according to their set of rules. The mechanics of the modelling environment in NetLogo is quite different from other commercial traffic simulation software packages. In particular, the speed limit is assigned to one, and the agents' speeds, initiated at zero, and measured during the modelling horizon as a fraction of this unit. The acceptable acceleration and deceleration rate of the candidate agents was set to be 0.099 (acceleration units) as of the absolute value of the speed unit. Goal-based cognition is adopted in this model to represent agents set of rules, in which the goal is to drive to and from work. The main principle in model, similarly to other gamified systems' models, is that, for each candidate agents, they update their information in each time step, and behave accordingly, given their goal-based cognition. The key difference between this agent-based model and any other traffic microscopic model is that the portion of the traffic volume (SUM) that exists in the network actively without specific trips' start and end.

6 Analysis and Results

The analysis considered two scenarios of market penetration (10% and 20%), with total network traffic volume of 350 units (assuming trip generation rate of 10 units per bock for purpose of computations feasibility). The modelling horizon is set to be 200 time step (comprising 10 modelling cycles). The simulation results provides high fidelity key performance metrics (see **Figure 8** and **Figure 9**), and support the early hypothesis of SUM changing impacts corresponding to different market penetration and network operational conditions scenarios.

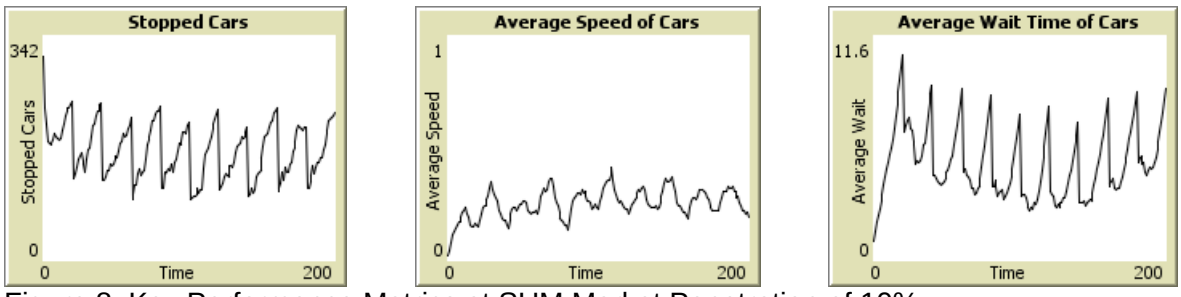

Figure 8: Key Performance Matrics at SUM Market Penetration of 10%

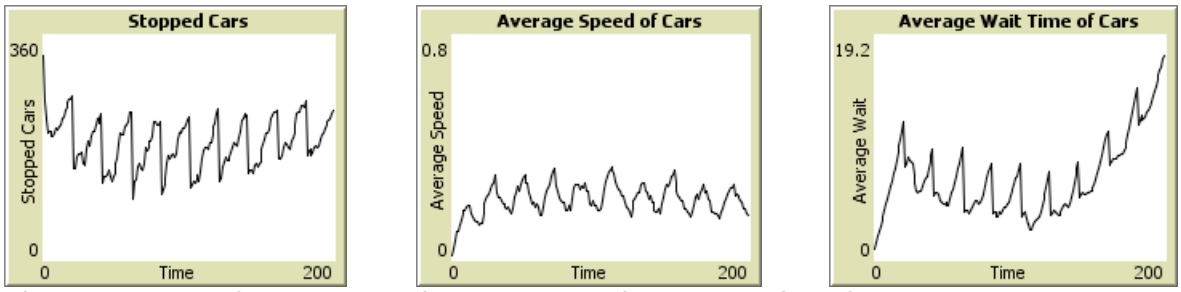

Figure 9: Key Performance Matrics at SUM Market Penetration of 20%

7 Conclusion & Recommendations

Although the agent-based model developed in this paper is simple, and given the lack of data and the confidentiality of TNC's protocols and objectives that placed non-trivial limitations on studying the phenomenon, yet, the approach proofs high fidelity and robustness in studying and quantifying network performance indicators corresponding to different scenarios of SUM market penetration. On one hand, this would help the decision makers and planner better understand this new trend of mobility services. On another hand, this proof of concept study opens the door to unleash the power of ABMS approach in exploring further performance metrics on the different levels of impact revealed in this paper. The recommendations made in this regard is to investigate the ABMS approach in modelling SUM in more sophisticated traffic microscopic simulation environment (e.g. Vissim), with agents attributes coded in a high-level programming language (e.g. Python).

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Capacity Analysis of the Stuttgart Stadtbahn 2018 Network Considering the Construction of Stuttgart 21

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After her graduation in 2008, she began working for VWI GmbH in Stuttgart, Germany. She has worked on projects on the topics of train dispatching, capacity research, standardized evaluations, and capacity building for clients such as Deutsche Bahn, Stuttgarter Straßenbahnen, Thales, and small and large communities and cities. After a 3-year break to learn Mandarin Chinese in Shenzhen, China, she returned to VWI GmbH in 2015 where she is currently working. The most important contribution of the MIP is that she was exposed to the different disciplines of infrastructure planning, which gives her a comprehensive view on the work she currently does.

Abstract: Due to the construction of the Project Stuttgart 21, the Stadtbahn (U-Bahn) connection between the Main Train Station and the Staatsgalerie Station was closed and new operational modifications had be done during this period. This presentation focuses on the resilience of the Stadtbahn, the alternatives to re-route the Stadt-bahn lines, and a recommendation as to which SSB network variation should be the 2018 Network. The project includes a capacity analysis, a bottleneck analysis, and an operational quality analysis. The following chapter shows the presentation slides presented during the conference MIPALCON 2018.

Key Words: Capacity Research, Capacity Analysis

Verkehrswissenschaftliches Institut Stuttgart

On behalf of the client:
SSB AG

University of Stuttgart
Master's Program Infrastructure Planning

Capacity Research of the Stuttgart Stadtbahn 2018 Network Considering the Construction of Stuttgart 21

MIP Alumni Conference 2018

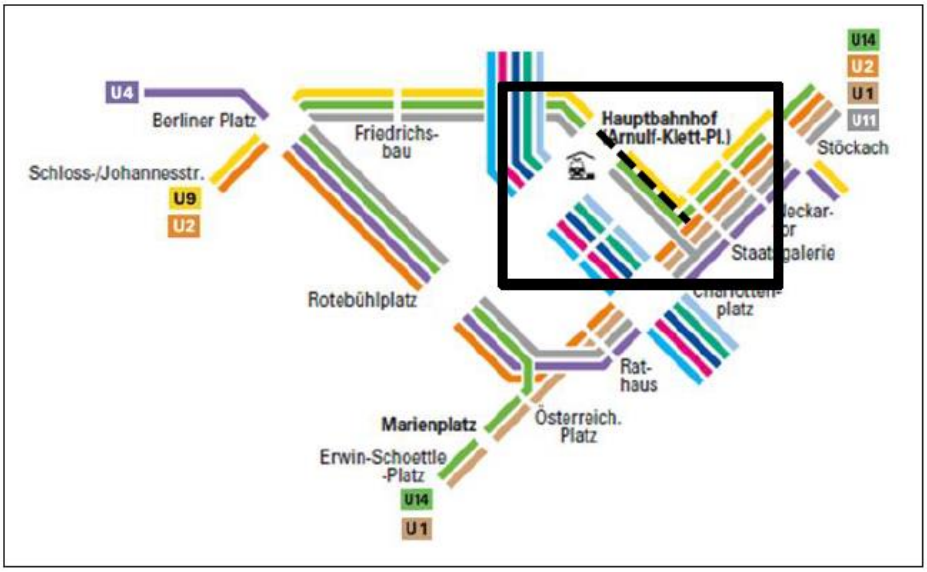
Maureen B. Kösters, M.Sc.

26.09.2018

Slide 1

Introduction

Due to the construction of Stutgart 21, the connection between the Main Train Station and the Staatsgalerie Station has to be temporarily closed.



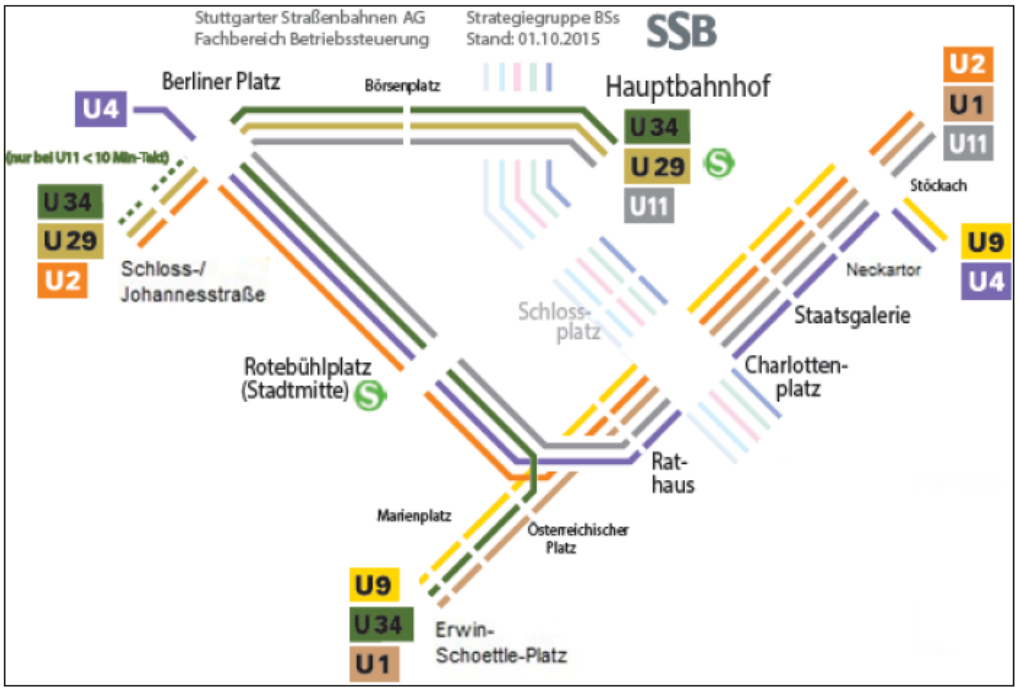
Slide 2

Questions

- How resilient is the Stadtbahn (U-Bahn) network when faced with infrastructure constraints?
- How should the Stadtbahn lines be rerouted in order minimize potential delays due to the change in the infrastructure?
- Which SSB network variation (Variation 1 or Variation 4) is better suited to be the „Network 2018“ based on:
  - Its overall capacity → **Capacity Analysis**
  - Its potential for bottlenecks → **Bottleneck Analysis**
  - Its ability to reduce delays that are already in the Stadtbahn network → **Operational Quality Analysis**

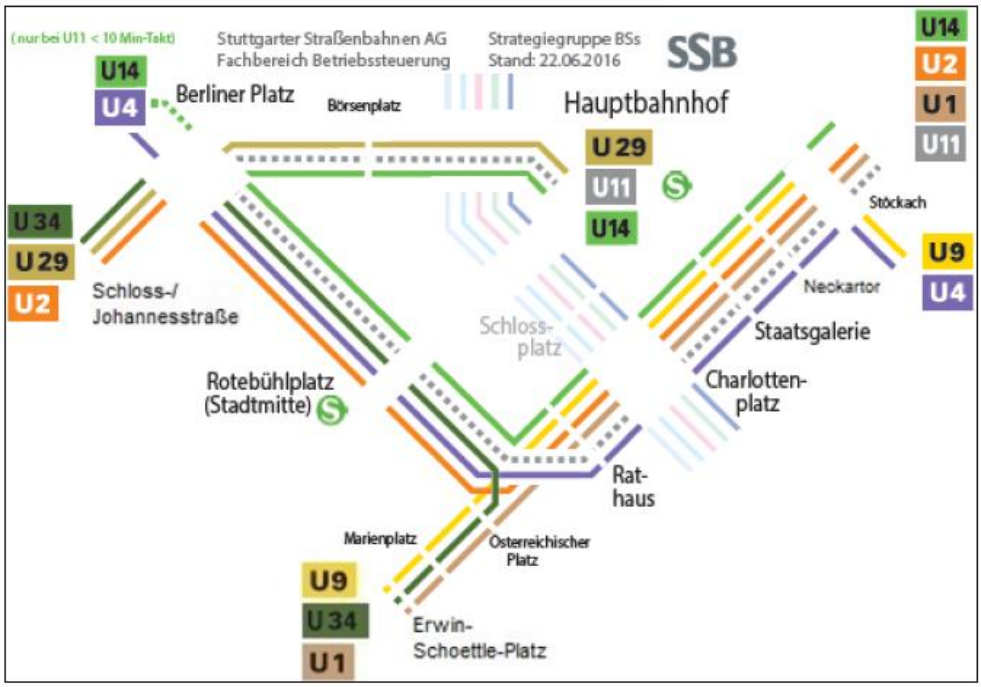
Slide 3

Variation 1



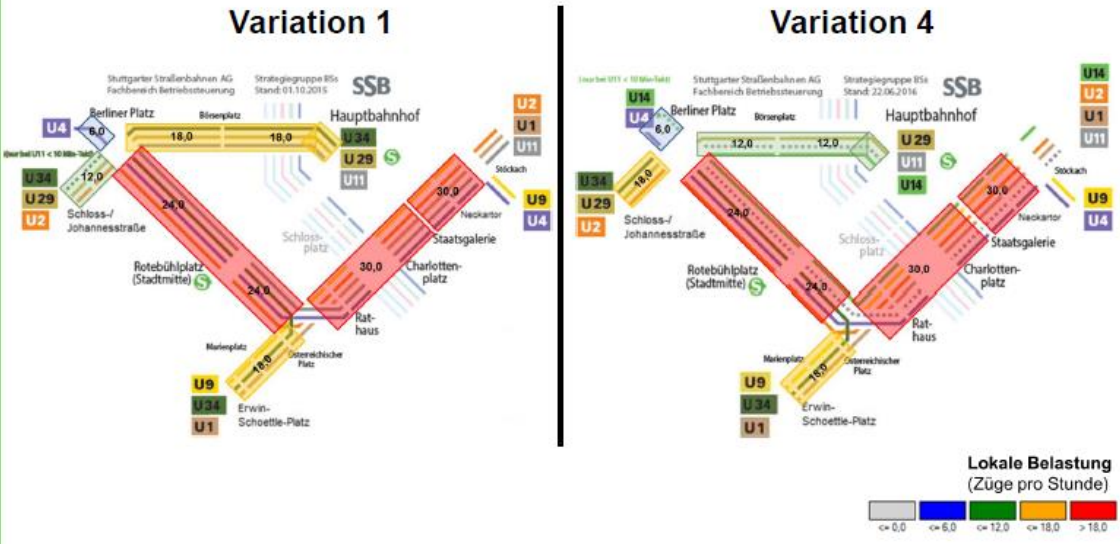
Slide 4

Variation 4



Slide 5

Comparison of the Variations



- The traffic flow in the entire study area was the same in both variations for regular service (84 trains/hour).

Slide 6

Cases based on Type of Service

	Variation 1	Variation 4
Regular service	U11: 10-minute headway	No U11
Event service 10 min.	U11: 10-minute headway	U11: 10-minute headway
Event service 5 min.	U11: 5-minute headway	U11: 5-minute headway

- For this presentation, only the case results based on „regular service“ will be presented.

Slide 7

Capacity Research

	Goal	Qestions	Reference
Capacity Analysis	Deterimnation of the capacity characteristics of the entire study area	• What traffic flow [trains/hour] is the most economical considering the given infrastructure and operating program? • How do the trains influence each other with respect to the traffic flow (trains/hour)?	Approximate operating program
Bottleneck Analysis	Localisation of potential bottlenecks	• Where are the bottlenecks? • What is the reason for the bottlenecks?	Approximate operating program
Operational Quality Analysis	Determination of the delay coefficient in the study area	• How do the delays caused by inputted timetable disruptions (initial delays, dwell time delays) change during the course of a concrete timetable?	Concrete timetable with specified disruptions

Slide 8

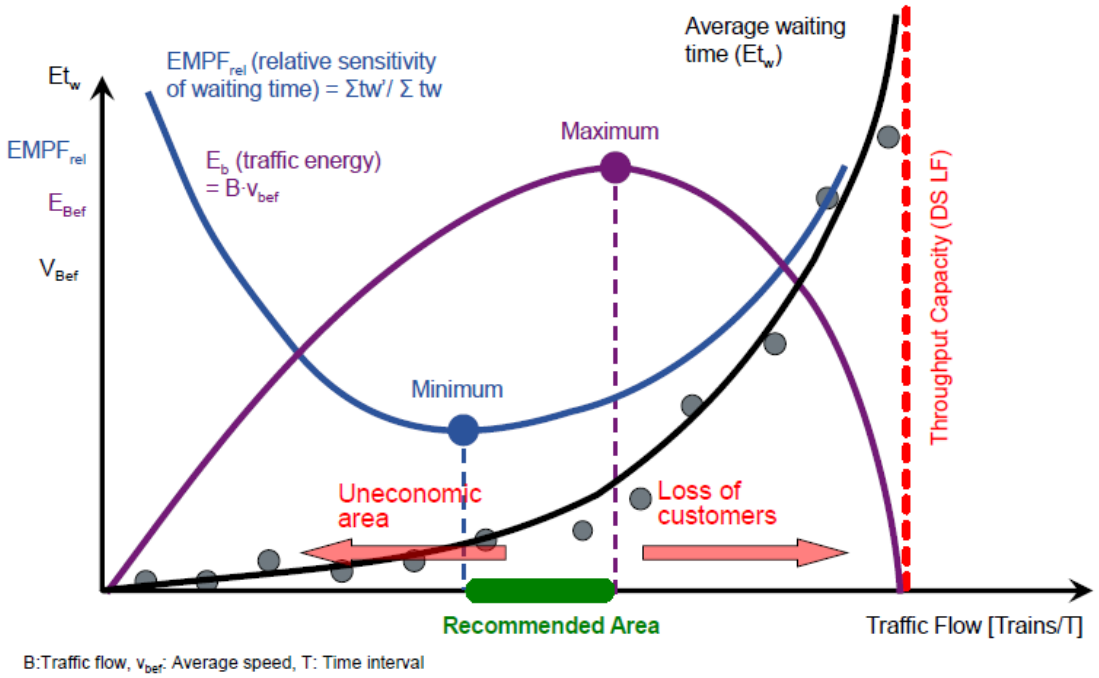
Software Used

- RailSys: A railway infrastructure and timetable simulation software

- PULEIV: Evaluation of capacity behavior for railway infrastructures
  (Untersuchung des Leistungsverhaltens von Eisenbahninfrastrukturen)

Slide 9

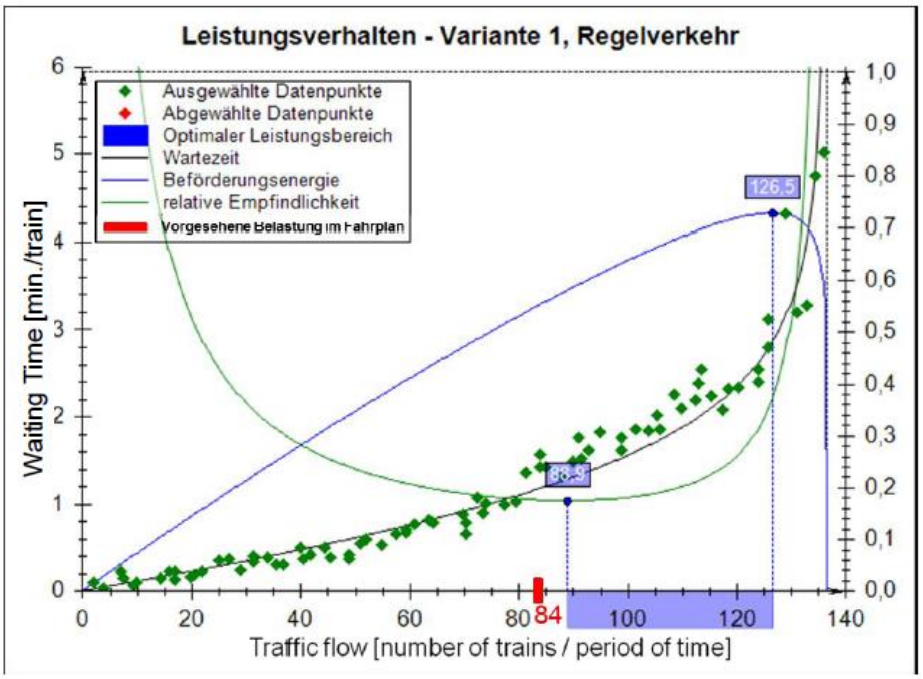
PULEIV for Capacity Anaylsis



B:Traffic flow, v_{bef}: Average speed, T: Time interval

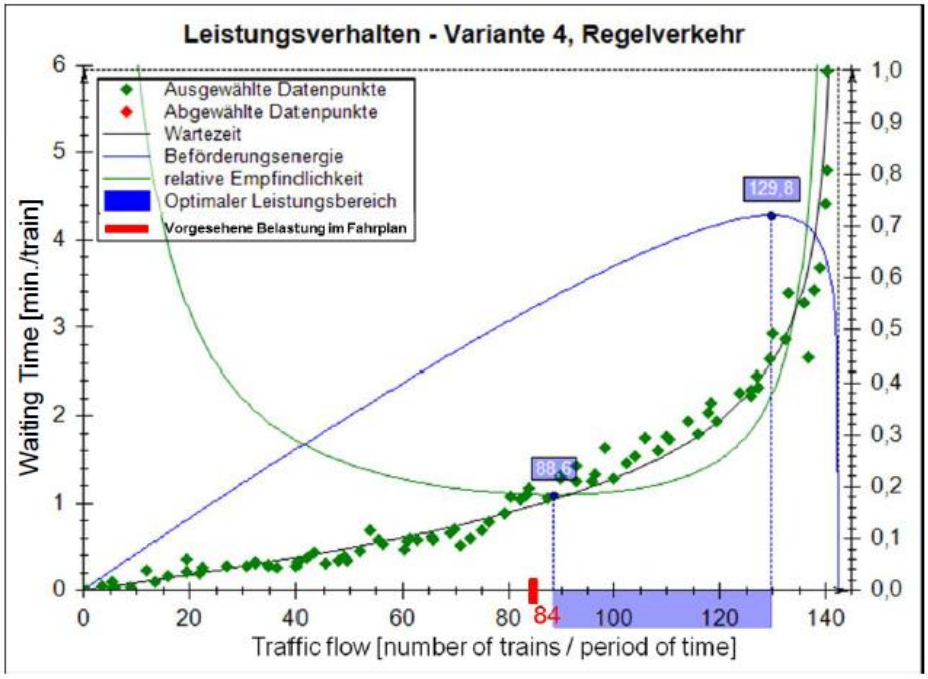
Slide 10

Capacity Analysis: Variation 1



Slide 11

Capacity Analysis: Variation 4



Slide 12

Operational Quality Analysis: Delay Coefficient

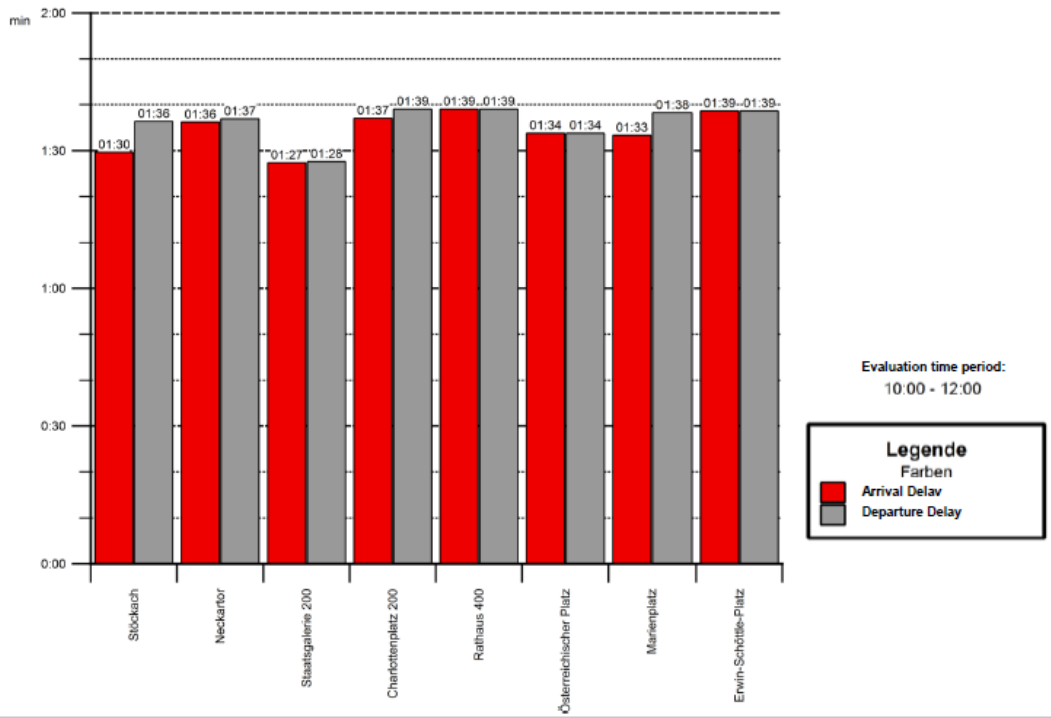
- Incoming delays are introduced from the disturbances outside of the system. Incoming delays are the sum of the initial delays coming into a system and the unscheduled waiting times of the dwell time and running time.

- Outgoing delays are the delays that are measured at the ending station or the outgoing point of the system.

$$DelayCoefficient = \frac{outgoing\_delays}{incoming\_delays}$$

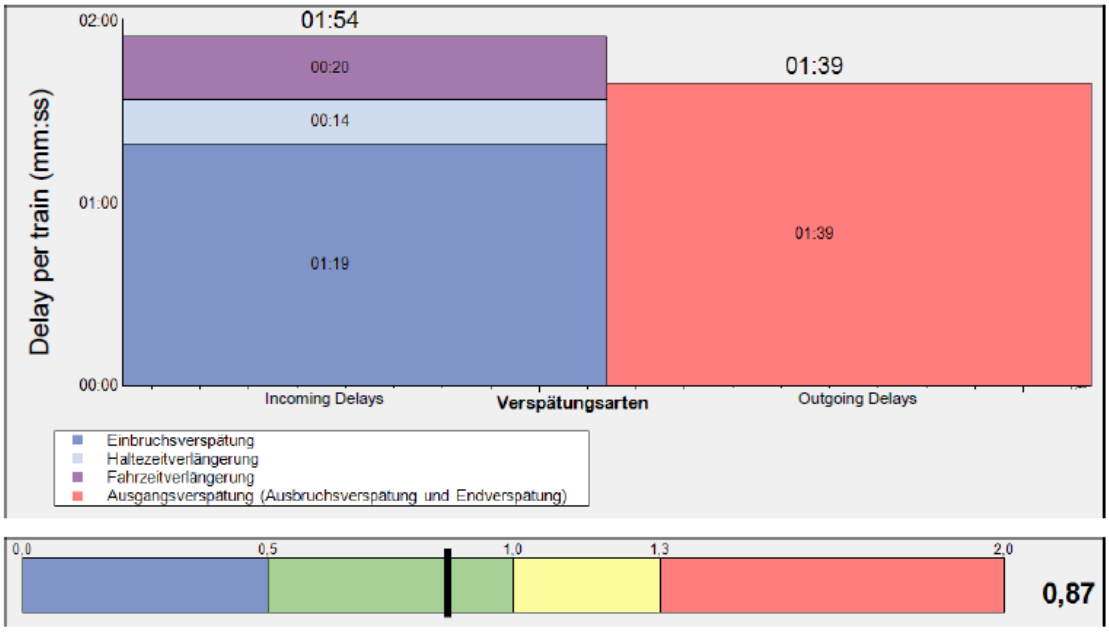
Slide 13

Operational Quality Variation 1 (U1 towards Vaihingen)



Slide 14

Operational Quality Variation 1 (U1 towards Vaihingen)



Slide 15

Conclusions

	Variation 1	Variation 4	Preference
Capacity Analysis	Average waiting time (per train): • Regular: **1,2** Min • Event 10 min: • Event 5 min:	Average waiting time (per train): • Regular: **1,0** Min • Event 10 min: • Event 5 min:	Variation 4 (because of regular service)
Bottleneck Analysis	Number of potential bottlenecks: • Regular: **3** • Event 10 min: • Event 5 min:	Number of potential bottlenecks: • Regular: **1** • Event 10 min: • Event 5 min:	Variation 4
Operational Quality Analysis	Delay coefficient: • Regular: **1,33** • Event 10 min: • Event 5 min:	Delay coefficient: • Regular: **1,01** • Event 10 min: • Event 5 min:	Variation 4

Slide 16

Everyday Mobility in Beirut: Reassessing Informal Transport

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After MIP, she was awarded a scholarship for Ph.D. in City and Regional Planning at Cardiff University UK, completing it in 2010. Between 2009 and 2014, she worked as an urban planner at Khatib & Alami consulting company on projects in the MENA region, focusing on social infrastructure, and public spaces. Simultaneously, she started teaching part-time in urban planning and architecture at NDU and ALBA in Lebanon. In 2014, she completed a post doc at the University of Reading, UK, on an Urban Studies Foundation fellowship; then full-time assistant professor at NDU, and chairperson of the architecture department since 2016. The most important contributions from the MIP to her professional career were interdisciplinarity, geographical variations, cultural considerations, shared urban issues, and systematic approach to addressing urban problems. Moreover, very important, building up a social network across the globe, and maintaining connections with the University of Stuttgart and Germany.

Abstract: This paper explores everyday mobility in Beirut and the reality of coping and adapting within a context of instability marked by securitization, and the lack of an organized transport system. It presents a reading of the current differentiated mobility experiences in Beirut with its population and urban dynamics. These dynamics relate to internal relocation of the population seeking job opportunities, the flow of refugees coming into the city, and real estate development that affects and is impacted by transportation infrastructure. The paper provides an overview of Beirut's urban mobility since the country's constitution in 1943, and explores the impact of the 1975-1989 civil war. During the reconstruction period, and after reconnecting the war-time divided city, urban mobility was vital to reinstating a return to everyday urban life, yet it had to cope with the country's and capital's perpetual instabilities, characterizing it as 'chaotic'. Part of the coping mechanism was the emergence of travel routes within the city, which are shared by pedestrians, shared taxi cabs or 'service', vans and buses. The paper will focus on the informal bus system and its relation to the public transport network in Beirut. The state of transportation infrastructure and modes of mobility are investigated by reviewing the literature and analyzing documents and city plans. In addition, this research examines different mapping and tracking systems of informal bus routes within Beirut as initiated by a grassroots group: 'Bus Map Project'. The founders of this group are collaborating with other initiatives such as 'Yalla Bus' among others. Through the use of ICT, these initiatives are redefining the formal/ informal binary, and inviting a participatory approach to mapping and understanding everyday mobility by buses in Beirut. The groups' purpose is to learn from the existing situation, to possibly affect people's perception of the bus system in Lebanon, and encourage people to use the available public transport as an alternative to the private vehicle. Building on some of the groups' ini-

tiatives, the paper argues that collective and differentiated mobilities exist in Beirut along with their opportunities and constraints. These have implications on how various user groups experience Beirut's spatial configuration. Could the 'Bus Map Project' affect this experience for some user groups? Some conclusions are presented on spatial justice and social inclusion in Beirut as reflected and manifested through its everyday mobility, be it on foot, by car or by using the available bus transport.

Key Words: Beirut, Informal Mobility, Social Media, Instability, Bus Routes

1 Introduction

Regardless of the country and city one is living in, commuting to work or other activities is an everyday life necessity. The transportation mode could vary, with some countries having organized public transport, and others being heavily dependent on private transport, and in both cases, being a pedestrian is inevitable. Either way, reliance on information technology is increasing at a rapid rate worldwide, and affecting mobility. While research on mobility and its organization is abundant in stable contexts, more could be explored in the case of conflict ridden contexts, often perceived as 'chaotic', to examine their inherent 'order'.

This paper explores the impact of mapping informal bus systems using information technology for the support of riders in the unstable context of Beirut, Lebanon. Using the conceptual framework of mobility in relation to spatial justice, the paper addresses the condition of public transport in Beirut, and investigates the contribution of one grassroots initiative: Bus Map Project (BMP), in terms of implications on differentiated mobility within the capital city. Following this introduction, the conceptual framework is explained, whereby mobility is qualitatively explored while considering social and everyday aspects of mobility from the perspective of the rider. Then the context of Beirut is briefly examined to understand the mobility of people in this city. Following the review of secondary data analysis and an interview with the two founders of the BMP, the paper presents the informal public transportation and its impact on spatial justice in Beirut. Finally, some conclusions and recommendations for further research are presented.

2 Understanding Mobility in Unstable Contexts: Beirut's Case

Mobility in this paper is explored at the level of riders within a context where consociational democracy and the urban context are closely entangled. Add to this that Beirut is a city that has undergone conflicts and still faces instability. The implications of this setting are further explored in this section, which establishes the framework through which informal mobility in Beirut would be examined, and proposes the parameters upon which a reading of this mobility from the rider's perspective is conducted to further understand spatial justice.

2.1 Mobility (walkability) and spatial justice

Everyday mobility is investigated qualitatively to address historical, social and political aspects in an unstable context [14]. This approach opens up the question of spa-

tial justice within urban contexts [1], and considers the dynamic relation between space and time in the city and implications on social practices and the inclusion or integration of the actors involved in them. The paper further explores the impact of conflicts such as wars on mobility [1] causing the marginalization of some people and their adaptation with creative strategies to ensure maintaining their mobility within the city. Mobility is analyzed through the lens of a grassroots initiative rather than professional and academic perspectives [6] in order to unpack what happens at the level of the rider.

Mobility is a reflection of everyday urban life, which connects to residence, work, leisure and wellbeing. Mobility helps in establishing spatial connectivity within the city and its different parts [6: 227]. In other words: 'it creates socialities, affinities, knowledge'. The importance of mobility equally lies in understanding the 'engagement' or positionality that inhabitants have with their urban contexts, and the experiences generated in their everyday urban lives [6: 228]. 'Mobility is also something we learn to do and that requires a constant manipulation and re-adjustment of skills and knowledge [5].' In Beirut's case Monroe [15] specifically refers to people's perceptions of the existing public transport, whereby one group of the population considers the buses for foreign, particularly Syrian workers, while other Lebanese consider people with such perceptions as snobbish. Moreover, mobility is a key factor in allowing social integration [6: 228], which is particularly important in a conflict ridden context. In unstable contexts, mobility cannot be taken for granted, as it is no longer an everyday practice equally available to all, it varies with 'spatial positionality' [6: 232]. In Beirut's case, mobility varies not only by socio-economic classes but also along political and sectarian differences. Note that in Beirut residential areas are usually mixed from a socio-economic perspective, yet rather homogeneous from a sectarian perspective [2]. While one research on mobility using mobile apps [23] suggested that residents in poor urban areas move for activities to other poor urban areas, a further investigation in Beirut would be interesting to see if people from different politico-sectarian communities move to similar or different ones within Beirut for their activities. Note that occupying the same urban space simultaneously does not imply that people in that space-time engage in the same activities [23], since insular behavior, allowing micro-cultures to cluster without interaction with others could also occur in urban contexts, specifically in the case of Beirut [2]. Mobility differs for those who do not use public transport and have insular spatial practices: 'spatial segregation is rather a messy dynamic process encompassing numerous and various practices.' [2] Often private automobiles as well as informal mobility fill in gaps within urban contexts to meet the needs of some segments of the society.

In studying mobility, it is important to indicate that informal mobility has a central role in cities worldwide, yet remains tangential to academic research [13: 5]. Moreover, the omnipresence of ICT has enabled the scattering or disaggregation of the management of public transport, and simultaneously the attractions of riders [13] irrespective of the formality of the mode of transport. Hence, this emphasis is made in studying the context of Beirut as explained in the following section.

2.2 An overview of Beirut's transportation system

To understand the current state of the transportation system in Beirut, it is essential to go back in time at least briefly, and relate this state to events and decisions made. The port city of Beirut was a potential development node throughout history, and the current system is imprinted in the French and then Ottoman decisions that aimed to facilitate trade and 'modernize' the city respectively. Connecting the port to Lebanon's inland facilitated trade, specifically silk trade [18]. Supplying public transport through trains and tramways projected an image of modernity, and the ability to resemble the 'west' towards the end of the Ottoman Empire [11].

In 1943 the Republic of Lebanon was constituted along a consociational democracy [19], which meant that state representation was divided among the various politico-sectarian groups in the country with the intention to share power and ensure equity among the multi-sectarian population. The reality of the situation was that 'authoritarian inner-state entities' [19] emerged and often catered for the needs of their communities from education, to employment [7, and 17] and even mobility as will be discussed in this paper. With respect to transportation and before the civil war in 1975, several plans for Beirut proposed the expansion of the road network, always emphasizing the facilitation of trade, while other aspects of the plans related to open spaces as well as public transport were overlooked [18]. Add to this the influx of migrants and immigrants seeking refuge or opportunities for a better life, which resulted in urban growth and expansion of Beirut, marked by population distribution along politico-sectarian affiliations [16]. The 1950s marked the peak of urban growth in municipal Beirut, with the appearance of two important areas: Ras Beirut to the west and Badaro to the south characterized by their ethnic, religious and cultural mix of inhabitants, marking the areas as secular to some extent. Urbanization in the country more generally was linked to its sectarian mosaic, with a sense of solidarity among the different groups [16]. Secular influence was often marginalized, socio-economic clustering was not always evident, and belonging to the public at large was dominated by communal belonging, which reflected in the lack of interest in public amenities and services. Nevertheless, various groups lived in cohesion until the war's outbreak, when 'confessional conflict took its immediate toll on the shared secular urban space' [16] including public spaces and the public transport system. The Lebanese political system thus contributed to 'a fragmented sense of urban identity' [16: 249], with an overarching sense of communal belonging rather than an urban one. Micro-cultures were formed within the capital, and only an inclusive urban process could reconcile these groups towards a common public identity. One such process could be public transport, which would cut across politico-sectarian communities, thus pollinating them with encounter and shared social practices, and contributing towards a fairer spatial experience of the city and sense of belonging. In the mean time, these micro-cultures are self-regulating to meet collective needs for both the poor [20] and rich [2]. Nevertheless, exogenous factors contribute to a 'fluidity of the urban environment' [16: 254] that requires readjustment of the communal micro-cultures, for example accommodating the influx of refugees and foreign workers, or demographic shifts.

In terms of transportation, the golden period of Lebanon (1950s-1960s), also referred to as the Chehabism [16] resembled other cities in the world with the tendency to promote car-orientated planning schemes [16]. During this period, there was an at-

tempt to shift towards institutions away from the firm-grip of the consociational politics with the intention to overcome ‘disorder’ [16: 196]. The road network was considered as a ‘tool of nation-building’ [16: 193]. This period was marked by an increase in the number of cars, requiring the management of circulation and traffic. The automobile ruled, similar to western countries, especially the United States [12]. Marking this period is the dismantling of the tramway system to accommodate more automobiles in 1961 [16]. Politicians then referred to cities in Europe to justify this shift under the guise of ‘modernity’ [16]. Based on archival research in local newspapers, Monroe [16] claims that the disorder of traffic in Beirut, currently referred to as ‘chaos’, actually preceded the civil war. Equally in that period, specialized police divisions and even military units participated in reinstating order within traffic management [16: 197]. This included giving tickets for parking on sidewalks, honking, going against the designated traffic direction, passing on a red traffic light and so on. In addition, raising awareness on how to navigate in the city as a pedestrian was instated [16: 200-201]; note that pedestrians trespass vehicular roads nowadays as well. Nevertheless, the struggle to reinstate order continued, and Monroe states that ‘the anarchy and necessity of “remedying a situation that continues to worse” (15 January 1959) ‘was tied to undisciplined drivers that use the urban roads as race tracks’ [16: 203], a scene still familiar in Beirut nowadays.

The war in 1975 and until 1989 affected the road network, whereby many roads were disconnected through physical blocking, and access along Damascus Road, the demarcation line from east to west was possible only at certain checkpoints [21] (see Figure 1). The city was converted to a polycentric one, and the historical centre became no-man’s land throughout the war years. After 1989 reconnecting the road network started by executing new road projects that were dormant since the 1960s, building ring roads within Beirut, and connecting Beirut to its surroundings. What were previously transportation hubs at the periphery of the capital became fully integrated in the urban fabric, absorbed by urban expansion rather than remaining at, and defining the city edges or boundaries, (example Charles Helou station, Daoura or Cola transportation nodes). The reconstruction plan for the Beirut Central District (BCD) by Solidere disregarded the rest of the city and circuM.Sc.ribed the center with highways. Urban explosion in some suburbs and densification occurred with the migration of Lebanese towards the capital, without an effective public transport system and with ongoing security issues. Add to this the influx of refugees, particularly Syrians in the recent years. To some extent, these and other factors generated formal and informal forms of mobility.

Intermittently after the war and particularly after 2005, the everyday mobility of people was negotiated and often compromised to the benefit of some political figures. ‘Mobility was circuM.Sc.ribed through the installation of barriers, blockades, checkpoints, and the rerouting of traffic flow.’ [15: 91] This added to the ‘disorder’ or ‘chaos’ as being ‘mobile’ in a highly securitized context implies that the shortest path or the preferred one is not always followed. The path is guided by events that lead to tactics and decisions, rather than mobility strategies that are clear to all users. Monroe states that ‘mobility plays a critical role in the production of differentiation and inequality in Beirut.’ [15: 92] This is related to the state of spatial justice that differentiates people by mobility, and helps in understanding the embedded order within the

apparent chaos of mobility in Beirut. Monroe refers to Bourdieu to explain this state as ‘collectively orchestrated without being the product of the orchestrating action of a conductor’ [4: 72]’ [15: 105]. This means that layers of mobility define spatial experiences and spatial rights within the city characterized by different rhythms. Monroe further observes that ‘being mobile in Beirut is a civic practice, one in which the apparent opposition between order and disorder commingle and different social and territorial boundaries are fashioned.’ [15: 107] In Beirut and depending on affiliation, one could get stuck in traffic or walk where the domain is designed and designated for vehicles only, or simply bypass traffic and reach one’s destination. The street network (see Figure 2) does not necessarily reflect the mobility of the population. This leads to asking: what does it mean to be a rider, driver or pedestrian in Beirut?

Fig. 1 Axial Map of Beirut Indicating the disconnection between east and west along the demarcation line (red dotted line) and impact on connectivity of the network: red being highest, and blue being lowest connectivity (Source: by Author)

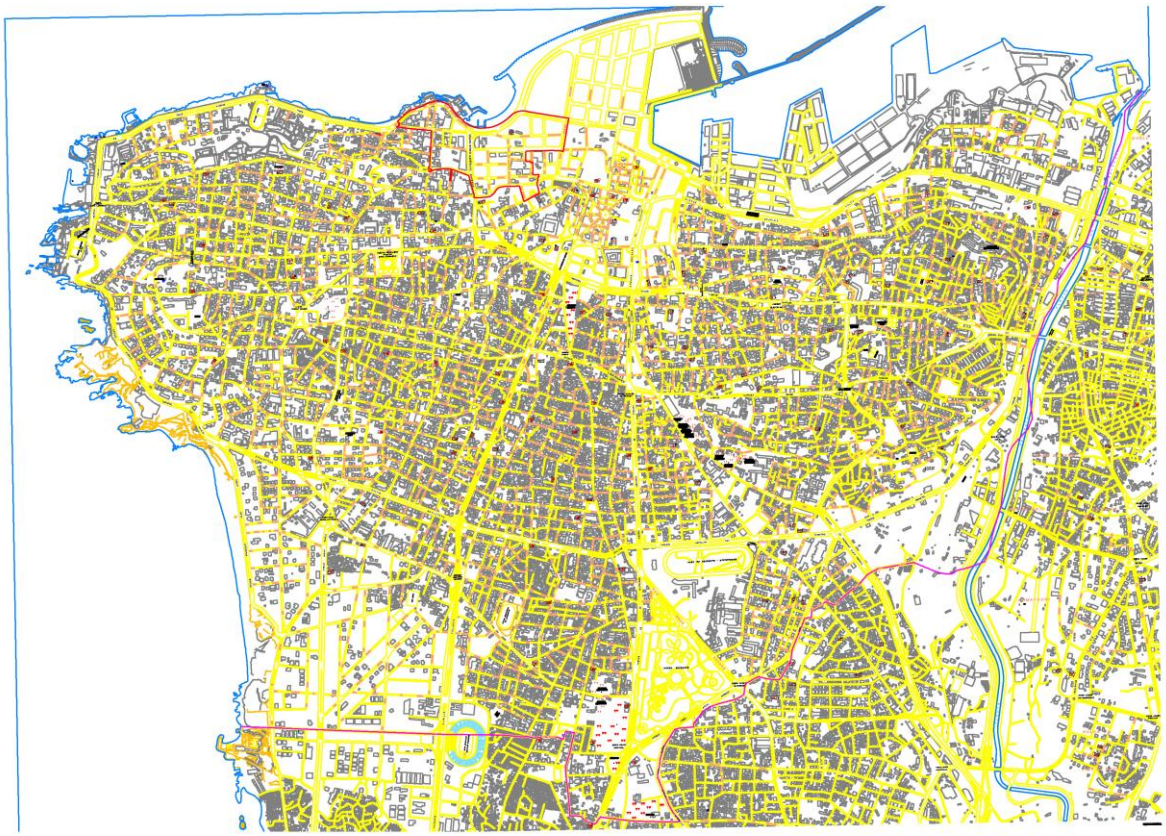

Fig. 2 Map of municipal Beirut (Source: by Author)

3 Public Transport and the Bus Map Project

Following the overview on mobility in Beirut and the numerous challenges this capital city faces in terms of urban expansion, the role of the real estate market, influx of refugees and a weak planning system within the consociational government, this section provides an explanation of the transport system in terms of infrastructure, state vehicles and operators (OCFTC under the Ministry of Public Works and Transport http://www.transportation.gov.lb/), and provides an overview of the informal bus network. Then it introduces the Bus Map Project (BMP), their utilization of social media and IT and what BMP reflect about informal public transportation in Beirut.

3.1 Informal buses

It is difficult to distinguish between formal and informal public transport in Lebanon generally or Beirut specifically, where infrastructure, vehicles and operations intertwine along this spectrum. The informal public transport comprises a fleet of minibuses or vans, buses, and shared taxis called ‘service’ [3]. In addition, taxis operating from registered offices, Uber or state-provided buses represent the formal public transport in Lebanon. Initially after the war, 22 bus routes were operational. ‘A large number of transport providers compete to serve a demand that is less than the existing available capacity.’ [3: 91] Moreover, these compete on the same route with taxis, shared taxis and the state provided buses.

Violations by informal public transport vehicles comprise running on diesel rather than gasoline, overtaking, no dedicated stops, carrying more passengers than the vehicle’s capacity, no announced schedule, speeding, and maintenance. Add to this

the driving pattern of service providers, similar to what was happening before the war, and not sticking to dedicated routes to mitigate congested segments of the network [3], or bypassing the vehicle capacity by carrying more riders. One shortcoming of the informal bus system is that each operator has its own ticket and therefore fares are paid separately and no integration exists, similar to informal transport in other countries [13].

One proposal in 1999 was to separate the role of government as planner and regulator of the transport system, from being a service provider, and rather provide the suitable conditions for fair competition among private providers who would finance the bus fleet and operations [3: 96]. Also, 'Both the taxi and service owners and drivers and bus owners have urged the government to reform and organize the public land transport sector in Lebanon. All three private sector syndicates have offered to fully support the regulatory role of the government and to cooperate with it to ensure a successful implementation.' [3: 98] One proposal was to have a shared or integrated fare across providers gaining access following a tender process [3:98]. These proposals remain dormant, paving the ground for a laissez-faire approach.

To sum up, in a country that is highly dependent on private cars, pedestrians and public transport reflect or are considered informal due to the inadequate available infrastructure (absence of sidewalks and pedestrian crossings on many streets), the fleet of vehicles and behavior of people [10]. In the absence of tramway and rail, and the heavy investment on roads, the existing informal system could provide some lessons learned in terms of flexibility and adaptability in a conflict-ridden and unstable context, or in other words, learn about the efficiency and resilience of this system [10: 29]. Some of the features of the informal transport system include that it is highly accessible, has broad coverage, responds to demand rapidly in comparison to vehicles stuck in congestion, and is able to respond to changes in rider, network and market needs. Informal transport is available there where shared taxi coverage is low or non-existent. 'Most of the service parameters remain unregulated but they operate within an organizational structure or an internal framework that rationalizes their service parameters' [22; 8]. Also, 'the informal transport sector is often held together in a loose, horizontal fashion, dependent upon carefully cultivated linkages and nurtured relationships among stakeholders, including fellow operators, parts suppliers, mechanics, local police, creditors, and street hustlers, among others.' [9] [10: 29] Yet these operators are not illegal as they have licenses and registered vehicles.

Without formal planning, coordination, and regulation: 'route associations however can bring relative power to its members, these exist to bring order and avoid inefficiencies and redundancies within a spatially defined service area.' [10: 29]; often these are supported by politico-sectarian groups. The drivers are often disadvantaged, with low skills, and have no social security. Riders vary in age, gender, and ethnicity. Female passengers prefer vans to shared taxis [20]. Van number 4 is one example of lines/numbers where 'informality is demand-driven, highly responsive to the needs of the consumer.' It provides 'mobility to marginalized socio-economic classes' and 'connect marginalized neighborhoods to the city, thus enhancing social integration in a highly polarized and segregated context.' [20] 'Informal transportation contributes to social integration providing mobility for women and lower income population as the informal transportation is usually cheaper. These systems however run

as localized monopolies, with no easy entry into the system, and offer little insurance to the informal workers involved. They are also not accessible or used by everyone, individuals of middle- or upper-income choose not to engage in public transportation and prefer to use private vehicles. This is most commonly due to maintenance and safety standards absent in the informal transportation.' [10: 31] The information in the next section is from the interview conducted on 14 June 2018 with the two founders. Note that bus line and bus number are used interchangeably to refer to one provider, while route is the designated itinerary of the bus.

3.2 Bus Map Project: The riders' perspectives

In 2008, a car-less concerned young citizen, software developer, using the available bus transportation system, decided to start mapping the available bus lines and bus routes. Within one year, and using basic GPS tracking mobile phone apps, he managed to publish online the 'Lebanon Bus Map'. In 2015, following a Twitter message, he joined efforts with another young citizen, graphic designer and writer, who was interested in learning from the existing bus system, and increase its visibility to the Lebanese. These two persons started the Bus Map Project (BMP). Their aim was to support riders of the available local transport system. Their objectives were: to raise awareness that a shared public transport system in Lebanon exists, to develop the available map that would support riders, and potentially to positively affect perceptions and ridership of this system.

The BMP founders identify themselves as a grassroots initiative, and have sought to become an NGO. They have collaborated with several other initiatives and NGOs including: Green Line (https://www.facebook.com/GreenLineAssociation/?rf=301760886560235), Frame (https://www.facebook.com/FrameBeirut/), SwitchMed (https://www.switchmed.eu/en/country-hubs/lebanon), Yalla Bus (https://www.yallabus.com/), and H2 Eco for the Smart Bus Stops.

In mapping bus routes and bus lines, BMP work as individuals but also got input from youth, and foreigners living in Lebanon who are interested in BMP. Using simple tools, such as free GPS tracking apps on mobile phones, data is collected and processed by the two founders. While this process can be done by any person, BMP has the initiative to continue developing and updating the map with people's input and engagement. The means of communication between BMP and others is mainly through Facebook (https://www.facebook.com/pg/BusMapProject/posts/?ref=page_internal) and a blog (http://blog.busmap.me/). BMP purposefully follow this 'slow way of mapping, to encourage people to get on the bus, and care to ride.' The map then becomes a tool that 'reduces the fear (of riding) without saying it out loud. It is a friendly way to help people get on the bus.'

Although BMP have not conducted systematic data collection on the users, drivers and operators, this seems to be a next step in developing their project. In the meantime, the focus was on understanding the geographic spread and distribution of the bus lines. What BMP have noted throughout their work is that users are from different nationalities and sects, so are the drivers. Users are also females who respond to BMP's questions in Arabic, French or English. In all cases, 'on the bus, everyone is a rider'. This contributes towards viewing this transportation system as a potential to develop civic belonging to the city rather than one colored by politics or sectarianism.

Moreover, BMP note that some routes break the demarcation line, defying it by linking areas across it. However, the distribution of lines among operators is still affected by politico-sectarian dominance in the various parts of Beirut. For instance, two areas outside Beirut could be connected to each other directly, yet the connection happens in Beirut. According to BMP, this reflects the lack of demand and interest of people in these two areas to be directly connected (note that the areas referred to had rivalries during the civil war with many causalities). In contrast, other lines connect areas that have no apparent relation to one another (Sabra south-west of Beirut to Nahr el Mot east of municipal Beirut). It turns out that the line serves people of one area who have the tendency to go for their shopping activities in the other, as both areas have the same sectarian constitution, with one being a minority of a certain sect, the other a majority. This creates the attraction or demand for transport between the two areas, as also discovered by Yip in his research [23].

BMP describe the system as 'dynamic, depending on the ecosystem around it.' BMP go on to explain how it adapts to demand across the various areas in Beirut, ecosystem referring to the prevailing politico-sectarian environment in an area. Moreover, one of the founders indicates how one Parliament Member (PM) managed to establish a route connecting his area of representation to Beirut, enabling people living in the villages to commute to Beirut by public transport. The founder indicates that on the one hand this resonates with the consociational structure of the government, yet on the other hand, it serves people within the existing situation of the country.

BMP indicated that each bus line or bus number has a history, which dates back to 1998 in the post-war period, when 22 bus routes were established, and first used by the state buses of OCFTC, followed by LCC (Lebanon Commuting Company), which was affiliated by the back then Prime Minister Rafic Hariri. After the limited services of those two entities, specific families with affiliations to the politico-sectarian leaderships in their regions gained entry into the bus transport system. A sample of the bus lines/numbers is provided in Table 1.

Bus number	***Origin***	***Destination***	***Region***
2	Hamra (Ras Beirut)	Antelias	Via Dora
6	Cola	Byblos	-
22	Dora	Baabda	-
5	Hamra (Ras Beirut)	Ain Saadeh	Via Bourj Hammoud
12	Hamra (Ras Beirut)	Bourj el Barajinah	Via Cola

Table 1 Examples of current bus routes in Beirut (source: https://busmap.tumblr.com/hubs)

Within Beirut, the trend is that providers own a fleet of buses, and hire drivers to operate them. However, there is also the case of bus or van owners who pay a fee to join in driving along an existing line. For the buses with operators, they provide tickets (see Figure 3), which are used to control the drivers rather than the passengers. Passengers nevertheless get the impression that the bus system is organized. In the particular case of bus number 5, some elderly people residing in social housing for Armenians, have a laminated, hand-written pass, allowing them to use this bus free

of charge. This reflects the culture and values of the bus provider. Providers remain family businesses that are akin to social entrepreneurs. However, due to their affiliations with politico-sectarian groups, some people consider them as mobs or mafias. This is due to their method of securing their own rights in the absence of a system that regulates them. Note that BMP referred to this situation as prisoners' dilemma, where security to the providers is not ensured, and hence each provider tries to secure their rights on their own, without necessarily any common gain to all providers.

Fig. 3 Tickets from buses operated by the state and bus line 5 (Source: provided by BMP)

The bus fleets all have red licensed plates, and violations could be in terms of permits for the drivers (especially if foreign), or running on diesel rather than gasoline. In the latter case, these buses reach only to entry points in Beirut so as not to be caught and fined. BMP note that traffic police that are part of the Internal Security Forces (ISF) use these buses as riders, and when on the ground, some of them negotiate breaches (diesel or driver's papers) as they need to deal with the reality of the bus system that nevertheless serves the mobility of one segment of the population.

Schedules and frequencies of these lines vary. Most lines start serving around 5.00 in the morning and stop at 19.00. The frequency is on average every 15 minutes for a bus, but could vary from 2 minutes to 30 minutes depending on the area, traffic congestion, time of day and day of the week. Managers are assigned to monitor and control drivers and make sure they run according to an agreed schedule. Frequency also depends on the number of buses pertaining to a line/ number. Again this varies from 350 buses for Number 4, 30 buses for each of numbers 2 and 5, and 17 buses for number 22. Note that the state run buses are now only 11 functioning ones.

The bus stations are spaces rented out from the Unions of Bus Drivers in various parts of Beirut (several unions work within a federation, reflecting the sectarian distribution of the providers), or even municipalities as in the case of Bourj Hammoud. Bus stops have emerged according to demand, and are defined once riders name them,

then they become reference points and landmarks. These could be next to pedestrian bridges, at intersections of several lines, entry points to areas in Beirut and so on.

The 21 routes generally cover the whole of Beirut and its wider surroundings, with exceptions, such as the southern entrance from Hazmieh to Ashrafieh, which is covered by shared taxis. BMP indicate that further investigation is required to validate whether this happens in agreement with the unions, to allow various drivers to make a living irrespective of the vehicle they drive (shared taxi, van or bus).

While most of the routes were maintained as per the 1998 proposed network, some changed itinerary due to changes in infrastructure, such as the construction of a bridge or highway (shifting demand to inner roads), or change in ridership demand within the various areas in Beirut (population density, and concentrations of certain riders in specific areas such as migrants, workers or refugees).

Here BMP explain that the basic definition of formality refers to the bus being operated by the state. BMP goes on to explain that in the Lebanese case, there are levels of formality. For instance, state operated buses have no dedicated stops or schedules, drivers still make discretionary decisions to help passengers sometimes. BMP thus argue that the privately operated lines have their own internal organization with their tracking technologies, and WhatsApp communication, they have licensed vehicles, and hence cannot be described as chaotic; they have their own order. BMP thus distinguish between public transport (Arabic version: Al Naql Al A'am) versus shared transport (Arabic version: Al Naql Al Mushtarak). BMP suggest that what is missing is organization and filling in gaps that the free market is unable to, such as covering remote areas or providing night buses. What is recommended is coordination between the state-provided and privately provided buses rather than regulation, and law enforcement, if the riders are to be served, if they are the main target.

Among the advantages of this system, BMP state its 'flexibility and adaptability rather than it being a monolithic system'. Another advantage is that these are family businesses with values and own cultures resulting in a friendly manner of dealing with the riders. Interaction and closeness to frequent riders is noted on different lines/ numbers. Some people might refer to this as disorder, but to BMP it reflects this micro-culture that is inherent to the Lebanese informal bus system. Among the disadvantages is the absence of night buses, though again BMP note that on some lines/ numbers where there are students or workers, the last shift is extended to serve them, after agreement with the drivers, once again reflecting how the system is dynamic.

Regarding perceptions of the bus system, these are summarized by BMP as: fear, stigma and ignorance, at least in the period 2004-2006. Since 2015, this situation has changed and more people, especially young people, are aware of the existence of a bus system and eager to know more about it. Within this atmosphere, BMP intend to reduce stigma, raise awareness that the system exists, (it has been mapped) and that people have options other than the private car, to commute from one area in Beirut to another. BMP are using the map to show that the network exists. However, the emphasis they lay is on the 'mapping process' that would provide people with a lived experience, and introduce them to the bus system's micro-culture. BMP are trying to help people face their perceptions about the system in order to change them, and

help improve this system. ‘People cannot say anymore: I don’t know there are buses’. In addition, BMP are generating information on the system as well as providing a platform that is interactive and will allow people to share their stories, knowledge and experiences of the system. This map and the platform could be used by municipalities and the general public to improve the system from within, without necessarily introducing an exogenous model.

4 Conclusion

This paper examined mobility from a qualitative and bottom up perspective in an unstable context, that of Beirut. It addressed social justice in relation to urban mobility, and the role of IT and social media in framing the informal public transport system. This exploration was underpinned by a review of Beirut’s mobility history, the impact of different periods in the rule of the country and the demise of the civil war on transportation more generally. This review highlighted the preference of the private vehicle over public transport even before the outbreak of the war, and to some extent this is associated with the consociational nature of the government, which tends to overlook secular initiatives to the benefit of sectarian ones. After the war, and with perpetual instability, mobility was negotiated, compromising the mobility of less-privileged people, and resulting in different spatial experiences within Beirut. Informal public transport then filled the gap for a certain segment of society. The paper revealed another facet of Beirut’s urban context through the informal mobility of buses as carriers of urbanites from various communities living in a consociational government marked by instability and the predominance of politico-sectarianism for the provision of public goods. Informal public transport in Beirut and its characteristics were presented, and how it functions in parallel to the state operated public transport, with its reduced fleet of 11 buses operating on selected routes. In this context, the informal public transport system is buttressed by various politico-sectarian affiliations and falls in a prisoners’ dilemma, while trying to provide a public good.

The positionality of riders, drivers and providers were addressed, as well as the perceptions of this informal public transport system through the literature and interview with the founders of BMP. Particularly important in Beirut are differentiations of politico-sectarian affiliations, and not necessarily socio-economic class and ethnic belonging. This exploration helped to understand the micro-cultures existing within it, and defining their presence within common or differentiated areas in the city.

The role of BMP, their aim and objectives as well as their collaborations with urbanites and other NGOs were presented. What BMP narrated on the informal public transport reflects varied states of mobility and social justice, ranging between overcoming war-time divides, to reflections of it. This variation is highly dependent on the location within Beirut and the connected areas, and the operators of the lines. Nevertheless, mobility is seen as a civic right, which enables spatial justice in the city.

BMP reflected on the advantages and disadvantages of the informal system, emphasizing on the crucial role of the state in coordinating public transport, and highlighting the endemic features in Beirut’s case, characterized by a micro-culture prioritizing social values, and dynamism reflecting the system’s resilience in the face of instability. The interview with the founders of the Bus Map Project revealed insights that re-

quire further investigation in terms of defining mobility in a post-conflict context and its reflection of spatial justice in a politically charged, unstable context. The self-regulating system that is capable of responding to riders' demands, the distribution of routes and gaps in the network, and validation of rider profiles in terms of encounter and integration across war-time divides, are all subjects for further research.

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Session 4

Resilience and Smart City Concepts in Water Management

Probabilistic Seismic Risk Assessment of the Quito's Water Supply Infrastructure: Towards an Efficient Resiliency Management

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Abstract: This paper aims to describe the process of the probabilistic seismic risk assessment of the infrastructure of EPMAPS[1] as a framework for the construction of resiliency for Quito's water supply system. The analysis was performed with the use of CAPRA platform[2], which is a tool that helps to assess risks by combining its hazard, vulnerability and probabilistic risk analysis modules in order to provide state of the art metrics of the analyzed risks. The assessment is conceptually oriented to facilitate mainstreaming risk reduction criteria into the planning process.

Key Words: Resiliency Planning, Probabilistic Seismic Risk Assessment, Probable Maximum Losses (PML)

1 Context

Quito, Ecuador´s capital city, has a significant seismic risk, experiencing over the past 250 years several earthquakes with ground shaking intensities so strong that standing becomes difficult. All of these events occurred when Quito was significantly less populated and developed tan it is today.

[1] "Empresa Pública Metropolitana de Agua Potable y Saneamiento" - EPMAPS is the Public Utility Company of Water and Sanitation of the Metropolitan District of Quito
[2] Comprehensive Approach for Probabilistic Risk Assessment - CAPRA Platform (www.ecapra.org)

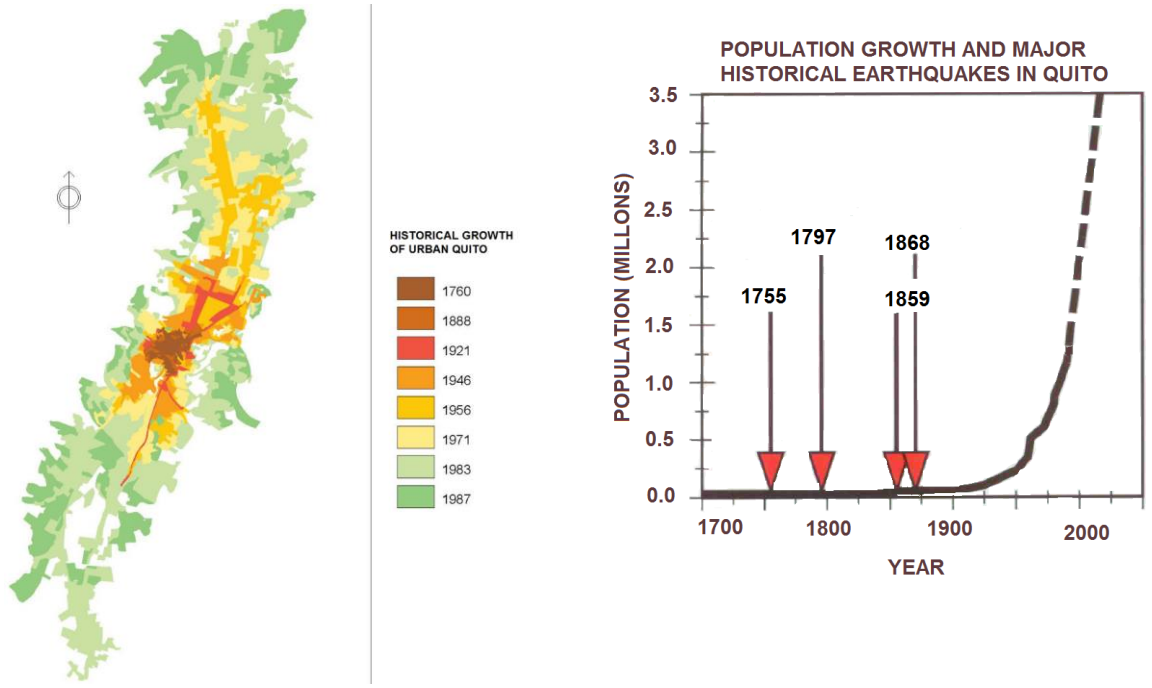

Fig. 1: Historical growth of urban Quito and major historical earthquakes [1]

In the previous 250 years, however, Quito has been shaken by many stronger earthquakes, including four that produced ground shaking so strong that it was difficult for residents to stand. These four earthquakes occurred in 1755, 1797, 1859, and 1968, when Quito was significantly smaller in population and less developed than today. In 1868, Quito was home to only 45,000 people, and its population was confined to approximately 4 square km [1]. Since then, Quito has grown more than 40 times in population (to 1.85 million residents on the urban area), and roughly 90 times in area, as it's shown in Figure 1.The seismic risk that affect Quito and its surroundings could develop the most important impact-probability scenario that would test the sustainability and viability of city itself, including the infrastructure that provides water and sanitation services to the city [2].

The "Empresa Pública Metropolitana de Agua Potable y Saneamiento" -EPMAPS is the Public Utility Company of Water and Sanitation of the Metropolitan District of Quito that provides water and sanitation to around 2.5 million people. The total coverage of the services within the District is around 98.61% for water supply and 93.05% for the sewage system. The unaccounted-for water is 28% and the average domestic water consumption is 180 lt/cap/day. Water quality fulfills all national and international requirements [3]. However, according to the latest description, the system that provides water to the Metropolitan District of Quito is likely to be challenged by the seismic hazard that affect the city and that could endanger the water supply of its inhabitants during catastrophically scenarios.

During or following a long-lasting crisis situation, an improved water supply can be the catalyst which enables those recovering to return to minimum levels of self-sufficiency [4]. Therefore, planning seismic risk management activities in the water sector is fundamental in the construction of resiliency within a disaster preparedness planning scheme.

One of the key strategic activities of seismic risk management is the assessment of the risk, which requires the use of reliable approaches that allow an adequate modelling of the potential impact of earthquakes over certain exposed elements.

This paper aims to describe the process of the probabilistic seismic risk assessment of the infrastructure of EPMAPS as a framework for the construction of resiliency for Quito's water supply system. The analysis was performed with the use of CAPRA platform, which is a tool that helps to assess risks by combining its hazard, vulnerability and probabilistic risk analysis modules in order to provide state of the art metrics of the analysed risks. The assessment is conceptually oriented to facilitate mainstreaming risk reduction criteria into the planning process.

2 Probabilistic Seismic Risk Assessment

Considering the possibility of future highly destructive events, risk estimation has to focus on probabilistic models that can use the limited available information to best predict future scenarios and consider the high uncertainty involved in the analysis.

The probabilistic seismic risk assessment provides a comprehensive methodology taking into account the nature of the seismic hazard where the frequency of catastrophic seismic events is particularly low, only limited historical data are available for analysis and there is high uncertainty involved in the assessment [5].

Several tools have been developed in order to assess the risk associated with natural events such as earthquakes. The Comprehensive Approach for Probabilistic Risk-CAPRA Platform is one of the available tools for this purpose.

2.1 CAPRA Platform

The probabilistic methodology - Comprehensive Approach for Probabilistic Risk Assessment -CAPRA [7] lies on robust model which identifies the most important aspects of seismic risk evaluation by combining its hazard, site effects, exposure, vulnerability and probabilistic risk analysis modules in order to provide state of the art metrics of the analyzed risks.

In order to assemble CAPRA's risk assessment modules for the current analysis, it has been taking into account the most updated Quito's seismic hazard study, the use of the spectral transfer functions for each of the Quito's seismic microzonation zones, the geo-referenced database of the major assets and infrastructure of the water supply and sewages systems of the Metropolitan District of Quito and its economical appraisal as well as the definition of vulnerability curves for each structural typology defined in the database. The scope of the assessment is described in the following Figure 2.

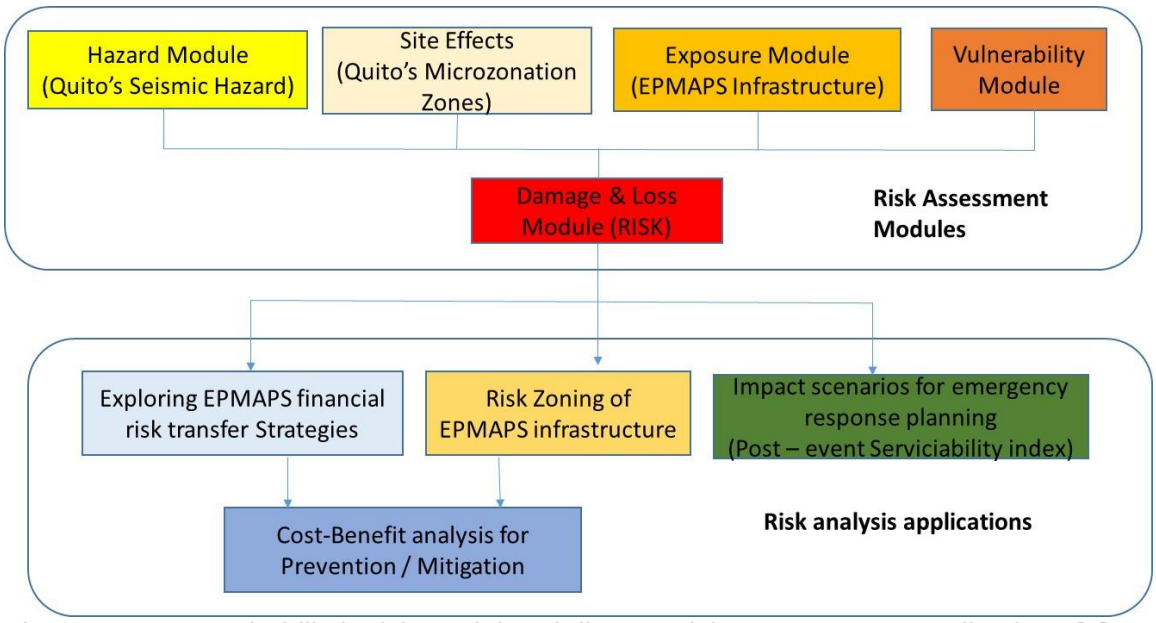

Fig. 2: CAPRA Probabilistic risk model and disaster risk management applications [7]

In terms of the application and post processing analysis of CAPRA, it is important to mention that the platform is conceptually oriented to facilitate decision-making process; by using risk results in terms of state of the art metrics, indicators and maps, providing sounding elements for designing risk transfer instruments, for evaluating probabilistic cost-benefit ratio of risk mitigation strategies, for improving operational and maintenance plans as well as for determining loss scenarios for emergency response, early warning and loss assessment mechanisms [6].

2.2 Quito's Probabilistic Seismic Hazard Analysis - PSHA

The implementation of seismic hazard module of CAPRA needed the use of latest probabilistic seismic hazard analysis (PSHA) of the area of influence of the most important water supply systems of EPMAPS [8]. This study was performed by the Geophysical Institute[3] of the National Polytechnic School for EPMAPS in order to provide a long-term overview of the relationships between strong ground motion levels and their occurrence frequencies, which by means of probabilistic analysis, represents the seismic hazard in terms peak ground accelerations, velocities and displacements, at the *bedrock level*. The following Figure 3 shows an example of one the outcomes of the PSHA performed.

[3] Geophysical Institute of the National Polytechnic School –IG-EPN provides official studies of seismic and volcanic hazards in Ecuador.

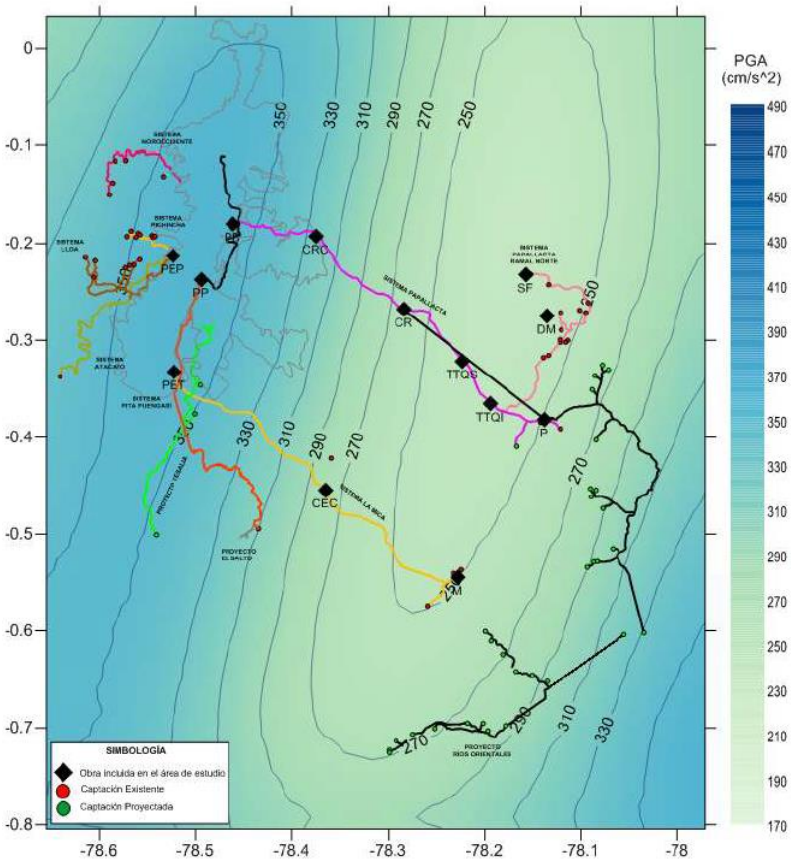

Fig 3: Seismic Hazard Map (Iso-aceleration- PGA; Return Period =475 years) of the area of influence of EPMAPS infrastructure of water supply [8]

The PSHA was carried out through the CRISIS$_{2007}$ program[4]. This tool has been selected due to its versatility for the generation of stochastic scenario files (AME), required by the EPMAPS and necessary in the risk analysis on the CAPRA platform.

The seismic model was developed considering 77 seismic sources that IG-EPN has identified through the latest investigations as the most relevant to characterize the seismic hazard - *at the bedrock level*- of the area of influence of the main water supply systems of Quito.

All input parameters, both the geometry of the sources and the coefficients of the Gutenberg-Richter equation and maximum and minimum magnitudes, have been taken from the files to generate the Seismic Zone Map defined for the Ecuadorian Construction Standard NEC -11[5]. 32 structural periods have been considered to perform the calculation of the maximum acceleration of the ground (PGA) in rock, with 5% of damping [8].

As a result of the performed PSHA more than 74000 stochastic events *-feasible earthquakes with different locations, magnitudes, dip angles, depths and occurrence frequencies, associated to all seismic sources analyzed*- were obtained and compiled into an AME file, for purposes of the current analysis.

[4] Ordaz, M., Aguilar, A., Arboleda, J., 2007. CRISIS 2007, Program for computing seismic hazard, Instituto de Ingeniería UNAM.

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2.3 Quito's seismic microzonation: Site Effects

As it is widely known in the field of seismic engineering, the site effect due to the dynamic behavior of the soil underlying the structures is a very important phenomenon to be taken into account in the seismic risk assessment due to the potential incidence in the amplification of seismic waves and the expectation of greater impacts on exposed infrastructure.

The Metropolitan District of Quito has a seismic microzonation study [9] that has defined 13 different homogeneous soil zones. The geographical location of each zone, as well as the numerical ID's linked to a specific set of transfer functions are presented in the following Figure 4.

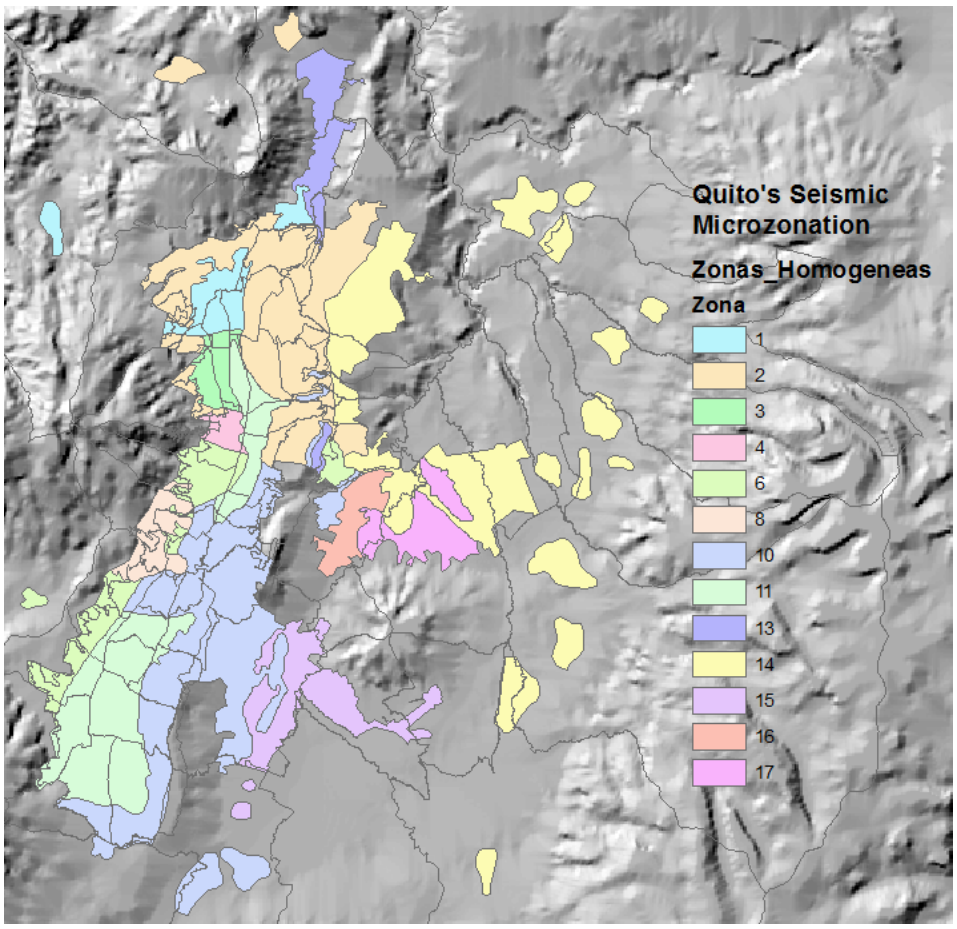


Fig 4: Seismic Microzonation Zones for Quito [9]

Based on geotechnical information obtained from previous studies, the information of the Quito´s Metro Project, as well as new field geotechnical survey including down-holes, seismic refraction and laboratory tests, the performed analysis computed the dynamic soil responses with a typical non-linear and one dimensional propagation model[6] in order to obtain the response spectra at ground level.

The results show that the dynamic behavior is depending on the level of seismic intensity of the input signal, therefore a set of spectral transfer functions for different seismic intensities have been defined for each of the 13 harmonized seismic zones

[6] SHAKE91 - Schnabel, John Lysmer y Harry B. Seed – University of California -Berkeley

defined in the study [9]. The following Figure 5 shows, as a manner of example for the harmonized microzone N° 1, the typical set of amplification factors for different seismic intensities (0.05 g, 0.1g, 0,2 g and 0.4 g).

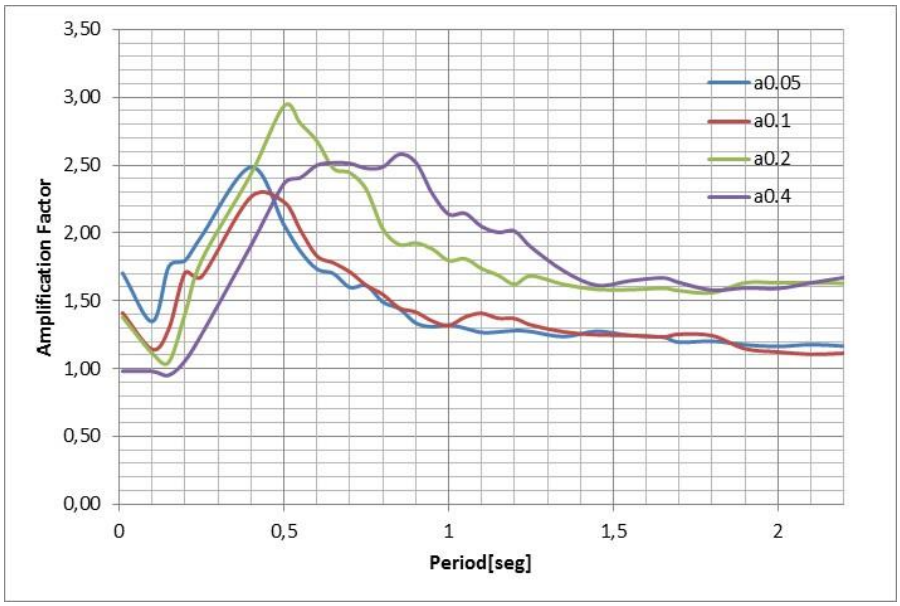


Fig. 5: Amplification factors for microzone N° 1 for different acceleration intensities [9]

Within the framework of a technical assistance to EPMAPS[7] and based in the results of the Quito's microzonation study, a binary file containing the spectral transfer functions was prepared for the area of analysis using the Site Effects module of CAPRA. For this purpose, a raster file with the ID of the zones is generated form the information shown in Fig. 4 and then, for each zone, a set of spectral transfer functions, as the ones presented in Fig. 5 is included for the assessment. This file is then used to multiply each event´s intensity for each spectral ordinate by the corresponding amplification factor value before calculating damage of EPMAPS infrastructure as part of the risk calculation.

2.4 Exposed assets database

The development of the exposure portfolio is based fundamentally on the geodatabase of EPMAPS infrastructure and it was complemented with a process of arranging, classifying and updating the existing information related to the exposed assets. The portfolio has been categorized in three groups: water supply infrastructure, sewage infrastructure and buildings. The structure of the exposure portfolio is described in the Table 1 and it presents a number of hydraulic and operational structures that would be part of the current analysis, also the table shows the relative share of the total exposed value of EPMAPS infrastructure.

A set of structural parameters has been defined for the current evaluation. Relevant criteria related to the expected behavior of each asset when subjected to earthquake hazard intensities range from: age, construction material, geometry and specific

[7] The Municipality of the Metropolitan District of Quito through its Urban Risks Reduction Program hired ERN Consortium to provide technical assistance to EPMAPS in order to assess its seismic risk, process that has been a first milestone of the present study.

structural condition. This process helped to characterize the exposure portfolio into 162 different structural typologies.

INFRASTRUCTURE PORTFOLIO	Relative share of the total value [%]
TOTAL	**100**
MDQ-QUITO´S WATER SUPPLY INFRASTRUCTURE	**57,11**
WATER SUPPLY NETWORK	33,65
CONDUCTION PIPELINES	14,48
WATER TREATMENT PLANTS	5,47
WATER TANKS FOR DISTRIBUTION	2,14
WATER WELLS	0,82
VALVES	0,38
WATER INTAKES	0,13
OPERATIONAL CHAMBERS	0,04
MDQ-QUITO´S SEWAGE SYSTEMS INFRASTRUCTURE	**37,05**
SEWAGE NETWORK	34,27
MANHOLES	2,78
ADMNISTRATIVE & OPERA-TIONAL BUILDING OF EPMAPS	**5,84**
BUILDINGS	5,84

Table 1: Exposed Infrastructure Portfolio of EPMAPS

Another important aspect of the development of the exposure portfolio is the economical appraisal of the infrastructure of the EPMAPS. As this analysis is set to be presented in metrics of the expected losses due to earthquake risks, this evaluation has to be determined in terms of the amount of money required to repair or rebuilt the damaged asset and take it back to the exact same conditions it was in before it was damaged, which by definition represents the replacement cost.

For this, it has been done a process of first carefully combine the geodatabase of the infrastructure of EPMAPS with the accountancy database of the company and then adjusting the economical appraisal in terms of the replacement costs of all analyzed assets. As a result, every single element of the geodatabase of the exposure portfolio is defined by it correspondent structural typology and its exposed value calculated in replacement cost terms.

2.5 Seismic Vulnerability of exposed assets

In order to complete the seismic vulnerability analysis, a set of vulnerability functions have been assigned to each of the 163 previously defined structural typologies.

The vulnerability function approach accounts for a continuous, quantitative and probabilistic representation of the physical damage of the assets for different levels of hazard intensities. It is important that, the vulnerability function relate the expected

loss with the seismic intensity that most appropriately correlate the impact over the exposed asset, considering also the dispersion [10].

In case of buildings, water treatment plants, tanks and other facilities, the relevant seismic intensity are spectral accelerations, however, for linear infrastructure such as conduction pipelines, water distribution networks, etc. velocities intensities were taken into account. Vulnerability functions for water wells and manholes use seismic displacement intensities. The following Figure 6 shows some examples of the vulnerability functions used in the assessment.

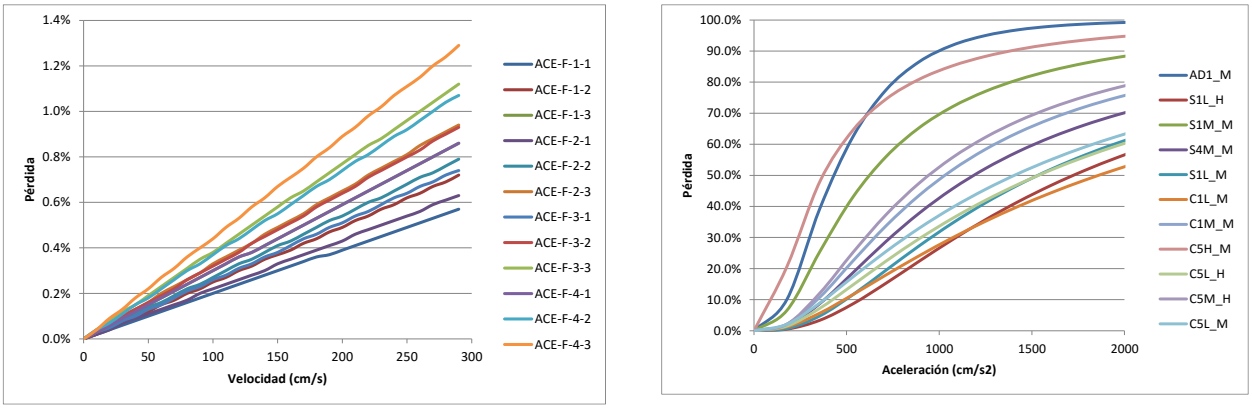


Fig. 6: Examples of some vulnerability functions for different types of steel pipes [left - 11] and for some of the different types of buildings of EPMAPS [right - 12]

In order to assign the most adequate vulnerability function to any given structural typology, an expert criteria approach[8] based on both analytical and empirical knowledges was implemented to first classify and define a specific structural typology and then use the recommendation provided by the technical literature to choose the most suitable function available.

For the case of pipelines, recommendations provided by the American Lifeline Alliance [11] were followed in order to obtain the repair rates, expressed in terms of the number of damages to be repaired by km. It was also of use, the fragility curves (to be latter transform into vulnerability functions) recommended by the US Federal Emergency Management Agency through its multi-hazard loss estimation methodology - HAZUS [12].

2.6 Seismic Risk Analysis

As it is described in the Figure 2, CAPRA risk module calculates risks quantitatively in terms of expected damages and losses of the exposed infrastructure by combining hazard, site effects ant the exposure and vulnerability analysis. The physical seismic risk is evaluated by means of the convolution of hazard with vulnerability of the exposed elements, within a probabilistic basis, in order to take into account the series of uncertainties that are inherent to the hazard and structural vulnerability.

[8] Based on the technical assistance provided by ERN Consortium to EPMAPS as well as a further process of optimization, re-assignation and updating of vulnerability functions according to an upgraded exposure database, matter of the current analysis.

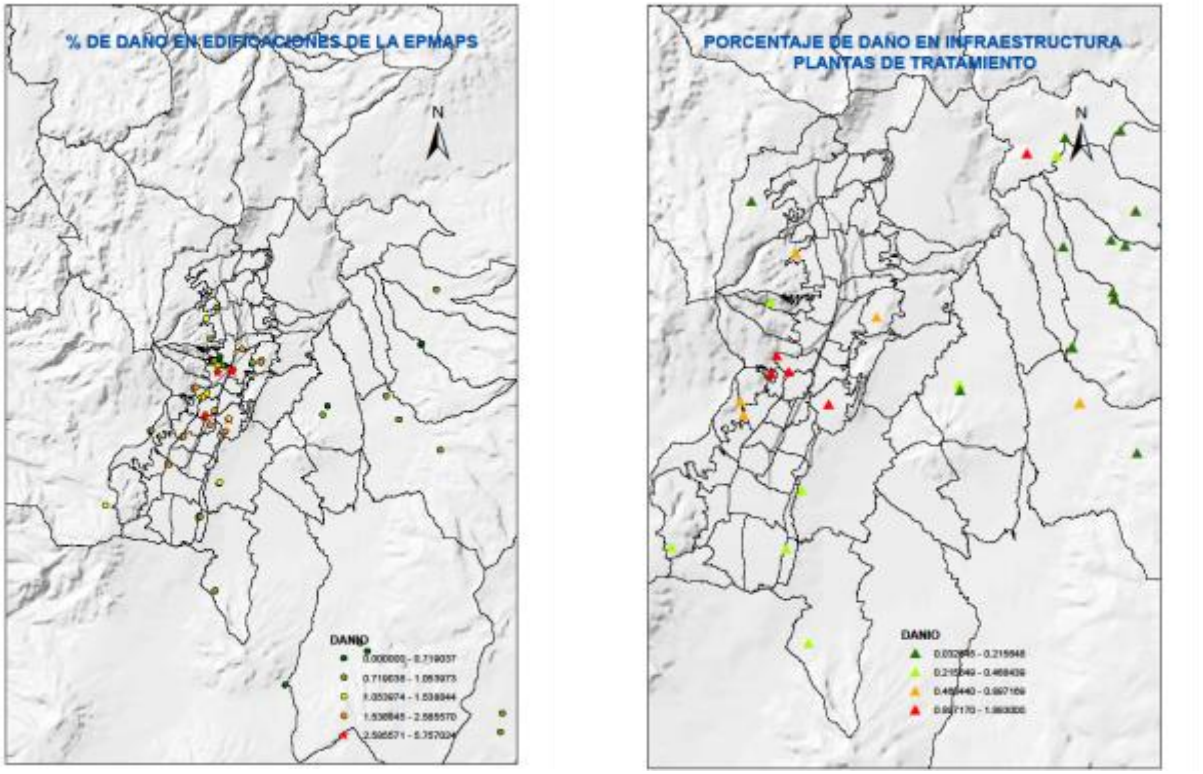
3 Analysis of Seismic Risk Results: Elements for Resiliency Planning

Once the expected physical damage is estimated (average value and its dispersion) as a percentage for each of the assets or infrastructure components included in the current analysis, one can make estimates of essential parameters required by risk managers and decision makers in order to enhance resiliency facing future seismic risk.

3.1 Seismic Risk Zoning of EPMAPS infrastructure

Spatial distribution of the losses can be mapped to show those facilities and specific infrastructure that would be mostly affected by the seismic risk. This tool could help to prioritize further analysis -within ad-hoc structural assessment- that can trigger structural reinforcement or building retrofitting, among other mitigation strategies, over critical infrastructure of EPMAPS.

Risk maps is a fundamental tool to address specific measures in specific locations in order to optimize a disaster risk reduction strategy. The following Fig. 7 shows some example of the risk maps obtained from the results of the probabilistic seismic risk assessment performed through CAPRA.



a) Seismic risk map of EPMAPS administrative and operational buildings

b) Seismic risk map of water treatment plants of EPMAPS

Fig. 7: Examples of some risk maps of specific infrastructure of EPMAPS

3.2 Quantifying losses over EPMAPS infrastructure: Financial assessment

From the financial point of view, it is essential to estimate and quantify potential losses in a given exposure time given that the budget for both emergency response and recovery and reconstruction could mean a financial challenge to the sustainability of

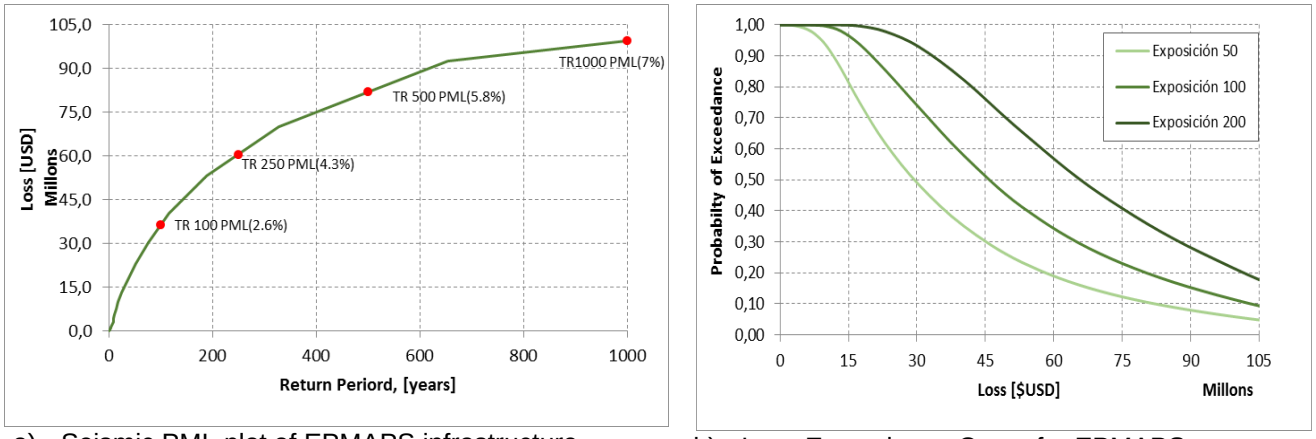
EPMAPS and its ability to provide water and sanitation services to MDQ. Estimation of contingent losses permits to set out strategies ex ante for reducing, financing or transfer the risks.

As previously described, the probabilistic risk analysis is done based on a series of hazard scenarios that adequately represent the effects of any event of feasible magnitude that can occur in the area of influence of EPMAPS infrastructure. Each of these scenarios has an associated specific probability of occurrence. The probabilistic calculation procedure comprises the assessment using appropriate metrics, in this case the economic loss, in terms of Average Annual Loss, Probable Maximum Lost, among others.

The Average Annual Loss (AAL) is the expected loss per year. Computationally, AAL is the sum of products of event expected losses and event annual occurrence probabilities for all the stochastic events considered in the loss model. In probabilistic terms, AAL is the mathematical expectation of the annual loss. The Loss Exceedance Curve (LEC) represents the annual frequency with which a loss of any specified monetary amount will be exceeded. It estimates the amount of funds required to meet risk management objectives. The LEC includes the possibility of one or more severe events resulting from earthquakes. The Probable Maximum Loss (PML) represents the loss amount for a given annual exceedance frequency, or its inverse, the return period. Depending on the stakeholder's risk tolerance, the risk manager may decide to manage for losses up to a certain return period [5].

Due to data confidentiality restrictions, the actual figures of AAL and PML are not shown in this study, however it is important to mention that CAPRA metrics of the seismic risk of EPMAPS infrastructure provide a highly reliable order of magnitude of the catastrophic risks profile of the infrastructure of EPMAPS.

The following Figure 8 shows the seismic LEC and PML of the current analysis performed for EPMAPS infrastructure.



a) Seismic PML plot of EPMAPS infrastructure b) Loss Exccedance Curve for EPMAPS

Fig. 8: Seismic Risk Metrics calculated for EPMAPS infrastructure through CAPRA Platform

The latter results facilitate the implementation of effective financial protection strategy to provide loss coverage of EPMAPS public infrastructure, as well as, it represents valuable information that would lead to budget allocation for structural retrofitting to reduce damages. These results may lead also to an optimization process of the risk

transfer strategies, due to a better knowledge of the EPMAPS catastrophic risk profile.

3.3 Cost-Benefit analysis applications

Furthermore, if evaluation is performed in disaggregated way, finding the share of losses that every single structural typology contributes on the total loss, a brief cost-benefit analysis can be done. For instance, the following Fig. 9, compares the relative share of the total exposed value of EPMAPS portfolio, in terms of its infrastructure components (Table 1) with the calculated relative share of the total annual loss of those components.

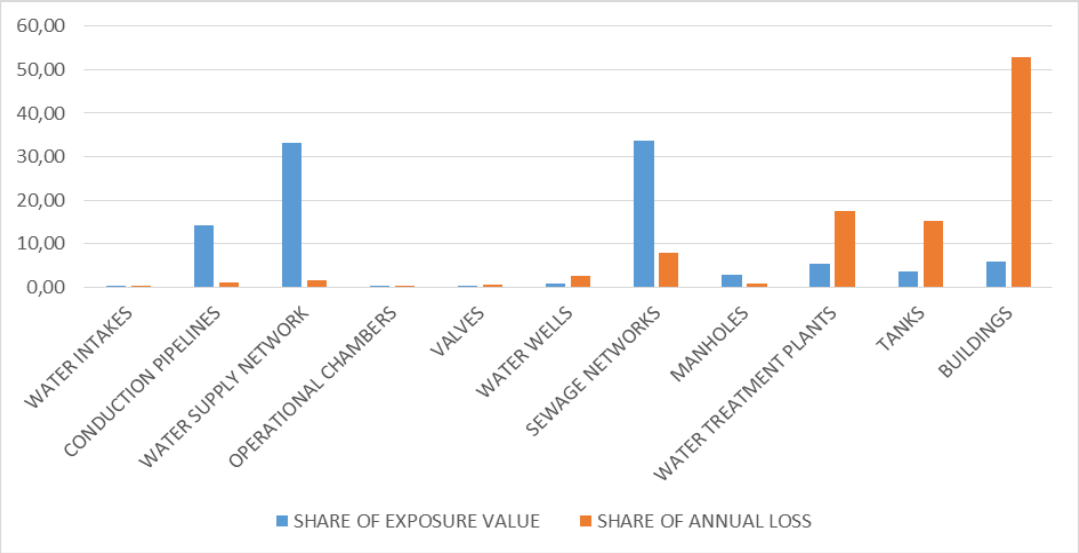


Fig. 9: Share of exposure value of specific infrastructure and share of expected annual losses

The subsequent analysis of the latter Figure 9 shows the fact that even though buildings represent a small share of the company exposed value (around 5%), buildings structures concentrate more than 52% of the expected annual loss.

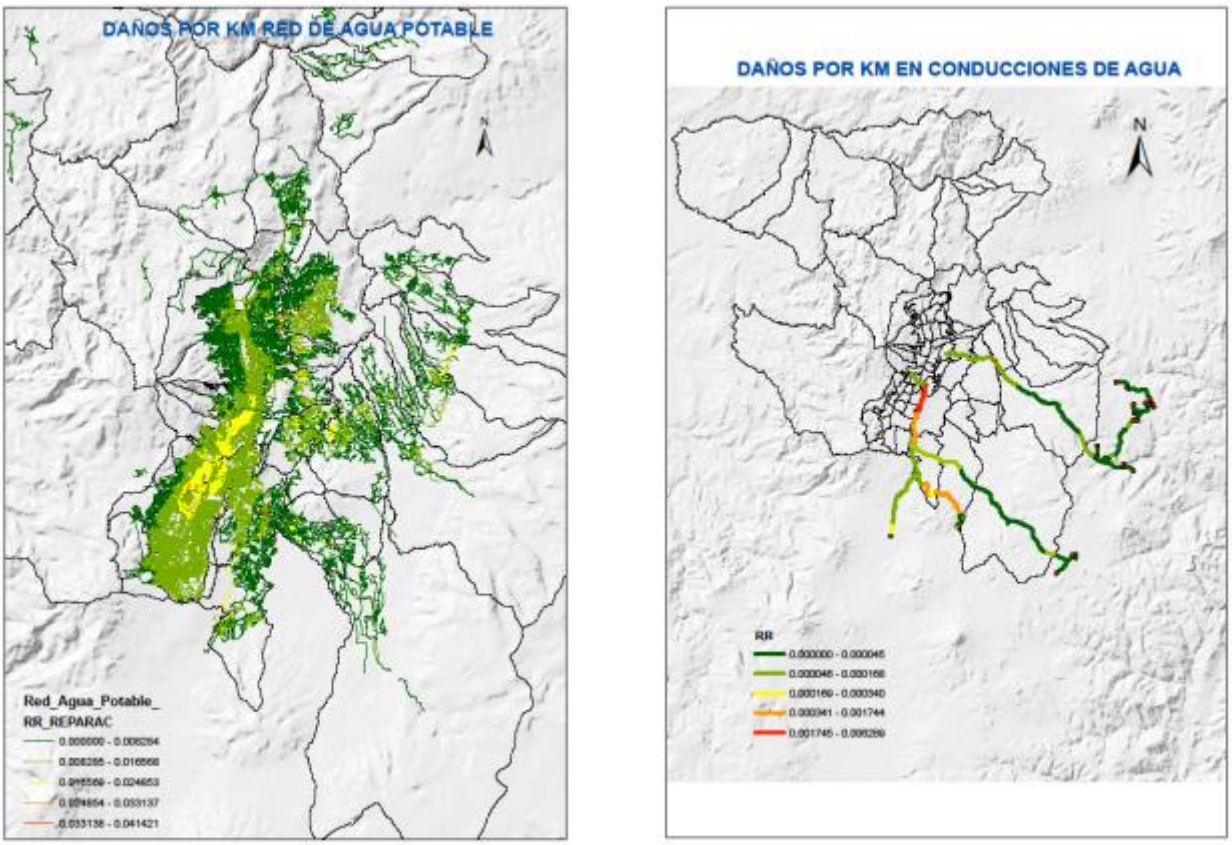
On the other hand, water supply and sewage networks sum up to more than 60 % of the exposed value, but both networks only represent a 9% of the total annual loss.

It can be concluded that risk mitigation strategies containing investment to enhance the seismic behavior of the buildings would be highly effective into reduce the economic impact over the analyzed portfolio. On the contrary, investments tending to mitigate seismic impacts on water networks and pipelines, would be, from the financial perspective, less effective to reduce the direct economic impacts over EPMAPS infrastructure.

3.4 Scenarios development for seismic emergency plans

Besides the assessment of financial impacts over EPMAPS infrastructure, it is also important to evaluate the operational implications of seismic risks. The current study could contribute to analyze potential impacts over operational objectives of post-disaster water supply of Quito. For instance, an order of magnitude, on a probabilistic basis, of the expected repair rates of linear infrastructure is shown in the Figure 10.

This information could be of use in activities related to expansion and maintenance strategies as well as for preparing emergency response plans for earthquake risk.



a) Water distribution network of Quito city

b) Main conduction pipeline systems of EPMAPS

Fig. 10: Examples of expected probabilistic Repair Rates [RR] per Km of linear infrastructure

Due to the fact that not all the important factors that have influence over the development of an impact scenario are suitable for probabilistic modelling, a deterministic approach, using the most relevant scenario could be used as important input to construct a comprehensive impact scenario for purposes of the development of the emergency and contingency plan of EPMAPS.

4 Conclusions

The practical use of the results of probabilistic seismic risk assessment performed through CAPRA platform has been presented in this paper. The study shows how this kind of assessment provides valuable information for EPMAPS that can be incorporated in a direct and explicit way in decision-making processes for seismic risk management, covering a variety of aspects ranging from traditional insurance schemes, prioritization of seismic risk mitigation strategies, updating and harmonization of the seismic contingency plans together with the identification of vulnerable structures and risk map zoning of EPMAPS infrastructure.

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One Water Planning for the City of Los Angeles, California: The Sustainable Management of Water Resources for Reliable and Resilient Water Supply

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Abstract: Water resources in the City of Los Angeles is affected due to rising temperatures and drought, sea level rise in coastal areas, forest fire and aging infrastructure. Effectively managing water resources is the solution of many uncertainties. The concept of one water is the future of the water industry where the science of water advances all portions of the water cycle. Many benefits are realized when the barriers traditionally separating water, wastewater, stormwater and water reuse are broken down in a reliable and resilient plan for life's most essential resource. The principle idea behind one water planning process includes (a) all water has value; (b) a focus on achieving multiple benefits; (c) watershed-based approach; (d) partnership for progress; and (e) inclusion and engagement of all. The One Water LA 2040 Plan (One Water LA) is a comprehensive planning process designed to increase sustainable water management for the City of Los Angeles. This planning effort sought to accomplish two main goals: (1) integrate wastewater facilities planning with stormwater, recycled water and water conservation with a planning horizon from 2005 to 2020; and (2) enlist public stakeholders in the entire planning process. The plan included capital improvement programs for wastewater and stormwater; an initial recycled water master plan; a financial plan; and a programmatic environmental impact report. One Water LA also set out to increase levels of stakeholder involvement and

interactions by casting a wider net for public participation and engaging all City departments and relevant regional agencies in the development of this plan. This paper includes the overall plan, primary results and future implementation plans including green stormwater infrastructure (GSI) such as, green streets, alleys, rain gardens, rain barrels, infiltration galleries, cisterns, and wetlands.

1 Introduction

In 1999, the City of Los Angeles (City) embarked on an unprecedented new approach for sustainable water resources management called the Water Integrated Resources Plan (Water IRP). This planning effort sought to accomplish two main goals: (1) integrate wastewater facilities planning with stormwater, recycled water and water conservation with a planning horizon from 2005 to 2020; and (2) enlist public stakeholders in the entire planning process. Adopted by the City in 2006 and widely supported by public stakeholders, the Water IRP included: capital improvement programs for wastewater and stormwater; an initial recycled water master plan; a financial plan; and a programmatic environmental impact report.

The One Water LA 2040 Plan (One Water LA) is a comprehensive planning process designed to increase sustainable water management for the City of Los Angeles. One Water LA (Plan) is building on the success of the City's Water Integrated Resources Plan, adopted in 2006.

Water resources in the City of Los Angeles is affected due to rising temperatures and drought, sea level rise in coastal areas, forest fire and aging infrastructure. Effectively managing water resources is the solution of many uncertainties. The concept of one water is the future of the water industry where the science of water advances all portions of the water cycle. Many benefits are realized when the barriers traditionally separating water, wastewater, stormwater and water reuse are broken down in a reliable and resilient plan for life’s most essential resource.

The One Water LA Vision Statement is defined as follows:

- One Water LA is a collaborative approach to develop an integrated framework for managing the City's water resources, watersheds, and water facilities in an environmentally, economically, and socially beneficial manner.
- One Water LA will lead to smarter land use practices, healthier watersheds, greater reliability of the City's water and wastewater systems, increased efficiency and operation of our utilities, enhanced livable communities, resilience against climate change, and protection of public health and our environment.

The idea behind one water planning process includes (a) all water has value; (b) a focus on achieving multiple benefits; (c) watershed-based approach; (d) partnership for progress; and (e) inclusion and engagement of all. The plan addresses the following:

- Reduced water demands and wastewater flows from increased levels of water conservation;

- Chronic and more severe droughts, reduced reliability of imported water supply, and rising prices of imported water from Metropolitan Water District of Southern California;
- Climate change, which is impacting the state's snow pack and long-term availability of imported water to Los Angeles, stresses on local ecosystems, greater risks of localized flooding, and sea-level rise which could impact critical water infrastructure near the coast;
- A newly adopted (2012) Municipal Separate Storm Sewer System (MS4) permit for Los Angeles County that allows municipalities to develop a more integrated approach for meeting Total Maximum Daily Loads (TMDLs) of stormwater discharges, which will be achieved through Enhanced Watershed Management Plans (EWMP).

The One Water LA plan also set out to increase levels of stakeholder involvement and interactions by casting a wider net for public participation and engaging all City departments and relevant regional agencies in the development of this plan.

The goal of this paper is to present various key components of the Plan, primary results and future implementation plans including green stormwater infrastructure (GSI) such as, green streets, alleys, rain gardens, rain barrels, infiltration galleries, cisterns, and wetlands.

2 Background

2.1 One Water LA 2040 Plan

One Water LA, a multipurpose and multi benefit project is building on the success of the 2006 Water IRP, while also addressing a number of emerging challenges and new conditions. To address these challenges and new conditions, the planning horizon for One Water LA was extended to the year 2040. One Water LA also set out to increase levels of stakeholder involvement and interactions by casting a wider net for public participation and engaging all City departments and relevant regional agencies in the development of this plan (Figure 1).

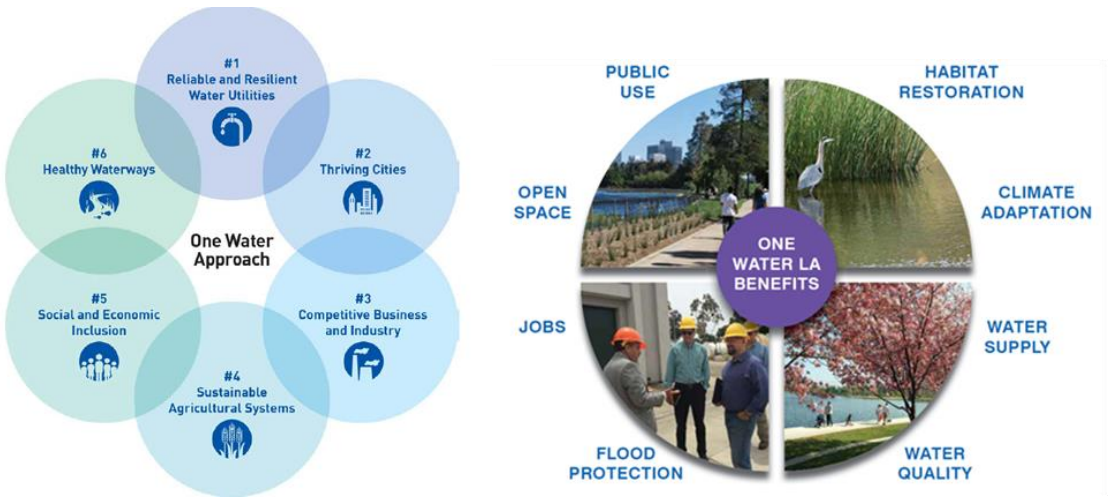

Figure 1. The Framework of the City of Los Angeles' One Water Planning Approach and Multiple Benefits from Stormwater Management Projects (Courtesy: USwateralliance.org)

One Water LA is being developed in two phases. Phase 1 has strengthened interactions among City departments and regional agencies by having dedicated focus meetings on water management. More than 300 public stakeholders were involved in the process of plan development. The One Water LA Phase 1 objectives are:

- Integrate management of water resources and policies
- Balance environmental, economic and societal goals
- Improve health of local watersheds
- Improve local water supply reliability
- Implement, monitor and maintain a reliable wastewater system
- Increase climate resilience
- Increase community awareness and advocacy

Phase 2 will involve more detailed planning and policy analyses, in coordination with currently on-going plans from the City's Los Angeles Sanitation (LASAN) and Los Angeles Department of Water and Power (LADWP). This phase will include updated wastewater and stormwater capital improvement programs, and recommended policies and procedures for increased coordination and integration of water between all City departments. Phase 2 involves detailed, integrated planning and policy analysis that will result in an implementation strategy to meet the One Water LA vision, objectives, and guiding principles.

By identifying the multiple benefits (environmental, economic, and social) of projects and programs, the City can implement more sustainable and cost-effective solutions. Ultimately, One Water LA will lead to smarter land use practices, healthier watersheds, greater integration of the City’s various water systems, increased utility efficiency, stronger communities, climate change resiliency, and protection of public health.

As part of the long-term strategy development through various elements (Figure 2), 25 ideas were developed, evaluated, scored and ranked. The most promising ideas will be combined as recommended long-term strategies to maximize recycled water use, contribute to supply resiliency and provide multiple water quality benefits. The combination of selected ideas will ultimately be integrated in the One Water LA Implementation Strategy.

Figure 2. Key elements of the LA One water plan

2.2 LA's Water Supplies

The City utilizes three different aqueducts that bring water to LA from the Delta, Owens Valley, and the Colorado River (Figure 3). Approximately 84 percent of the water the city of LA uses comes from hundreds of miles away. The remaining 16 percent of the City's water supply comes from local groundwater, stormwater, and recycled water.

Figure 3. Existing Sources of Water Supply

The City's current water supply mix results in heavy dependence on snowfall and sufficient storage in Northern California, Eastern Sierras and the Colorado River watershed. Recent drought conditions and climate change severely impacted snowfall in the Eastern Sierras and the Colorado River watershed. As those water supplies fluctuate, so does the quantity of imported water from these sources. Moreover, all three aqueducts cross the San Andreas Fault and are subject to prolonged interruptions in case of a major seismic event. The One Water LA Plan recognizes that developing local supplies-sources that the City can rely upon under any circumstances-is a top priority of the City.

2.3 Water Conservation Practices

Water Loss Reduction Program. The City created a Water Loss Task Force to reduce water loss through initiatives such as improved pressure management and increased active leak detection.

Save-the-Drop Campaign. Under this program, outreach materials include public service announcements, radio spots, event handouts, and public signage. The City has developed extensive public information and school education programs including offering training classes that assist customers in making the switch from turf to sustainable landscapes.

Cash in your Lawn. This program provides homeowners with rebates to remove thirsty grass and replace it with California-friendly landscaping. Despite having only 10 percent of the State's population, the City has already contributed to more than 95 percent of the State's goal. To date, City of LA residents have replaced nearly 50 million square feet (4.6 million m2) of grass with low water using, sustainable landscaping-saving more than 1.9 billion gallons (7 million m3) of water each year.

2.4 Stakeholder Process

With a goal of increasing and widening stakeholder involvement, Phase 1 of One Water LA had five levels of interactions (Figure 4). Core to the stakeholder process were the interactions between the Steering Committee, Inter-Department/Agency Focus Meetings, and Stakeholder Advisory Group meetings. These core interactions provided direction and content to the Public Stakeholder Workshops and to inform the Public Outreach at large.

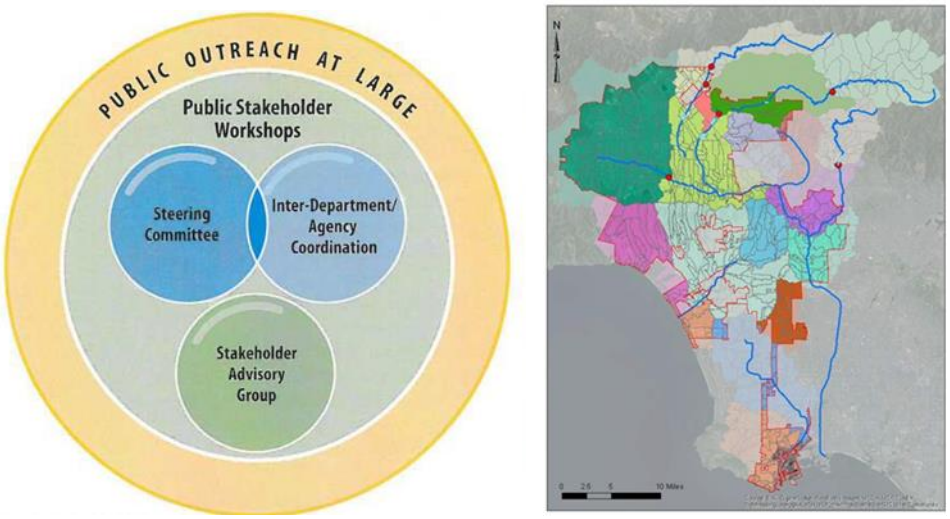

Figure 4. Phase 1 Stakeholder process and the LA watershed map

In many cases, plans start with identifying technical solutions to solving problems and then move towards ranking those solutions to arrive at a preferred implementation strategy. A unique aspect of One Water LA was to first solicit stakeholder input on answering three fundamental questions before undertaking any technical analyses:

1. What is the overall purpose?

2. What are the goals to accomplish the goals?

3. How the plan will be implemented successfully?

If these questions remain unresolved, participants in the planning process may not agree on the appropriate measures needed to achieve success. However, when these questions are answered at the beginning of a planning process, they can help identify common ground among stakeholders, build consensus and achieve long-lasting advocacy.

Objectives describe the major goals of a plan in clear and easily understood terms. Together with the vision statement, objectives provide a picture of what constitutes success. Furthermore, clearly stated objectives can form the basis for developing evaluation criteria against which potential choices and actions can be compared. The objectives for the plan are as follows:

- Integrate management of water resources and policies by increasing coordination and cooperation between City departments, partners and stakeholders.
- Balance environmental, economic, and societal goals by implementing affordable and equitable projects and programs that provide multiple benefits to all communities.
- Improve health of local watersheds by reducing impervious cover, restoring ecosystems, decreasing pollutants in our waterways, and mitigating local flood impacts.
- Improve local water supply reliability by increasing capture of stormwater, conserving potable water, and expanding water reuse.
- Implement, monitor, and maintain a reliable wastewater system that safely conveys, treats and reuses wastewater, while also reducing sewer overflows and odors.
- Increase climate resilience by planning for climate change mitigation and adaptation strategies in all City actions.
- Increase community awareness and advocacy for sustainable water by active engagement, public outreach and education.

In summary, the goals of the LA water plan are:

1. Increase water use efficiency, reuse of wastewater, and capture of stormwater to reduce future reliance on imported water and increase resiliency.
2. Develop multi-purpose/multi-beneficial stormwater projects for improving water quality and health of local watersheds.
3. Develop, monitor and maintain a sound wastewater system that safely conveys wastewater to water reclamation plants, while reducing sewer system overflows and odors.
4. Work to balance water supply development with Los Angeles River Revitalization for social, environmental, and economic benefits.
5. Support the beneficial role of trees and green spaces in public areas throughout the City.
6. Incorporate climate change mitigation and adaptation strategies in our actions.

7. Coordinate among all City departments to achieve: stronger integration of water-related codes and ordinances in the City's planning, zoning, engineering and building and safety requirements and incorporation of water management into City's recreation & parks and street design and services.
8. Coordinate with regional water management planning activities, such as Los Angeles County Integrated Regional Water Management Plan, Sanitation Districts of Los Angeles County, and Metropolitan Water District of Southern California.
9. Address funding for capital and operation and maintenance costs for water management and facilities - with a focus on "green" infrastructure.
10. Ensure that stakeholders are representative of the LA community and have a voice in the direction of One Water LA.
11. Support education and learning center activities that further One Water LA goals.

One Water LA will provide a comprehensive strategy consisting of new project, program and policy opportunities to manage water in a more integrated, collaborative, and sustainable manner. The Plan will consist of multiple deliverables that will form the foundation of the Implementation Strategy, which provides a roadmap to make the One Water LA Vision a reality.

3 Recommended Strategies

The plan was developed through extensive collaboration from a variety of groups. The steering committee fostered integration and the members comprise of 30 representatives from 14 city departments and 6 regional agencies. This stakeholder driven planning approach with broad involvement had about 300 stakeholder group and more than 150 organization who participate in the development of the plan. One Water LA's long-term strategies consist of a mix of projects and programs that support the sustainable City plan goals and the supply strategy. Focus of the water supply plan is to shift in reuse of wastewater from all non-potable to a mix of non-potable and indirect potable.

Figure 5. Recommended strategy with all opportunities with urban water cycle

In summary, the concepts of the plan include a wide variety of stormwater, groundwater, potable reuse, and other local water management strategies. Expected outcome of the plan includes:

- Improve local water supply reliability
- Maximize potable reuse to minimize discharge to the ocean
- Minimize dry-weather runoff to receiving waters
- Protect the City's facilities and assets from climate related risks Increase climate resilience

4 Stormwater and Urban Runoff Facilities Plan

The Stormwater Facilities Plan (SWFP) explores to maximize the benefits of recommended projects through a three-legged stool approach integrating water quality, water supply and flood risk mitigation benefits (Figure 6). The projects with the maximum benefits were at the top of the list. The plan also includes funding strategies for the projects, and recommended policies and programs. Under this plan, the number of distributed green infrastructure projects, regional green infrastructure projects and grey infrastructure projects are 619, 197 and 326, respectively.

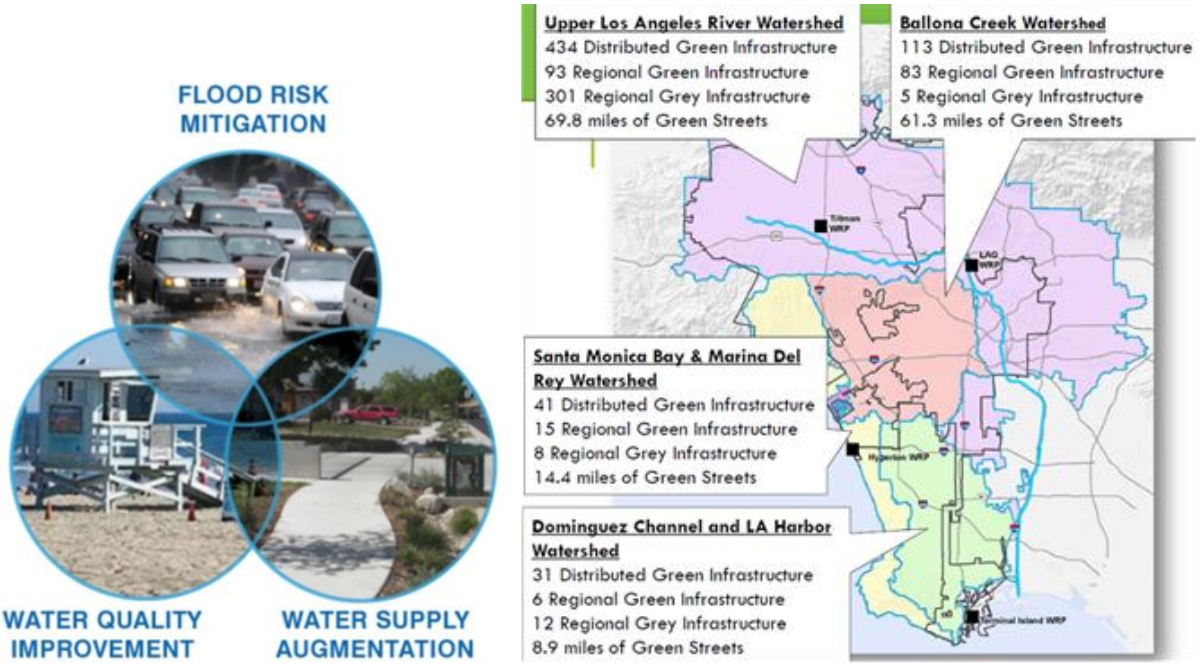

Figure 6. Stormwater and urban runoff planning approach and a map showing locations

About 1,142 projects address stormwater and runoff facilities plans with 71% projects are green infrastructure projects including 250 km (155 miles) of green streets.

4.1 Stormwater Capture and Green Infrastructure

Goals of the stormwater capture projects are to quantify stormwater capture potential, identify new projects/programs, prioritize based on water supply criteria, refine costs for proposed projects/programs. Stormwater management includes lake ecosystem rehabilitation, total maximum daily load implementations, various best man-

agement practices (BMPs) such as, low impact development (LID), construction of green streets, and rainwater harvesting (Figure 7).

Green streets Rainwater harvesting

Figure 7. Various types of green infrastructures for stormwater management

As a part of the stormwater management program, the LA river restoration plan includes water supply; water quality; flood control, connecting communities, habitat and ecosystem restoration and recreation (Figure 8).

Figure 8. McArthur Park, Los Angeles. (Courtesy: One water LA progress report, 2017)

4.2 Low Impact Development (LID)

LID is a big component for water storage in the One water plan. Common Low Impact Development (LID) practices include bioretention, permeable pavement, and other infiltration BMPs that prevent runoff from leaving a parcel. Rainfall harvest practices such as cisterns can also be used to capture rainwater - that would otherwise runoff a parcel - and use it to offset potable water demands. Since the vast majority (nearly 70%) of the runoff from the developed portion of the watershed is generated from impervious areas on a parcel, LID is a natural choice as key strategy to treat runoff from parcel-based impervious areas. LID can be viewed as “first line of defense” due to the fact that water is treated onsite before it runs off from the parcel and travels downstream. Figure 9 shows some the LID implementation techniques used in the plan.

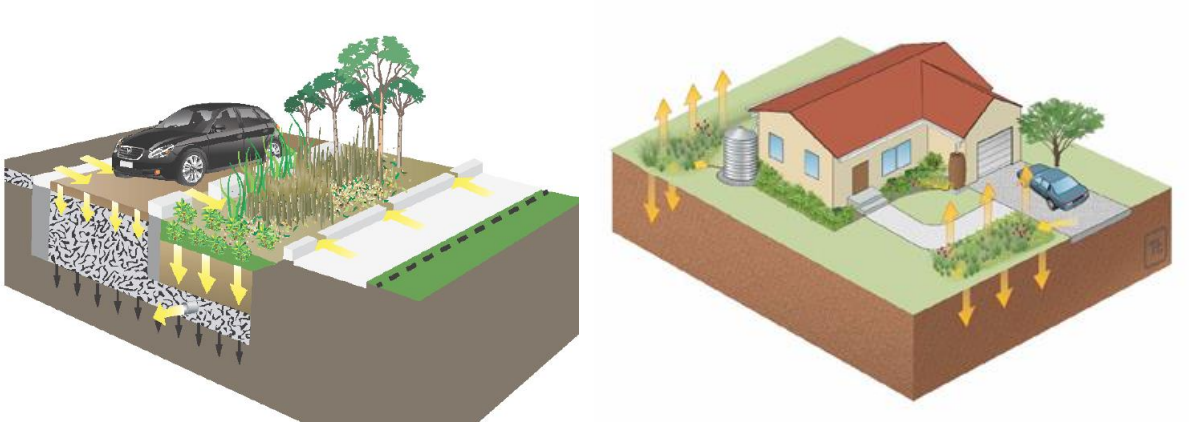

Figure 9: LID implementations on a parcel (arrows indicate water pathways)

Green streets, another LID method, receive runoff from the gutter via curb cuts or curb extensions (sometimes called bump outs) and infiltrate it through native or engineered soil media (Figure 10). Permeable pavement can also be implemented in tandem such as in parking lanes of roads as a potential LID system.

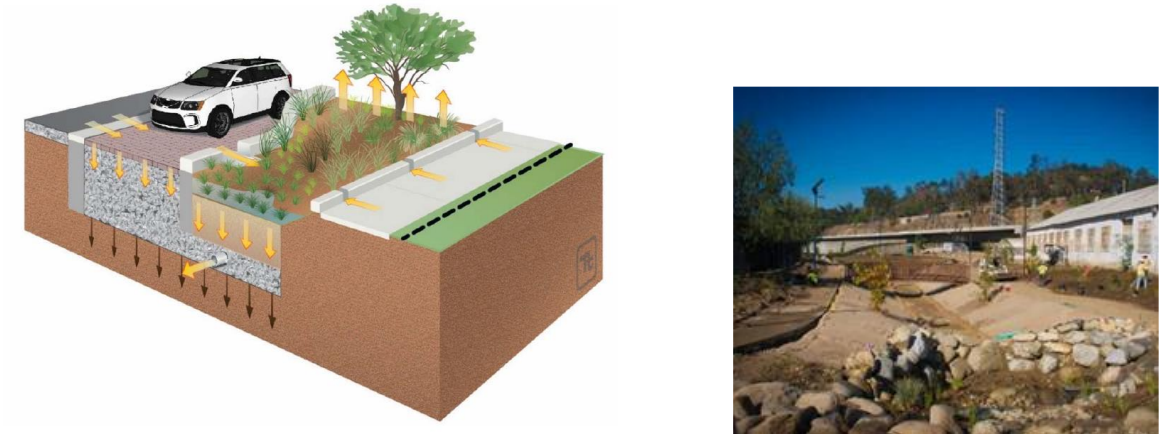

Figure 10. Illustration of a green street (arrows indicate water pathways) and a picture

These natural systems provide multi-benefits beyond stormwater management, such as pedestrian safety and traffic calming, street tree canopy for heat island effect mitigation, increased property values, and reduced crime rates.

5 Climate Change Impacts

Global climate change models indicate higher temperatures, slightly reduced precipitation in some places, and more extreme precipitation in other places. This results in greater peak (summer) water demands, imported water challenges due to earlier snow melt in the mountains and increased localized flooding.

Example Infrastructure Response to Precipitation and Sea Level Rise was examined at the Venice Pumping Plant (wastewater system), San Pedro outfall (stormwater system). Higher sewer and storm drainage flows and increase in the frequency of sanitary sewer overflows (spills) due to flooding was predicted. Extreme climate events will cause increased inland flood events and critical infrastructure and service will be at risk due to climate change (Figure 11).

Under Phase II of the Critical resiliency assessments of critical wastewater and stormwater infrastructure due to climate change, climate vulnerability assessment and adaptation plan (wastewater, stormwater and solid resources programs) was developed. Some progresses are:

- Used USEPA's Climate Resilience Evaluation and Awareness Tool (CREAT) to prioritize at-risk assets and develop planning level cost estimates to protect those assets.
- Identified flood and tsunami impact zones for the City's pumping plants and coastal wastewater treatment plants.
- Conducted field evaluations of critical and vulnerable facilities, such as sewer lift stations and stormwater pump stations.

Under this plan, practical solutions are developed to mitigate risk, such as relocating vulnerable electrical equipment and building barriers to protect against extreme flooding (Table 1).

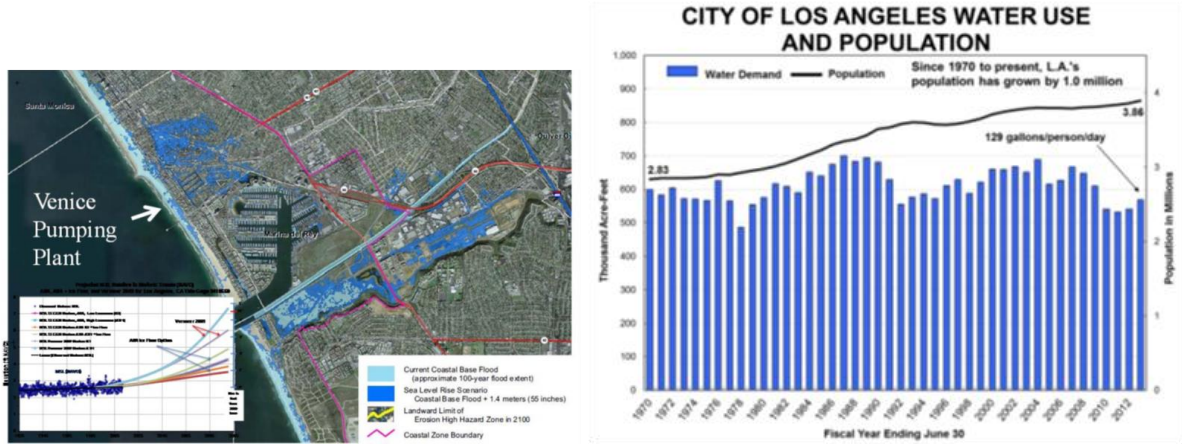

Figure 11. Coastal inundation map due to sea level rise and annual water use pattern

Practical solutions for climate change adaptation plan to increase climate resilience are:

- Waterproof structures
- Perimeter walls around facilities
- Slope stabilization
- BMPs for stormwater management
- Waterproof protection of electrical equipment
- Below-ground pump station modifications

Climate Threat	Impact to water infrastructure	Possible adaptive measure
Increased temperatures	Diminished snowfall and earlier snowmelt in the Sierras	Develop more local water supplies to reduce dependence on purchased imported water
Increased number of hot days	Higher peak water demand	Increase distribution pumping capacity
Increased storm intensity	Higher flood risk to coastal infrastructure (e.g., pump stations)	Raising infrastructure and installing submarine doors.
	Higher flows and infiltration entering pipelines/facilities	Increasing conveyance and pump station capacity
Increased prolonged drought	Declining surface water storage and groundwater levels	Increase water conservation, stormwater capture and expand recycled water production for groundwater replenishment
Sea level rise	Damage potential from storm surges and tsunamis	Reinforce perimeter walls and build waterproof structures

Table 1. The most likely and impactful scenarios due to climate change

6 Funding Plan

A total of $13.3 billion has been identified as the plan's potential fiscal impact (Figure 12). However, $8.8 out of the 13.3 billion is from currently planned projects from other City plans. Investment is needed to meet the City's water challenges and can be done through collaboration and by leveraging resources.

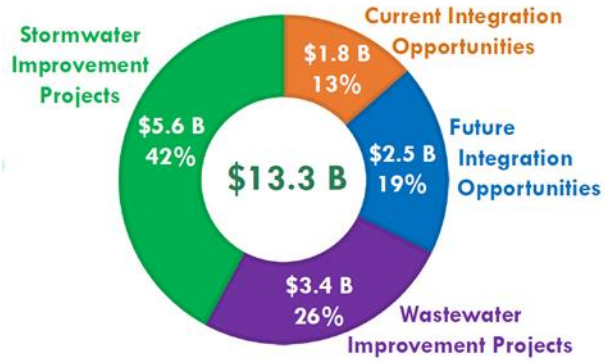

Figure 12. Cost distribution for the LA one water plan recommendations

- Explore stormwater tax or fee options
- Review and streamline grant management process
- Understand how multiple agencies could identify benefit-based costs for water-related projects
- Increase use of State Revolving Funds for multi-benefit projects
- Develop partnerships to reduce costs and maximize upstream solutions

One Water LA will provide a comprehensive strategy consisting of new project, program and policy opportunities to manage water in a more integrated, collaborative,

and sustainable manner. The Plan will consist of multiple deliverables that will form the foundation of the Implementation Strategy, which provides a roadmap to make the One Water LA Vision a reality.

7 Implementation Strategy

A special focus on integration opportunities will enhance collaboration among City departments, regional agencies, and partners including businesses, non-profits, neighborhood organizations, and schools. The Implementation Strategy will include timelines based on known and anticipated triggers and goals, such as, completion of key projects; future flows and demands due to growth; stormwater compliance deadlines; and potable reuse regulations. To achieve the Sustainable City plan water supply reliability goals, the City has already started with the implementation of specific projects (Figure 13). The One Water LA 2040 Plan will include an evaluation of a large number of new project ideas that will result in the recommendations presented in the One Water LA roadmap to 2040 and beyond.

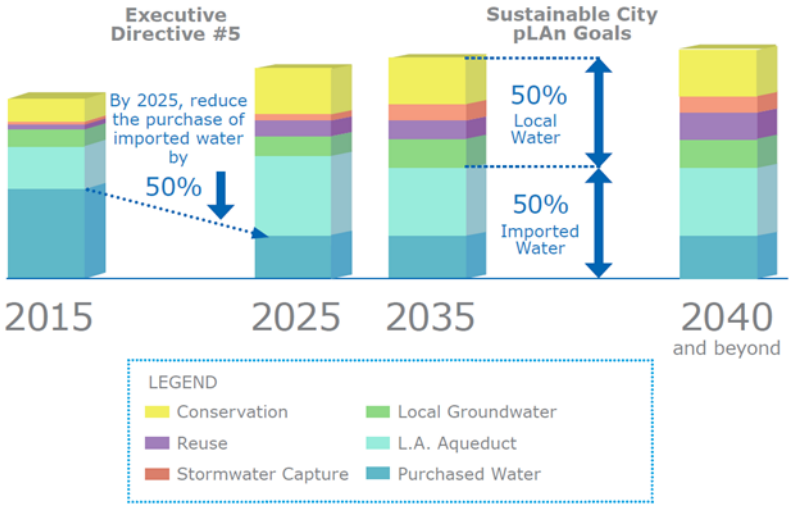

Figure 13. The One Water LA's implementation goal

8 Summary and Conclusions

The key outcomes of the One Water LA program include:

- A framework for integration opportunities between City departments, regional agencies, and other stakeholders.
- A strategy to maximize potable reuse opportunities and reduce reliance on purchased imported water.
- A strategy to maximize stormwater capture that considers water quality, flood mitigation, and water supply benefits.
- More stringent stormwater quality regulations
- Increase stormwater capture and recharge through Low Impact Development (LID) and green infrastructure projects and programs.
- Increase stormwater capture, treatment, and reuse at neighborhood, sub-watershed, and regional levels.

- Increase use of the groundwater basin for storage through new recharge projects.
- Optimize and maximize recycled water for irrigation, commercial, industrial, and groundwater recharge uses.
- Replace aging infrastructure
- Adapt to changing flood protection needs
- Balance environmental, economic and societal goals by implementing affordable and equitable projects and programs that provide multiple benefits to all communities.
- Improve health of local watersheds by reducing impervious cover, restoring ecosystems, decreasing pollutants in our waterways and mitigating local flood impacts.
- Improve local water supply reliability by increasing capture of stormwater, conserving potable water and expanding water reuse.
- Implement, monitor and maintain a reliable wastewater system that safely conveys, treats and reuses wastewater while also reducing sewer overflows and odors.
- Increase climate resilience by planning for climate change mitigation and adaptation strategies in all City actions.
- Increase community awareness and advocacy for sustainable water by active engagement, public outreach and education.
- Continue water conservation by residential, commercial, and industrial users.

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A Policy Proposal for Solid Waste Management toward Smart City based on Households Preferences: A Randomized Experiment in Surabaya City, Indonesia

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Abstract: There is no single definition of a smart city. Each city in each country has a different concept in defining the elements of a smart city. Nevertheless, most of the concepts involve smart infrastructure as part of the elements. One of the government concern in providing good public infrastructure services is efficient waste management. Since waste remains a big issue in developing country, there have been growing studies of better waste management system by eliciting households' preferences in developing countries. This study extends the previous studies in that we examine the preferences of households on waste management system using a new approach called a randomized conjoint analysis. We proposed seven attributes for conjoint analysis. Those are rule for organic wastes to bring into collection station, walking distance to the nearest collection station, collection frequency of organic waste, number of separation for non-organic waste, intermediate processing technology, final disposal technology, and monthly payment in addition to retribution. The research findings show that the number of separation for non-organic waste and inter-

mediate processing technology are the most preferred attributes, while payment attribute seems to be a burden for the households. The results can be taken into account by policy-makers in formulating a new policy regarding household waste management, especially in a developing country like Indonesia, since the preference can be seen as a representative of public support toward a new proposed policy in achieving smart city. The following chapter shows excerpts of the presentation slides presented during the conference MIPALCON 2018.

Keywords: Conjoint Analysis, Household Preference, Randomized Experiment, Smart City, Waste Management

Policy Proposal for Solid Waste Management toward Smart City based on Households' Preferences: A Randomized Experiment in Surabaya, Indonesia

Presented by:
Rulli Pratiwi Setiawan
Prof. Shinji Kaneko

MIPALCON 2018
University of Stuttgart

September 26, 2018

Slide 1

Introduction

Smart cities

- There is no universally accepted definition of a smart city.
- Various infrastructure components are included as the core elements of a smart city.
- One of the elements is efficient waste management.

Slide 2

Introduction

Why do we focus on waste management?

- Waste generation is perceived as one of the most serious global environmental issues, especially in developing countries.
- Waste problems in developing countries are characterized by: mixed collection for organic and non-organic waste, limited implementation of intermediate processing and low payment for the service.
- Waste is one of environmental problems caused by human behavior, thus the problems can be overcome by changing human behavior (Steg & Vlek, 2009).

Slide 3

Introduction

How can we change behavior/perception/preference:

- Informational strategies are commonly used to increase knowledge, which eventually will change attitude & behavior (Owens & Driffill, 2008).
- The effectiveness relies on the type of information provided and the context in which the information is communicated (Delmas et al., 2013).
- Despite the accumulated experimental evidence, analysis of the effectiveness of such strategies have provided mixed results (Delmas & Grant, 2010; Delmas et al., 2013).

Slide 4

Introduction

Studies on information-based environmental policies in RCT* setting (1):

- Mainly conducted in the fields of:
  - energy conservation/electricity consumption
    (Schultz, 2007; Allcott, 2011; Costa & Kahn, 2013[1]; Wilhite & Ling, 1995[2]).
  - water use
    (Jalan & Somanathan, 2008[3]; Bennear et al., 2013; Guiteras, 2014[4]; Ferraro & Miranda, 2013[1]; Brown et al., 2017[5]).
  - waste
    (Rhodes et al., 2014; Wadehra & Mishra, 2018)
- Types of information commonly used (summary):
  - non-pecuniary: feedback, norms
  - pecuniary: monetary saving & incentive

  (e.g., Ferraro & Miranda, 2013).

Note:
[1]USA; [2]Norway; [3]India; [4]Bangladesh; [5]Cambodia
*RCT: Randomized Controlled Trial

Slide 5

Introduction

Studies on information-based environmental policies in RCT setting (2):

- Results:
  - Non-pecuniary can reduce energy consumption (Schultz et al., 2007, Allcott, 2012, Costa and Kahn, 2013) and water consumption (Ferraro and Price, 2013 and Ferraro et al., 2011).
  - Better billing feedback leads to a more-conscious consumer (Wilhite & Ling, 1995).
  - Pecuniary incentives bring strong effects of price signals on the electricity consumption (Faruqui et al., 2010; Newsham & Bowker, 2010)
  - Pecuniary strategies might be counterproductive for energy conservation (Bénabou & Tirole, 2005; Bowles, 2008).

Slide 6

Objective

- **Research objectives:**
  - To estimate the impacts of information treatment on the preferences of households across groups.
  - To examine the impacts of information treatment on the willingness to pay across groups.

Slide 7

Methods

Study Area

Figure 1: Study Area-Surabaya City

- Sub-district: Airlangga
- Population (2015): 20,806
- Area: 1.16 km^2
- Neighborhood Association *(RW)*: 8
- Neighborhood Unit *(RT)*: 73

Slide 8

Methods

Experimental Design - Information Treatment

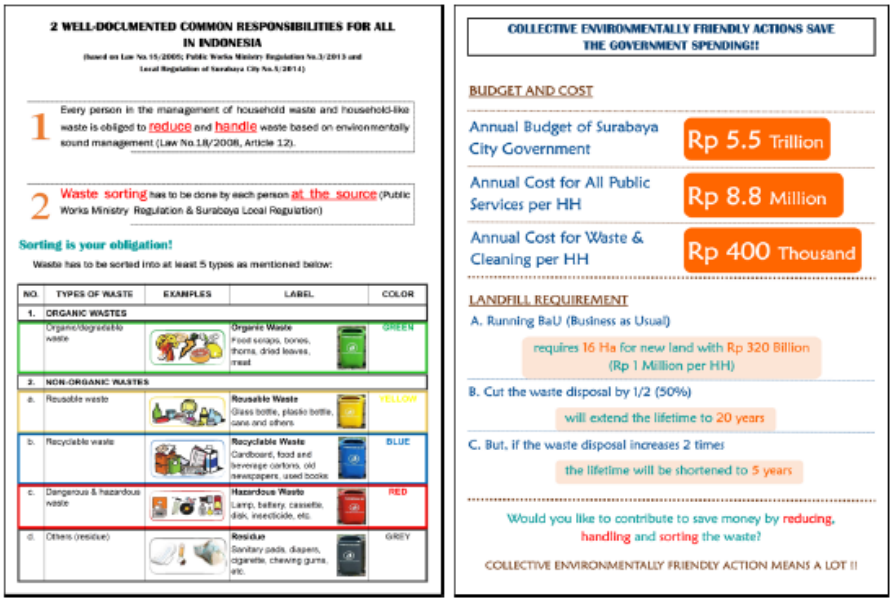
2 Types of information provided:

1. Technical information (non-pecuniary)
   - Two main obligations stated in the Law No.18 of 2008 concerning Waste Management
   - Tips/technical way to separate the waste based on the Regulation of Public Works Ministry No. 3 of 2013
2. Financial information (pecuniary)
   - Information on budget and cost of city government
   - Simulation of landfill site requirements

Slide 9

Methods

Experimental Design - Information Treatment



2 WELL-DOCUMENTED COMMON RESPONSIBILITIES FOR ALL IN INDONESIA

(based on Law No.18/2008; Public Works Ministry Regulation No.3/2013 and Local Regulation of Surabaya City No.5/2014)

1 Every person in the management of household waste and household-like waste is obliged to reduce and handle waste based on environmentally sound management (Law No.18/2008, Article 12).

2 Waste sorting has to be done by each person at the source (Public Works Ministry Regulation & Surabaya Local Regulation)

Sorting is your obligation!

Waste has to be sorted into at least 5 types as mentioned below:

NO.	TYPES OF WASTE	EXAMPLES	LABEL	COLOR
1.	ORGANIC WASTES			
	Organic/degradable waste		Organic Waste: Food scraps, bones, thorns, dried leaves, meat	GREEN
2.	NON-ORGANIC WASTES			
a.	Reusable waste		Reusable Waste: Glass bottle, plastic bottle, cans and others	YELLOW
b.	Recyclable waste		Recyclable Waste: Cardboard, food and beverage cartons, old newspapers, used books	BLUE
c.	Dangerous & hazardous waste		Hazardous Waste: Lamp, battery, cassette, disk, insecticide, etc.	RED
d.	Others (residue)		Residue: Sanitary pads, diapers, cigarette, chewing gums, etc.	GREY

COLLECTIVE ENVIRONMENTALLY FRIENDLY ACTIONS SAVE THE GOVERNMENT SPENDING!!

BUDGET AND COST

Annual Budget of Surabaya City Government	Rp 5.5 Trillion
Annual Cost for All Public Services per HH	Rp 8.8 Million
Annual Cost for Waste & Cleaning per HH	Rp 400 Thousand

LANDFILL REQUIREMENT

A. Running BaU (Business as Usual)

requires 16 Ha for new land with Rp 320 Billion (Rp 1 Million per HH)

B. Cut the waste disposal by 1/2 (50%)

will extend the lifetime to 20 years

C. But, if the waste disposal increases 2 times

the lifetime will be shortened to 5 years

Would you like to contribute to save money by reducing, handling and sorting the waste?

COLLECTIVE ENVIRONMENTALLY FRIENDLY ACTION MEANS A LOT !!

Figure 4: Technical Information and Financial Information

Slide 10

Methods

Experimental Design - Randomized Conjoint Analysis

The hypothetical waste management policy is described by 7 attributes:

1. Walking distance to collection station (Chu et al., 2013)
2. Collection frequency (Chu et al., 2013; Yuan and Yabe, 2015)
3. Monthly payment (Sakata, 2007; Chu et al., 2013)
4. Rule for organic waste to bring into collection station
5. Number of non-organic waste separation
6. Full implementation of intermediate processing facility
7. Final disposal technology
   (4 to 7 are mandated by the Ministry of Public Works Regulation)

Slide 11

Methods

RCA - Attributes and Levels

Table 1: Attributes and Levels

No.	Attributes	Level 1	Level 2	Level 3	Level 4
1	Rule for organic wastes to bring into collection station	No restriction (any time)	3 days a week	One day a week	-
2	Walking distance to the nearest collection station	< 5 minutes	5-15 minutes	15-30 minutes	-
3	Frequency of city government to collect waste from collection station	5 times a week	3 times a week	Once a week	-
4	Number of separation for non-organic wastes to bring into collection station	No separation	Reusable, recyclable, hazardous and others	-	-
5	Full implementation of intermediate processing technology	None	Composting	Recycling	Incinerator
6	Final disposal technology	Controlled landfill	Sanitary landfill	-	-
7	Payment per month per household in addition to Retribution	IDR 96,000	IDR 192,000	IDR 288,00	-

Note: Level 1 represents status quo (except the payment attribute)

Slide 12

Methods
AMCE Estimation

Average Marginal Component Effect

$$Y_{ijk} = \beta_0 + \sum_{l=1}^{7} \sum_{d=2}^{Dl} \beta_{ld} X_{ldijk} + \epsilon_{ijk}$$

where:
Y_{ijk} is the binary choice indicator for the jth profile in task k of respondent i
X_{ldijk} is the dummy variable for the dth alternative of attribute l
β_0 is the corresponding coefficient
Dl is equal to the total number of positions for attribute l
ϵ_{ijk} represents the error term, which is statistically independent of the regressions due to the randomization of the attributes

Note:
* based on Hninn et al., 2017
Internal Probability: a policy is preferred to other policy
External Probability: a policy is preferred to the status quo

Slide 13

Results
Descriptive Statistics

Table 2: Descriptive Statistic

Socio-economy characteristics	Category	No Info		Technical Info		Financial Info		Total	
		Freq.	%	Freq.	%	Freq.	%	Freq.	%
Age	18-34	34	11.33	42	14.00	38	12.67	114	12.67
	35-60	204	68.00	202	67.33	213	71.00	619	68.78
	>60	62	20.67	56	18.67	49	16.33	167	18.56
Gender	Male	110	36.67	87	29.00	104	34.67	301	33.44
	Female	190	63.33	213	71.00	196	65.77	599	66.56
HHH education years	<10	69	23.00	53	17.67	64	21.48	186	20.71
	10-12	158	52.67	144	48.00	157	52.68	459	51.11
	>12	73	24.33	103	34.33	77	25.84	253	28.17
HHH occupation	civil servants	21	7.00	27	9.00	14	4.70	62	6.90
	private	127	42.33	114	38.00	129	43.29	370	41.20
	self-employed	90	30.00	87	29.00	89	29.87	266	29.62
	retired	37	12.33	36	12.00	29	9.73	102	11.36
	others	25	8.33	36	12.00	37	12.42	98	10.91
Family member	1-4 people	237	79.00	217	72.58	238	79.87	692	77.15
	5-6 people	53	17.67	74	24.75	49	16.44	176	19.62
	>6 people	10	3.33	8	2.68	11.00	3.69	29	3.23
Home ownership	self-owned	268	89.33	269	89.67	272	90.67	809	89.89
	rented	32	10.67	31	10.33	28	9.33	91	10.11
Monthly income	>3 mio IDR	166	55.33	131	43.67	156	52.35	453	50.45
	3-6 mio IDR	108	36.00	124	41.33	106	35.27	338	37.64
	>6 mio IDR	26	8.67	45	15.00	36	12.08	107	11.92

Slide 14

Results

AMCE for All Groups

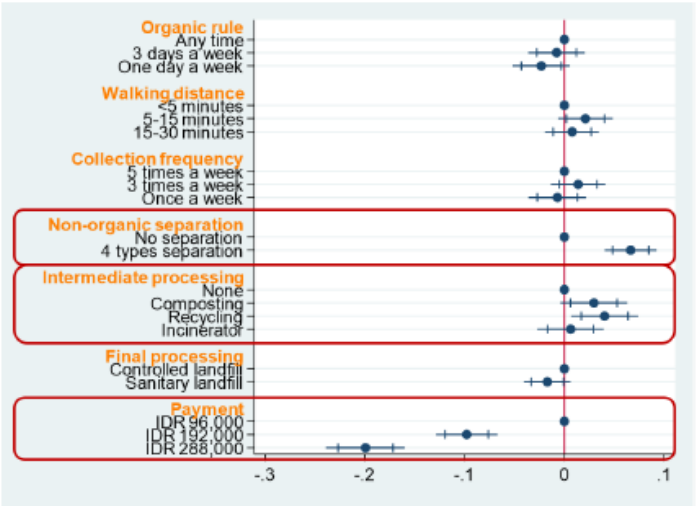


Figure 6: AMCE on external choice probabilities ($\beta_0 = 0.798^{***}$)

Note: The estimates are based on the OLS regression with clustered standard error; horizontal bars represent the 90% and 95% confidence interval.

Slide 15

Results

AMCE Among Groups

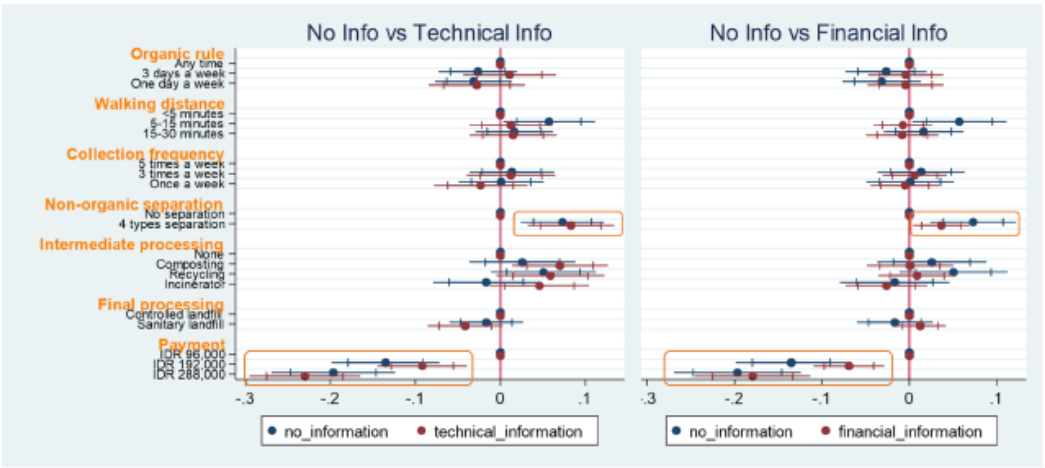


Figure 7: AMCE on external choice probabilities among groups

Note: The estimates are based on the OLS regression with clustered standard error; horizontal bars represent the 90% and 95% confidence interval.

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Results

Approval Rate of WTP Across Groups

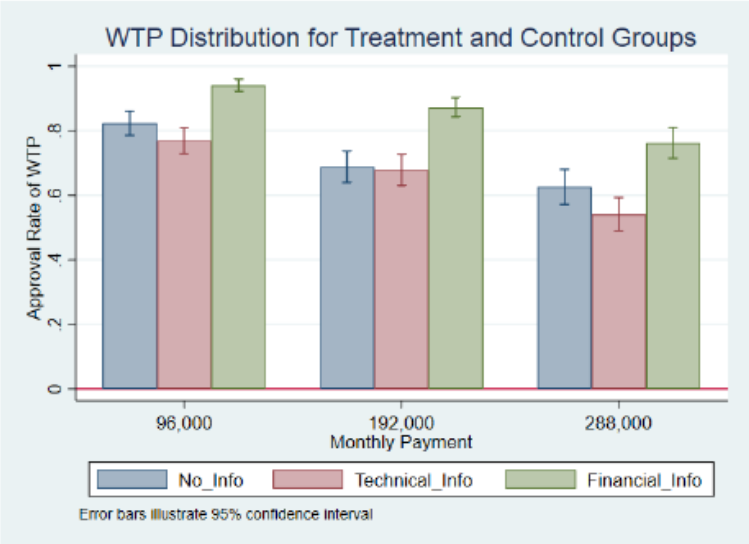

Figure 8: WTP Distribution for Treatment and Control Groups

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Findings

Objective 1:

Impacts of information treatment on the preferences of households across groups

- Number of non-organic separation and intermediate processing are the most preferred attributes, while monthly payment shows negative significant results.
- Households who received technical information tend to prefer more to the attribute of separation rule for non-organic wastes rather than households who receive financial information.
- In addition, the technical information group is also more likely to refuse the additional monthly payment compare with those who received no information as well as financial information.

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Findings

Objective 2:

Impacts of information treatment on the willingness to pay across groups

- Financial information can influence households to pay more for an improved waste management program.
- Financial information can increase the willingness to pay by 20.5 percentage higher than the baseline (no information).
- The average WTP for no information group, technical information group and financial information group are IDR 205,088, IDR 190,811, and IDR 247,225, respectively.

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Policy Implications

The government should consider:

- implementing waste separation program intensively, because the research findings show that the households prefer waste separation rather than no separation.
- using pay-as-you-throw system as the waste collection charge, the evidence shows that by giving a proper information, households are willing to pay for better waste collection and disposal program.
- formulating the best strategy in communicating a new policy/program to get more support.

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Session 5

Economic Aspects in Resilience - Oriented Planning and Smart Cities Concepts

Sustainability Performance Model for Highrise Developments - a Step by Step Development Process

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After completing his master's degree, Dr. Muhammad Riaz Akbar worked for the World Bank Project with The Urban Unit, P&D Department, Government of Punjab, Pakistan focusing Urban Issues in five (5) Large Cities of the Province in 2006. Afterwards, between 2008 and 2012, he worked as Ph.D. Research Scholar at University of Ulster, Belfast, UK, and developed a Sustainability Performance Indicator Model (SPIM) by adopting a robust process to the existing debate on the sustainability of tall buildings through evidence-based approach that can be applied in the real estate market. This project examined the theoretical significance and practical application of factors that enhance sustainability performance of buildings. From 2012 to today, he has worked with SNC Lavalin Inc. ATP Canada as Senior Planner as part of Project Management and Project Controls team in different divisions. He considers that the Master Infrastructure Planning established sound base and enhanced his analytical, interpersonal and communication skills.

Abstract: The purpose of this research paper is to provide an overview of sustainability criteria drawn from the literature to outline the theoretical stance on energy efficiency and environmental performance of multi-storey high rise developments. Second, it discusses methodological approach used to develop performance model to evaluate sustainability in high rise developments. Nevertheless, the iterative and robust multi-method approach for the selection of design criteria and development of the model can be a useful tool to develop and revise building rating systems.

Buildings have obvious effects on the environment and the dwellers, which can be observed during the construction, operation and management phases of a building's lifecycle. The adoption of different design considerations, technical solutions, materials, construction and management techniques may significantly influence the cost,

performance, environment, occupier satisfaction and above all quality of life. Currently, professionals, policy makers, developers and regulators are not only adopting innovative energy efficient technologies but also working on the mechanisms to evaluate buildings to analyse and enhance social, economic and environmental rewards and overall sustainability of the project. Different mathematical and statistical tools and assessment techniques in the construction industry are being taken seriously, particularly their ability to demonstrate the long term objectives of environmental improvements without compromising economic and social gains.

There is no single process of sustainability assessment because each assessment tool is influenced and associated with local social, economic, environmental, technical and cultural considerations in order to achieve its sustainable development targets. Similarly, there is no single technique outlined in the literature that develops sustainable indicators or a model framework for the assessment of different building types and other land use analyses. Therefore, well accepted, proven and widely used approaches and methods always provide firm grounds to achieve meaningful results. This study outlines the main structure of the research approach and describes the logical plan, theoretical review, empirical strategies and the development of the sustainability performance model. This integrated approach underpins the development of an assessment framework incorporating factors that have significant influence on high rise developments and their surrounding areas.

Key Words: Sustainability, Assessment, Process, Performance, Environment

1 Introduction

The concept of sustainability is the core of current research and development debates. It is being used to distinguish traditional and modern developments through analysis of existing housing needs along with social, economic and environmental benefits [1]. The contemporary initiatives of sustainable homes have become the best option to improve quality of life for all generations [2] while considering earth's finite resources, biodiversity and environmental concerns. These initiatives are also shaping the roadmap of sustainable development, communities and society [3]. Sustainability is the crux to achieve carbon reductions from more than the housing sector and reflects a decision making process ensuring balance among three important factors i.e. social, economic and environment [4]. Sustainability represents a paradigm shift from traditional to sustainable development and this has become the principal model of modern times. Sustainable development is not merely combination of two terms 'sustainability' and 'development', indeed it is much more [5]. Rather, it depicts an interface between environmental, economic and social sustainability [5]. The concept whilst it has gained significant recognition at a global level, there remains weak global governance on the issue, and there is still a long way to go for policy makers, planners, environmentalists and even the general public to achieve the requisite targets for sustainable development [6]. The motivation for this research stems from the UK's commitment to reduce carbon emissions by 2050 to combat climate change challenges [7].Nevertheless, UK government intentions to improve social and environmental impacts of the buildings parallel to economic benefits can be observed by reviewing the proliferation of sustainable development strategies, planning policy

statements and significant improvements in the building regulations, planning system, the Building Act 2004 and 2008 and the sustainable communities' agenda [8]. During the past 20 years of development, building assessment tools have become invaluable in measuring performance as sustainable development has become a global trend. Moreover, among the contemporary building rating systems, high rise building evaluation is a neglected area [9]. Whilst BREEAM Multi-Residential provides a systematic framework and guidelines to achieve higher performance levels, still there is further need to understand the theoretical and practical dimensions of sustainable high rise buildings. This research study contributes a robust methodology to develop a set of criteria for the assessment of sustainability within high rise buildings through adopting an evidence based approach to the development of a performance model that can be applied to the real estate market.

2 Research Process

This research adopts a multi-method approach to develop sustainability performance model as depicted in Figure 1.1. The adopted methodology is based on exploratory techniques and assessments including theoretical review, an evaluation of various assessment tools such as CSH, LEED, CASBEE etc., the development of a sustainability matrix and listing of sustainability factors, pilot survey and the evaluation of best practice sustainable development case studies against the agglomeration of sustainability factors derived from the matrix. Moreover, the research methods include expert panel judgements for the development and ranking of individual criterion of the sustainability performance model.

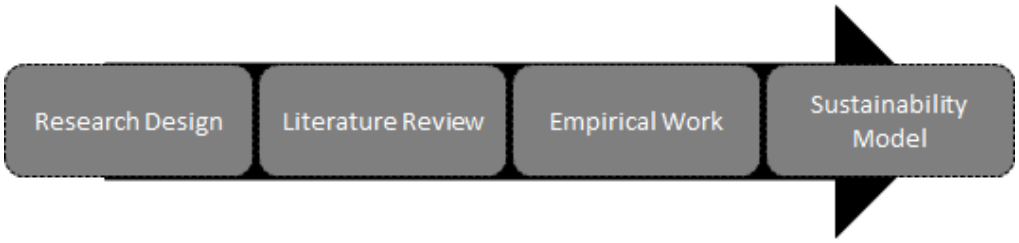

Figure 1.1: Research Process

The researcher also reviewed and evaluated different research methodologies (Appendix - I) to help justify the adopted approach and utilised a thorough discussion with professionals to ensure a robust process was in place to achieve the research aim and objectives. The reviewed literature concludes that most of the research opted a literature review to obtain their listing of sustainability indicators, followed by questionnaire surveys and expert panel discussions to prioritise and rank the indicators. Few researchers tested the results with the live case studies.

3 Literature Review

The literature review was designed to update, analyse and evaluate the existing research in the study area, as well as related topics and disciplines. This research study covered the theoretical and conceptual aspects by thorough literature review of the existing and past research results, theories and assessment models on various

aspects of energy efficiency and environmental performance of buildings. Initially a wide range of factors contributing to the social, economic and environmental sustainability of the buildings were identified through the literature (Figure 1.2). This draft or initial list was established, based on the following sources, for screening and refinement according to the selection criteria.

- Sustainable Development initiatives (Code for Sustainable Homes / EcoHomes / BREEAM / Green Star etc.).
- Potential and challenges to high rise buildings and application of CSH.

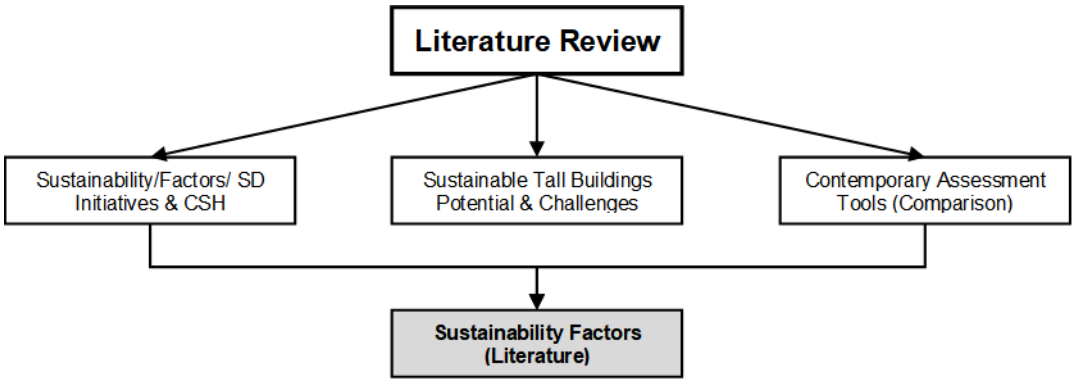

Figure 1.2: Literature Review

Comparative analysis of contemporary assessment tools.

- Publications (research reports / research papers / technical guides / books etc.)

The outcomes of the literature review facilitated the establishment of the first set of sustainability criteria for the empirical Investigations used to develop the model.

4 Empirical Work

Empirical work involves observation, data collection, evaluation and analysis. To conduct the empirical phase a questionnaire was developed based on the literature findings which formed an initial set of indicators. This was further strengthened by sharing the initial indicators with professionals to help determine their application in the context of sustainable high rise buildings. The empirical part of this study comprised six integrated stages (Figure 1.3). These stages included;

(i) Refinement of the sustainability factors

(ii) Piloting

(iii) Assessment and evaluation of high rise case study developments

(iv) Grouping professional opinion through electronic survey

(v) Expert panel survey to prioritise and assign weightings; and

(vi) Development and application of the sustainability performance model.

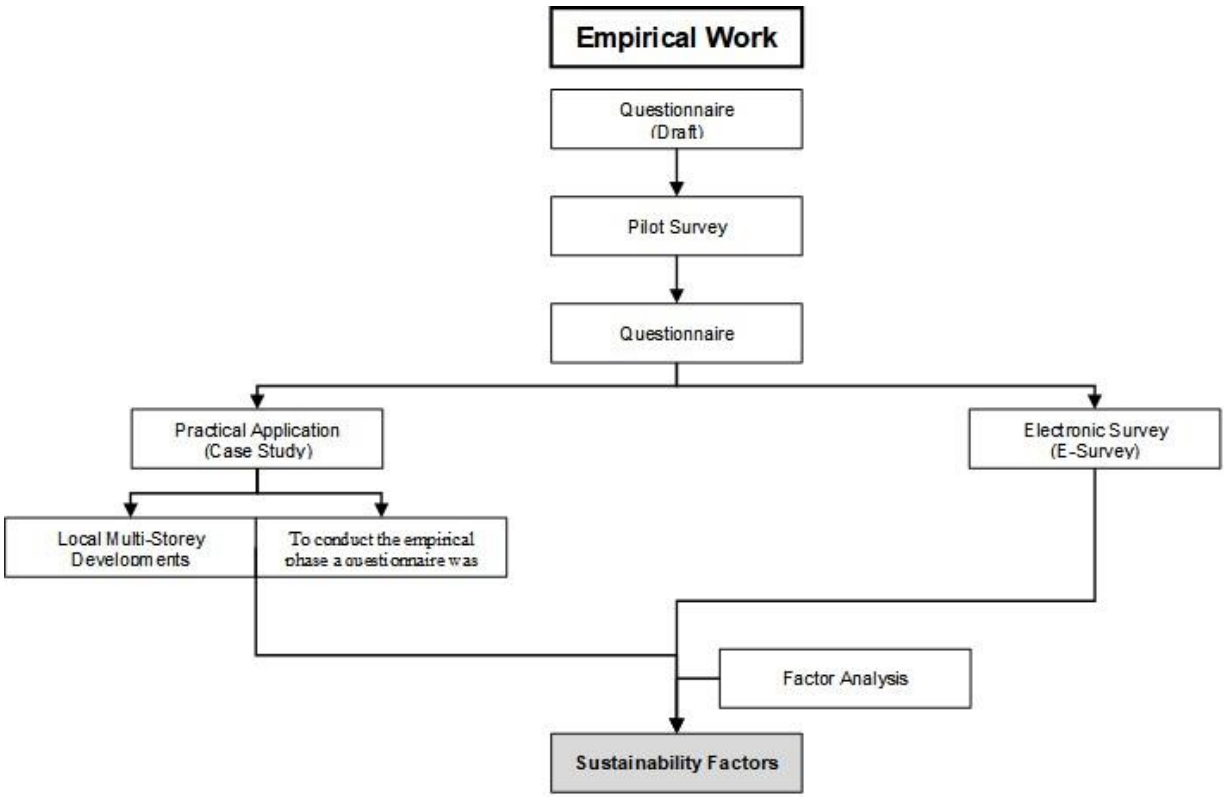

Figure 1.3: Input Process of Sustainability Factors

4.1 Sustainability Factors

The sustainability indicators derived from literature were refined and scrutinised against the following criteria to obtain the initial set of factors for piloting and further empirical investigations.

- Measurable (operationally feasible and practicality)
- Relevant (relevant and effective to the core issue of sustainability and energy efficiency of the high rise buildings in UK)
- Reliable (robust and complete)
- Achievable (Available and accessible - easy to define, detect, assess and interpret)
- Useful to potential users in the building industry.

These characteristics helped the researcher to screen and develop an initial list of factors for further analysis as a part of an iterative process before the final scoring and weighting.

4.2 Pilot Survey

The questionnaires are piloted within the target population to ensure acceptability, validity and reliability [10]. A pilot survey was conducted before delivering the questionnaire for professional opinions and practical assessment of sustainability factors in high rise buildings. The main objective was to obtain expert opinions about selected factors, check ambiguity, unclear instructions, time to complete, re-arrangement of factors, addition and deletion and layout to improve the quality of information to be

gathered. Recommendations and suggested improvements in the factors, their description and the overall layout of the questionnaire were incorporated to improve the appropriateness and practicality of the questionnaire.

4.3 Practical Application of Sustainability Factors: Case Study Analysis

A case study approach was adopted to examine the application and significance of the sustainability factors within a set of selected local and non-local high rise developments. The process included a questionnaire survey with a twofold objective; first what factors are being considered on ground, second to update and refine the list of factors before heading towards professional surveys i.e. electronic and expert panel survey. All participants were recruited from the design team of these high rise buildings using purposive sampling [11]. The objective of the purposive sampling was to engage proactive professionals on the sustainability of high rise buildings and carbon emissions. Results obtained from the case studies highlighted a higher level of practical consideration and level of importance in non-local high rise buildings as compared to the local developments (Table 1.1).

4.4 Electronic Survey (E-Survey)

Electronic survey was conducted to gather professional opinions, suggestions and the priority of different factors within sustainable high rise buildings. The professionals were recruited from professional forums across UK. The purpose of this e-survey was to evaluate the consideration and importance of different factors in the delivery of sustainable high rise buildings. The analyses from e-survey were carried out in two stages. The first stage provided the descriptive analysis and included the background information and professional characteristics of the respondents. The mean and ranking of the factors were calculated whilst independent t-test was used to determine whether the perception of the importance of individual factor differs between the professional groups and regions. The second stage involved the factor analysis. The pre-requisites for factor analysis i.e. Pearson's Correlation analysis and reliability analysis i.e. Cronbach's alpha coefficients (α) were also performed to check the appropriateness and applicability of the statistical technique. Factor analysis also provided the primary factors construct for the final weightings through expert panel survey.

4.4.1 E-Survey (Key Observations)

The professional opinion from the e-survey identified high significance level of sustainability factors. Following were the key observations;

- The top rank sustainability factors suggested a mix of social, economic and environmental parameters to achieve energy efficiency, environmental performance and optimum functionality of high rise development.
- Comparative analysis of the mean values of the main categories of local high rise buildings, non-local high rise developments and e-survey represent the professional perceptions of different groups involved in the study. Table 1.1 shows that the integration of renewable technologies category has been considered the least

important in the context of Northern Ireland (NI) high rise buildings. This reflects a dominant culture of low rise developments, a weak and non-statutory legal and regulatory provisions, additional space and capital investment, specialised expertise and resource requirements, operational and delivery capacity and site specific best combination of onsite renewables. The current government intentions and policies i.e. 40% renewable electricity and 10% renewable heat by 2020 is the way forward and the built environment, tall buildings in particular are expected to play a positive role in contributing to the carbon reduction goal.

- Professional opinion from e-survey presented the highest level of significance (Table 1.1) to achieve the targets of energy efficiency and environmental performance in the high rise developments. The results exhibited significantly high level of consideration and importance of the suggested factors for a hypothetical high rise building. But different aspects of sustainability and prioritising social, economic and environmental considerations in high rise buildings design depend on many other factors such as location, owner occupied or speculative development, cost drivers specially to integrate intelligent technologies and resources, owned by government, located at a place with particular environmental issues, local legislation, culture, surrounding developments and the market demand etc. These challenges are being reflected in the local and non-local high rise buildings and corresponding mean values of all factors and categories. But in all three cases (i.e. local building, non-local buildings and professional responses from e-survey) all category values were found above 3 that showed moderate to high level of importance for the sustainability factors which provided an evidence to practically include these factors to assess and enhance sustainability performance of high rise buildings.
- Trip reduction (car-pooling/sharing) and waste chutes (ENVAC system) are the least considered in practice and received least importance level out of total 74 criteria.

CATEGORY	FACTORS	LOCAL	NON-LOCAL	E-Survey
Location	C1	3.750	3.893	4.237
Water	C2	3.000	3.143	3.749
Waste	C3	3.225	3.536	3.830
Material	C4	3.400	3.857	4.460
Management	C5	3.629	4.082	4.139
Pollution	C6	3.267	3.571	4.060
Economic Sustainability	C7	3.350	3.464	3.696
Transport	C8	3.229	3.837	3.892
Ecology	C9	3.343	3.367	3.966
Renewable Technology	C10	2.400	4.143	4.181
EE Equipment	C11	3.440	4.000	4.135
Health & Well-Being	C12	3.480	3.943	4.091
Climate & GHG Emissions	C13	3.029	3.551	3.846
Innovation	C14	3.400	3.286	3.937
Impact	C15	3.100	3.786	4.601
Embodied Energy	C16	3.100	2.929	4.065

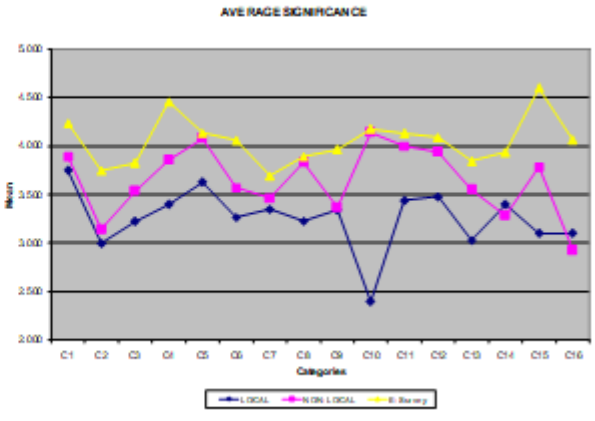

Table 1.1: Comparative Analyses of the Responses

- Professional responses across the UK about different building assessment stages revealed the significance of design, post construction and post occupational stage assessments. It can be observed from the results that 73% of the total responses at design stage assessment fall between important to most important range. This

shows the importance of integrating sustainability parameters at the design stage to improve the overall performance of the buildings as well as reducing the potential additional cost that these factors bring to the total development cost. On the other hand, 89% of the total responses considered post occupational assessment to be between important to most important range. The results highlighted the market dimensions, in particular the relationship between application of sustainability parameters and the occupational reality, which underline the actual performance of the building. This is particularly important given that the occupier is the one that achieves the benefits of the sustainability factors but it is the developer who pays for this upfront. Meir et al. (2009) also emphasised the importance of post occupancy evaluation to achieve actual sustainability levels and carbon emission reductions [12]. Furthermore, post occupancy evaluation is expected to provide an opportunity to underline the impact of the development on users and vice versa. The results are in line with the findings of Meir et al. (2009) and provide a professional response to incorporate post occupational assessment in the building assessment tools to achieve carbon reduction targets.

- Results from independent t-test provided strong evidence that professionals share the same views on the importance of the sustainability factors needed to develop sustainability performance model for high rise buildings. It was also found that the factors namely trip reduction and waste chutes received least significance level out of total 74 criteria. This result is in line with the findings from case study buildings.

Sustainability of high rise developments demands a balanced combination of social, economic and environmental criteria to ensure minimum environmental deterioration and maximum social and environmental prosperity for the users and community in general. The process of obtaining sustainability criteria from literature, investigating practical applicability and professional opinion enabled the researcher to finalise 70 sustainability factors (criteria) for further statistical analyses. Four factors namely waste internal storage and segregation, waste external storage and segregation, waste chutes or ENVAC system and trip reduction were excluded from the set of sustainability criteria. The first two factors were considered by the 61% professionals as repetition and part of the solid waste management plan whereas waste chutes and trip reduction were rated least important (average mean values are < 2.75) during the practical and professional investigations of the criteria. The final set of 70 criteria provided the basis for the factor analysis and the Analytical Hierarchy Process (AHP) to ascertain the weightings and ranking of individual criterion.

4.5 Factor Analysis

Factor analysis was used to construct a smaller number of dimensions with common characteristics based on the inter relationships among the sustainability factors. The primary objective of the exploratory factor analysis (EFA) was to identify common factors influencing the sustainability of high rise buildings and the strength of relationship among observed variables. The appropriateness of factor analysis is depended upon the fulfilment of certain prerequisites, which include sample size, variables correlation, reliability of scale and Kaiser-Meyer-Olkin (KMO) measure of sam-

pling adequacy and Bartlett's test of Sphericity. These parameters are briefly discussed below;

- A small sample can provide accurate outputs from factor analysis with a "strong data" i.e. high communalities and loadings of factors [13]. Guadagnoli and Velicer (1988) have suggested a minimum sample size of 100 to 200 observations [14]. In the present study, there were 153 responses from the e-survey and 138 were valid. This falls in the range of 100 to 200 and the factors have four and above loadings greater than 0.60 and all 70 variables are greater than 0.40, which is above the values as suggested by Guadagnoli and Velicer (1988), it was wise to continue with a factor analysis.
- To assess the strength of association among the sustainability factors, Pearson's Correlation Coefficients were computed. Generally Pearson's correlation coefficient (r) ascertains correlations among demographic variables, but it also identifies non-occurrence of linear dependency prior to factor analysis [15]. The e-survey data was analysed to calculate correlations among all sustainability factors, which ranged from -0.003 to 0.760. The empirical data displayed non-existence of linear dependency among the factors (i.e. $r<0.8$) and provide strong evidence to execute the factor analysis to derive the latent factors from professional responses in order to develop a framework for the sustainability performance model.
- The reliability statistics of the extracted items i.e. Cronbach's Alpha coefficient (α) for the 138 valid responses and 70 variables (factors) was 0.965[1]. This indicated high an internal consistency and strong a correlation among the components (Table 1.2).

Case Processing Summary

		N	%
Cases	Valid	138	100.0
	Excluded[a]	0	.0
	Total	138	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	N of Items
.965	70

Table 1.2: Reliability Statistics (Cronbach's Alpha)

- Table 1.3 presents the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy and Bartlett's test of Sphericity. The KMO value for the 138 valid e-survey responses was 0.831, which supported the appropriateness of factor analysis. Moreover, Bartlett's Test of Sphericity was also conducted to verify sufficient correlations among the variables i.e. sustainability factors. Bartlett's Test of Sphericity tested the null hypothesis that there was no relationship among the variables (i.e. correlation matrix is an identity matrix) [15] [16]. Therefore, a significant value (i.e. less than 0.05) using Bartlett's test is essential to execute factor analysis. The outcome of e-survey data showed high significance using Bartlett's test (i.e.

[1] The value of α is usually taken between the range 0 to 1. In general 0.7 value of α is considered acceptable and a cut-off point, whereas value of α above 0.8 and closer to 0.9 shows strong correlation among the items (factors) and internal consistency (Aron & Aron, 2002, Field, 2005, and Lee, 2008).

p<0.001) and the R-matrix (i.e. correlation matrix) was not an identity matrix. The value of KMO[2] (0.831 / "great" Table 1.3), Barlett's Test of Sphericity (8530.759) and p<0.001 confirmed that factor analysis was the most appropriate method to further categorise the 70 variables.

KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.831
Bartlett's Test of Sphericity	Approx. Chi-Square	8530.759
	df	2415
	Sig.	.000

Table 1.3: KMO and Bartlett's Test

4.5.1 Extraction of Factors

Principal Component Analysis (PCA) was applied to determine underlying factors. "PCA summarises the interrelationships into smaller orthogonal principal components or axes, which are linear combination of the original variables" [16]. According to Pett et al. there are three basic rules/ways to extract the variables;

1. Factors with eigenvalues greater than 1.0
2. Percentage of variance (i.e. last factor accounting for variance < 5%); and
3. Examination of the scree plot.

The analysis of eigenvalue (Appendix II) for each factor shows that the first 15 factors comprising 70 variables have eigenvalue greater than 1.0. Gorsuch (1983) suggested this criterion best suitable for variables less than 40 with a large sample size [17].

The second method to work out the number of factors is based on cumulative percentage and extraction of factors until a threshold for maximum variance is achieved. According to Hair et al. (1995) factor extraction in natural science should account for 90% of the explained variance or the last factor should comprise less than 5% of the explained variance [18]. This is in contrast to the 50-60% explained variance adopted in social science research [16]. Appendix II shows the extracted and cumulative percentage of variance and it can be noted that factors that have explained variance less than 5% are from the third to fifteenth factor and the 8 factors combination accounts for 61% of the cumulative variance.

The third criterion for deciding the number of factors is the scree plot against eigenvalues of extracted factors in descending order of their magnitude. Gorsuch, (1983), Tabachnick & Fidell (2001) and Pett et al. (2003) suggested computing different factor analysis solutions on the plot in case of unclear cut-off point [19]. The result shows unclear cut-off point for the number of factors, although beginning of the straight line can be noticed from 10th factor. Factor solutions from sixth to tenth factor was computed that resulted in the best fit 8 factors construct with a cumulative variance of 61% (Appendix II).

[2] The value of KMO varies between 0 to 1. According to Kaiser (1974) and Field (2005), the value of KMO greater than 0.5 is considered appropriate and acceptable.

4.5.2 Best Fit Factor Structure

Factor analysis was computed for 6 to 10 factors using PCA with Promax rotation to obtain a simple and best fit factor structure. The 8-factors solution was selected as the best fit to the data, for the following reasons (Table 1.4).

- Only 8-factor solution gave the logical grouping[3] of different variables under each factor. For instance, “Site and Community” is the first factor which represents the variables defining location and site suitability of the high rise building and associated community facilities to ensure better quality of life.

Factor	Logical Grouping	Maximum Variance Explained	Overlapping of Variables	Correlations > 0.40	Loss of Important Variables
6 Factors	No	No	Yes	Yes	Yes
7 Factors	No	No	Yes	Yes	Yes
8 Factors	Yes	Yes	Minimum	Yes	No
9 Factors	No	Yes	Minimum	Yes	No
10 Factors	No	Yes	Minimum	Yes	No

Table 1.4: Best Fit Factors Construct

- The 8 factors construct constituted 61% of total explained variance (Appendix II) that was greater than the range i.e. 50-60% explained variance suggested by Hair (1995) and Pett et al., (2003).
- Variables in 6 and 7 factors constructs showed multiple loadings i.e. same variable was appearing under 2 to 3 factors with different weights and selection of these factor constructs could undermine the value of the variable under the particular factor. Whereas 8 to 10 factor constructs showed minimum and manageable multiple loadings in accordance their loadings and correlation with other variables.
- 8 to 10 factor construct did not show risk of losing important variables unlike 6 and 7 factor constructs
- A Correlation of greater than 0.40 was taken as a threshold level for all the loadings and factor constructs.

Best fit 8 factor construct, each factor consists of the following different groups of variables:

- **Factor 1** includes 9 variables such as community facilities, optimisation of potentials, community consultation, and minimisation of the challenges associated with the building and surroundings, existing infrastructure with respect to site, private space, capacity building, weather risk at site and community connection with the existing public and infrastructure facilities. This factor is named **Site and Community**.
- **Factor 2** comprises 5 variables concerning cost and benefits associated with development of sustainable high rise building. The factor includes life cycle cost, economic activities, building adaptability, carbon credits and commissioning. Therefore, this factor is named **Economic Sustainability**.
- **Factor 3** contains 14 variables relating to measures for environmental protection & enhancement and water management measures associated with sustainable

[3] Logical grouping refers to the accumulation of variables under a factor having higher loadings and strong association with each other

high rise buildings. Therefore, this factor is termed **Water and Environmental Quality**.

- **Factor 4** composes of 13 variables relating to measures for building management and arrangement not only to enhance the quality of life but also quality of the building. Hence the factor is named **Facilities Management**.
- **Factor 5** represents 5 variables requiring building garbage and construction waste management during the construction and operational life of the high rise developments. Therefore, this is named **Waste Management.**
- **Factor 6** comprises 13 variables concerning CO_2, NOx emissions, GWP, sources of materials and integration of renewable technologies, which are mainly measure to improve the indoor quality of life. As a result, this factor is called **CO_2 emissions and Indoor Environmental Quality**.
- **Factor 7** composes of 6 variables requiring measure to improve mobility (by parking, public and pedestrian facilities) within the development and different activity places within the community and city. Therefore, the factor is named **Pedestrian and Transport Facilities**.
- **Factor 8** contains 5 variables concerning embodied energy and innovative arrangement to exploit the resources. These variables include local materials, recycled content, site orientation, internal space management and area for planting. This factor is named **Innovation and Regional Contribution**.

5 Expert Panel Survey

Analytical Hierarchy Process (AHP) was employed to engage professional experts to rank, prioritise and weight the different factors. The method adopted to weigh the factor, sub-factors and variables was divided into two phases. Phase one included the development of an analytical hierarchy structure and an expert panel questionnaire survey to obtain weightings and ranking of criteria. Phase two comprised the collection and synthesis of individual matrices by employing the geometric mean method. This also included the calculation of a consistency ratio (CR) and significance level at the lowest level of hierarchy and Kendall's coefficient of concordance to verify appropriateness to combine judgements of both groups to obtain the weighted average and corresponding weights.

The primary level includes the 8 factors, namely site and community (F1), economic sustainability (F2), water and environmental quality (F3), facilities management (F4), waste management (F5), CO_2 emissions and indoor environmental quality (F6), pedestrian and transport facilities (F7) and innovation and regional contribution (F8).

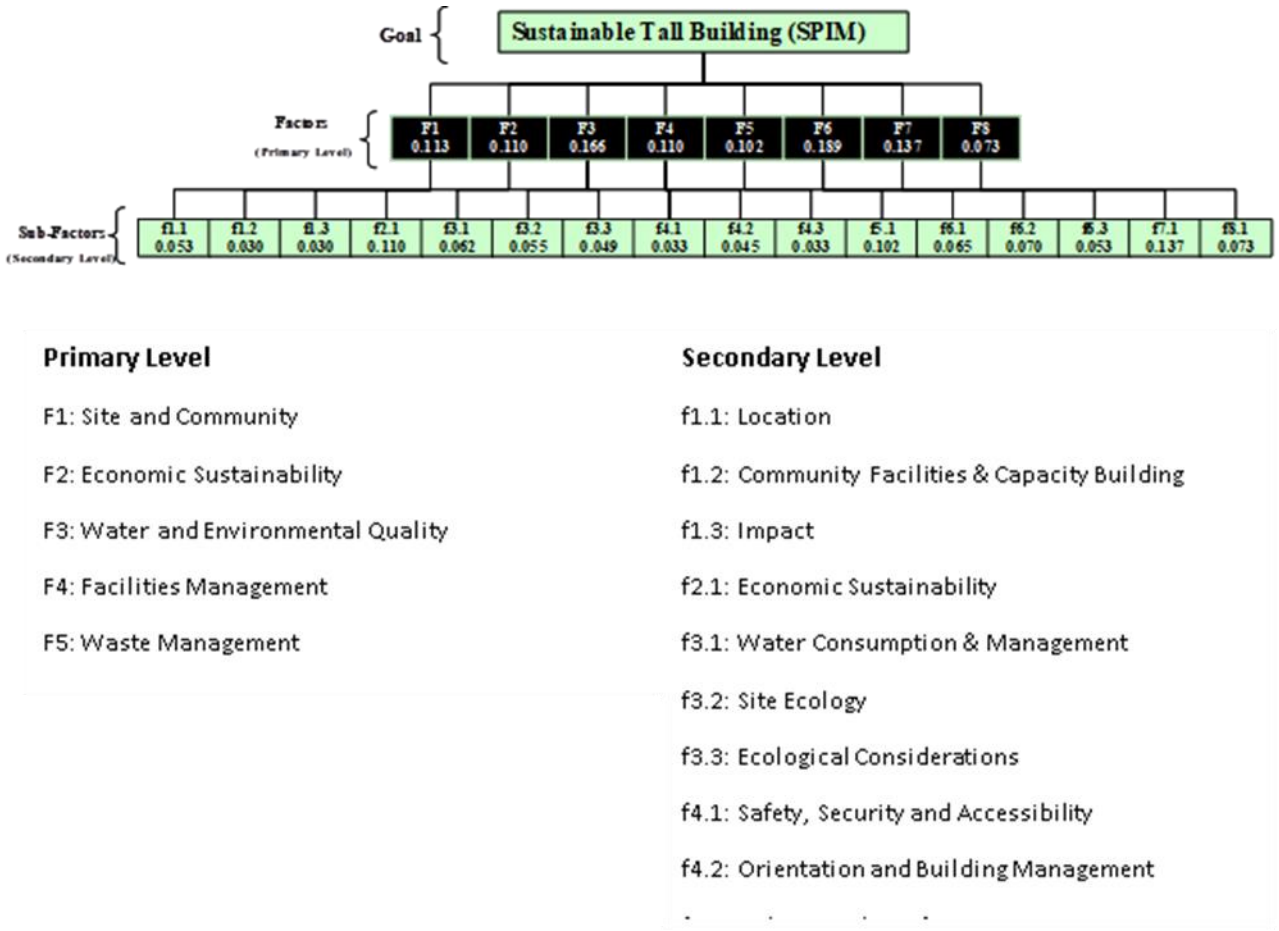

Figure 1.4: Summary of Priority Weights at Primary and Secondary Levels

Pair-wise comparisons were conducted to identify the priorities of these 8 sustainability objectives towards the sustainability of high rise buildings. The secondary level comprises sub-factors derived from the main factors at the primary level. The variables under each factor were grouped into sub-factors according to their characteristics and correlation with other variables. Out of total 8 factors at the primary level, only 4 factors comprised different but correlated and more than six variables, which were divided into sub-factors for pair-wise comparison at secondary level. For instance, Water and Environmental Quality (F3) comprised 14 variables that covered three sustainability issues namely water, existing site ecological value and ecological enhancement measures. The variables under this factor were sub-divided into sub-factors that included water consumption and management (f3.1), site ecology (f3.2) and ecological consideration (f3.3). Pair-wise comparisons were performed for the 12 sub-factors and experts weighted each sub-factor according to the relative importance with respect to others and variables under each sub-factor (Figure 1.4).The second round of the expert panel survey is the tertiary level of the hierarchy i.e. 70 variables as a part of the iterative process in order to obtain relative importance and weights of each individual variable. The objective at the tertiary level was to compare and contrast the results of 31 experts with 138 professional responses from the e-survey. The analysis shows moderate to high level of importance between both professional groups with the e-survey reflecting a slightly higher individual and group values.

5.1 Final Weights of Variables

Kendall's *W* was employed to validate the agreement among the experts' judgements and professional responses from the e-survey. The null hypothesis (experts' ratings are unrelated), was rejected at the 0.01 significance level, which showed significant agreement among the experts and professionals on the prioritisation and weightings of variables. Therefore, judgements of 169 participants (experts and professionals) were combined (i.e. by taking weighted average) to determine final weights of the individual variable.

The outcome provided the final weights of individual criterion for the sustainability performance model assessment framework to evaluate energy efficiency and environmental performance of sustainable high rise buildings. A constant score of 10 is assumed as the maximum score for each individual variable at the tertiary level. The purpose of the constant score is to entertain level of compliance and evaluate actual sustainability performance against any criterion.

6 Conclusion

The building assessment tools provide guidelines and principles to enhance and evaluate the sustainability of buildings that includes social prosperity and inclusion, improved environmental performance and economic rationality. According to Ali and Al-Nsairat (2009) most of the tools in developed countries including the UK are more sensitive to environmental considerations but the results from sustainability performance model highlighted social and economic considerations along with environmental management measures [20]. The model provides a systematic framework to assess sustainability levels and guiding principles to assist in formulating strategies and to integrate different design criteria to optimise sustainability of high rise building. The model not only focuses on measures to minimise environmental impact of the high rise buildings on the users and surroundings but also social and economic sustainability. The introduction of model parameters at the concept stage or pre-design stage provides an opportunity to exploit the potential of the site and to minimise negative impacts to insure higher sustainability levels. Moreover, post occupation assessment of the building will help to evaluate real building performance and the use of integrated intelligent systems will reduce carbon emissions and improve functionality.

The main contribution of this study is the development of the model based on an iterative and robust process. It addresses parameters of environmental, social and economic well-being to enhance sustainability performance of high rise buildings. The integration of different sustainability parameters and their corresponding weightings provides fresh insight and reflects market dimensions for sustainable high rise buildings. The study adds new dimensions and parameters to the family of building assessment tools by incorporating a set of factors highlighted in literature and empirical investigations. This fills the gaps and highlights the role and significance of different sustainability criteria e.g. location, economic sustainability, existing infrastructure, vertical transportation etc. contributing to the sustainability performance of high rise buildings. Nevertheless, the iterative and robust multi-method approach for the selec-

tion of design criteria and development of the model can be a useful tool to develop, review and revise future building rating systems.

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Appendix-I

Research Title and Summary of Research Approaches

Title	Author (year)	Literature Review	Indicators /KPIs/Factors	Case Study	Questionnaire	Expert Panel	MCA/AHP /Delphi	Testing
An aggregated weighting system for evaluating sustainable urban regeneration	Hemphill et al., (2002)	√	√	-	√	√	√	-
Do indicators help create sustainable communities?	Gahin et al., (2003)	√	√	√	-	√	-	-
An indicator-based approach to measuring sustainable urban regeneration performance: Part 1/2, conceptual foundations and methodological framework	Hemphill et al., (2004)	√	√	√	√	√	-	√
Key Performance Indicators (KPIs) and priority setting in using the multi-attribute approach for assessing sustainable intelligent buildings	ALwaer and Clements-Croome, (2010)	√	√	-	-	√	√	-
Key Performance Indicators and assessment methods for infrastructure sustainability: A South African construction industry perspective	Ugwu and Haupt, (2007)	√	√	-	√	√	√	
Responsible property investment criteria developed using the Delphi Method	Pivo, (2008)	√	√	-	-	√	√	√
developing a green building assessment tool for developing countries: Case of Jordan	Ali and Al-Nsairat, (2009)	√	√	-	-	√	√	√
Developing an assessment framework for affordable and sustainable housing	Pullen et al., (2010)	√	√	-	-	√	-	-
Energy sustainability indicators for local energy planning: Review of current practices and derivation of a new framework	Neves and Leal, (2010)	√	√	√	√	-	-	-
A methodology to identify sustainability indicators in construction project management: Application to infrastructure projects in Spain	Fernández-Sánchez and Rodríguez-López, (2010)	√	√	√	-	√	√	-
A method of identifying and weighting indicators of energy efficiency assessment in Chinese residential buildings	Yang et al., (2010)	√	√	-	√	-	√	-
Building sustainability assessment	Bragança et al., (2010)	√	√	-	-	-	-	-

Factor Analysis: Total Variance Explained

Total Variance Explained

Component	Initial Eigenvalues		
	Total	% of Variance	Cumulative %
1	22.118	31.598	31.598
2	6.599	9.427	41.025
3	3.2	4.572	45.596
4	2.633	3.761	49.358
5	2.4	3.429	52.787
6	2.243	3.204	55.99
7	1.849	2.642	58.632
8	1.817	2.595	61.227
9	1.704	2.435	63.662
10	1.698	2.425	66.087
11	1.396	1.994	68.081
12	1.329	1.899	69.98
13	1.306	1.866	71.846
14	1.264	1.806	73.652
15	1.065	1.521	75.173
16	0.928	1.326	76.499
17	0.918	1.312	77.811
18	0.899	1.284	79.095
19	0.877	1.253	80.348
20	0.816	1.165	81.513
21	0.723	1.033	82.546
22	0.72	1.029	83.575
23	0.644	0.92	84.495
24	0.625	0.893	85.388
25	0.593	0.847	86.234
26	0.529	0.756	86.99
27	0.508	0.726	87.715
28	0.503	0.719	88.434
29	0.497	0.71	89.144
30	0.468	0.669	89.813
31	0.448	0.64	90.452
32	0.422	0.603	91.056
33	0.406	0.579	91.635
34	0.383	0.547	92.182
35	0.367	0.524	92.706
36	0.353	0.505	93.211
37	0.334	0.477	93.688
38	0.326	0.466	94.154
39	0.31	0.443	94.597
40	0.278	0.397	94.995
41	0.258	0.368	95.363
42	0.249	0.356	95.719
43	0.236	0.337	96.056
44	0.219	0.314	96.369
45	0.216	0.308	96.677
46	0.2	0.286	96.963
47	0.191	0.273	97.237
48	0.168	0.24	97.477
49	0.165	0.236	97.712
50	0.153	0.219	97.931
51	0.146	0.209	98.14
52	0.133	0.191	98.331
53	0.125	0.178	98.509
54	0.116	0.165	98.674
55	0.106	0.152	98.825
56	0.097	0.138	98.963
57	0.093	0.132	99.096
58	0.085	0.121	99.217
59	0.075	0.106	99.323
60	0.07	0.1	99.423
61	0.064	0.092	99.514
62	0.052	0.074	99.588
63	0.051	0.073	99.661
64	0.046	0.066	99.727
65	0.043	0.061	99.788
66	0.038	0.055	99.843
67	0.035	0.05	99.893
68	0.029	0.041	99.934
69	0.027	0.039	99.973
70	0.019	0.027	100

Extraction Method: Principal Component Analysis.

Smart Moscow

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Abstract: Latest technology, digital revolution and very rapid expansion of Internet into all daily activities lead to development of completely new urban planning and development strategies and tools. Innovative approaches to data collection and management are established to cope with the fast paced development of cities in the new digital world, giving rise to a Data Driven City.

Innovative data-based technology is widely implemented in Russian capital Moscow systems of city planning and management. Moscow experiences a new trend, when the local authorities gain more power for management of issues such as, but not limited to, road traffic monitoring, optimization of transportation, open online citizen service portals, surveillance, health management (UMIAS system), accessibility to resources and data. Creation and success of such Internet based platforms, as Gosuslugi.ru ("State services"), Ag.mos.ru ("Active citizen"), Gorod.mos.ru ("Our City"), activities of which also penetrate into social media, lead to more involvement of general public into city management. Such portals allow residents to vote on various proposals and report issues around the city immediately and reach the responsible authority. The authorities can also control the work of various companies dealing with parking, landscaping, cleaning, waste removal etc.

Moscow has recently undergone optimization of public transport. More high quality mobile applications appear on the market such as Yandex.Transport, allowing citizens track public transport and road traffic conditions in real time in a very precise manner. Applications for taxi services such as Uber are extremely wide spread in Moscow as well. Smart traffic lights, automatic notification in case of accidents are one of the directions the city management is going.

Security is one of the important fields where advanced technologies are implemented. As a huge metropolitan area with rapid urbanization and population growth, Moscow deals with security and safety issues on regular basis. Starting from traffic acci-

dents and ending with terroristic acts, advancement of surveillance and real time monitoring and reporting, such projects as “Mobile inspector” are helping to prevent or investigate certain crimes. Social network and mobile applications allow citizens to actively engage in this process as well.

Moscow is improving its data-based solutions, and heading to path of sustainable implementation of a concept of Data Driven City, however certain aspects, such as smart waste management systems, environmental management, smart lighting, are still subject for improvement in Moscow.

Key Words: Smart City, Smart Moscow, Data-Based Technology, Data Collection, Data Management, Data Driven City, Intelligent Urban Systems, Intelligent Public Transport, Urban Management, Innovation, Electronic Services, Public Engagement

1 Introduction

Moscow is going through step-by step integration into the digital and technological world. Until 2011, the state program “Digital Moscow” was in operation, which created the basic infrastructure and networks [1]. Next year the program “Information City” was adopted. By 2017 a uniform portal www.mos.ru was created as well as similar centralized websites, and a lot of government services were transferred to digital format. The program ”Smart city”, ordered by Mayor of Moscow, Sergey Sobyanin, is scheduled to launch in 2019 and to be completely integrated by 2030 [2]. It is developed by the Department of Information Technologies of Moscow with the involvement of experts and citizens.

2 “Smart City” Program

“Smart City” program will help reaching a more advanced level of development of electronic services. It will involve artificial intelligence and large data analysis which will improve the effectiveness of urban management practices. Synthesis of speech, images and video, automatic translation will be used actively.

The citizens are already actively engaged into the process of planning and development. Such portals as www.ag.mos.ru (“Active citizen”) and www.Gorod.mos.ru (“Our City”) are widely used and allow citizens to participate in various problem-solving, voting and submitting their issues electronically. Technologies assist the government, execute bodies, various civil institutions and services.

Fig. 1 Centre of Information Technology “Smart City” in Moscow, complex VDNKH (Source: https://www.tripadvisor.ru/ShowUserReviews-g298484-d13129585-r548831555-Smart_City-Moscow_Central_Russia.html)

A special project smart City Lab was established to keep track of the entire world’s most advanced technologies and innovations in IT and to integrate them in Moscow infrastructure.

In July 2016, PricewaterhouseCoopers (PwC) has published a study “Data driven cities, where the experience of the implementation of the DDC concept (data driven city) of 28 major world megacities, including Moscow, was analyzed. This report is based on two methods: a semantic analysis of metadata about cities and technologies and an expert assessment of data driven decisions [3]. It mentions Moscow as being on the top levels of readiness to become a smart city, with the current emphasis on technological solutions for intelligent transportation systems, healthcare management and open portals for citizens [4].

The goal of “Smart city” program is to be more comprehensive and cover almost all aspects of citizens’ lives and to create a single point of access to any service. The project is based on five key principles: orientation on a person, technology of urban infrastructure, improving of the quality of urban resources management, comfortable and safe environment, emphasis on economic efficiency, including the service component of the urban environment [5].

Digital technologies in Moscow are actively present in almost all areas of city life: from healthcare to security.

2.1 Healthcare system

The healthcare management has gone through modernization, with introduction of a new system - Uniform Medical Information and Analytical System (“UMIAS”, www.emias.info), which also includes electronic medical records and prescribing. There’s a mechanism in the system that helps managing the planned appointments and the queues to the doctors in city’s clinics. The process of medical examinations, such as for the driver’s licenses, had been automatized as well. The work is being done to connect the policlinics with outpatient treatments with hospitals with inpatient ones.

There is also a free mobile application “UMIAS.Info” available, which simplifies the process for smart phone users. The visit of the clinic begins with tapping the smartphone with the generated code to the information terminal to get the receipt.

The study of PricewaterhouseCoopers (PwC) "Data driven cities", published in 2016, indicated Moscow as the leader in healthcare digital technology and the only one of the studied cities that fully integrated the digital management of healthcare [4].

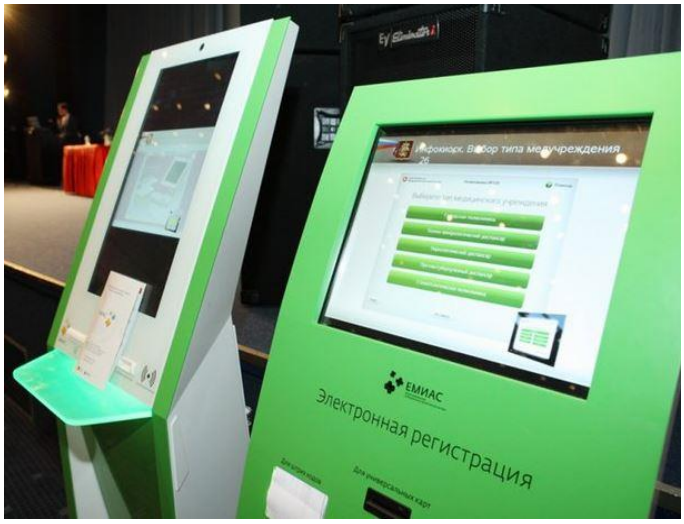

Fig. 2 Electronic registration (Source: http://www.vestifinance.ru/articles/85531)

2.2 Utilities

One of the main achievements in the area of utilities, housing and communal services was the launch of the Unified Dispatch Center, connecting several local centers, which process all applications for municipal services. Smart meters automatically send readings of consumption of resources to the system. In addition, smart meters alert an unusually high flow and report a potential leak. The websites www.mos.ru and www.gosuslugi.ru are used by citizens to receive housing, communal and utilities services.

2.3 Education

The project "Moscow Electronic School" project ("MESH") has been developed and launched in the sphere of education. It is not only an electronic library, predominantly developed by teachers, but it also comprises digital infrastructure, interactive blackboards, digital lessons, Wi-Fi and laptops in schools. There are more than 200 interactive applications developed within the system [1].

The system also helps parents to monitor school children’s school activities: for example such service as “Electronic Diary”, which keeps track of grades, exam results, homework, and various other notes from teachers. There are also possibilities to register kids to various after school activities and events. The goal of this system is to use already existing digital infrastructure in combination with latest smart technologies, which will allow creating more flexible, effective and individualized studying process.

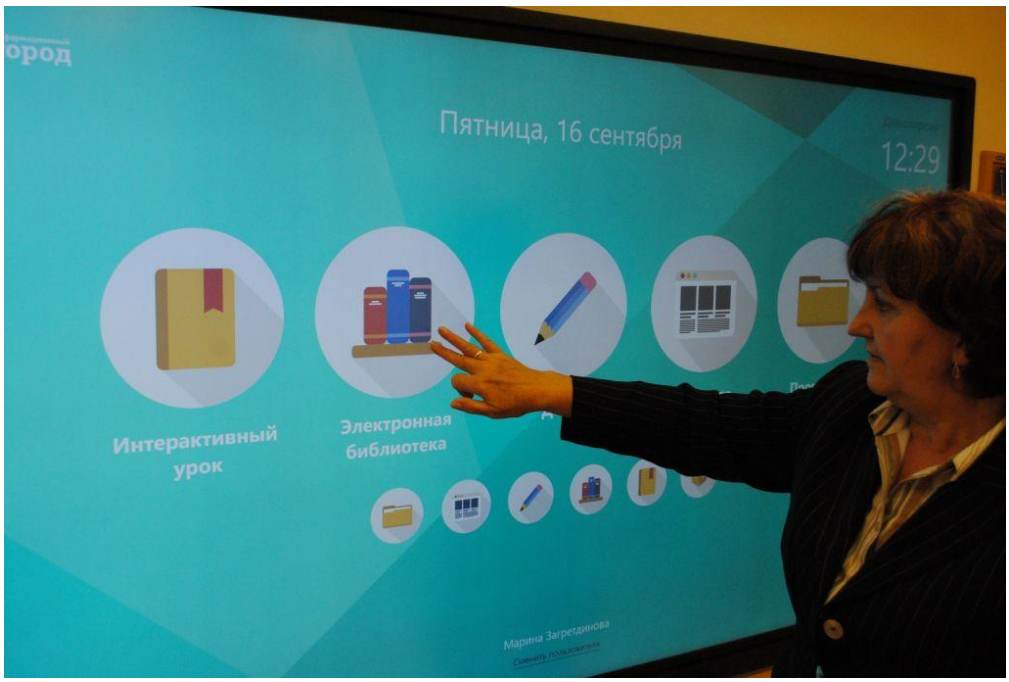

Fig. 3 Interactive board (Source: http://pkvartal.mskobr.ru/mesh)

2.4 Security

The system "Mobile Inspector" allows registering traffic violations and accidents and issuing applicable penalties using a tablet and an integrated mini printer. Traffic police officer has access to all databases and can communicate with colleagues efficiently.

The coverage of surveillance camera, including cameras with face recognition system has expanded. The recordings from the cameras and kept in one data storage and processing center and it is possible to retrieve information from the necessary camera.

Cyber security is also an important issue and is being improved. There are approximately one million hacker attacks on Moscow government systems per week [1]. The Federal program “Safe City” sets its goal to increase the level of public safety and security by significantly improving the coordination of the activities of responsible agencies, using integrated information system which provides forecasting, monitoring, prevention of possible violations and threats.

The citizens actively participate in threat prevention and warning, as well as in emergency situations, using social networks and hashtags.

Fig. 4 Mobile Inspector tablet (Source: https://mguu.ru/2014-09-16-10-37-09/)

2.5 Transportation systems

Public transportation system in Moscow is going through major renovations and adjustments to the newest technologies. Bus stops are equipped with screens with schedules and bus routes. Travel fares can be paid using electronic payment systems and online. There's an uniform transportation card "Troika", which can be used on all types of public transport and provides reduce fares.

There is a variety of applications, for example Yandex.Transport or Moscow Transport that help to choose a suitable transport route using different modes of transportation. These applications and websites work with GPS and GLONASS and are able to locate the position of the needed bus, tram or trolley bus precisely, calculate delay time, notify of various changes to other routes available, calculate travel time, including travel by metro, provide information on all types of parking, toll roads etc.

Intelligent Transportation system allows collection and processing of various data. The traffic detectors and cameras gather data on traffic and forward it to Traffic Management Centre, where the data is analysed and various traffic patterns can be forecasted. Static model is created to forecast various changes in road conditions for a longer period. It studies the activity and time of movement of people from one area to another, count the volume of the traffic flow, and use the analysis of large data. Dynamic model monitors parameters such as: speed and intensity of traffic flows, movement of public transport, accidents etc [3].

The Internet-of-things plays a major role in improvement of urban transportation system. All vehicles of city services and utilities are equipped with a positioning system, as well as speed and fuel consumption sensors. Obtaining this kind of information allows the city to optimize routes and use of the city transport network efficiently, especially during the cold season.

Fig. 5 Moscow Traffic Management Centre (Source: https://www.glassdoor.com/Photos/Traffic-Management-Centre-of-Moscow-Government-Office-Photos-IMG894068.htm /)

Car sharing and carpooling also gain popularity. Such websites as: www.cars-sharing.ru provide interactive map with all car sharing options in Moscow in real time. Services like Uber are widely used and there are local similar services as well, for example: Yandex Taxi.

2.6 City digital infrastructure

The city has its own Wi-Fi network, which operates in the public transport, ground public transportation, various central streets, parks, cultural and entertainment places. The study of the statistics of cellular operators on the movement of subscribers around the city allowed to determine the points where Wi-Fi is in high demand. The expansion of this network and provision of more individual access points will continue. The Internet-of-things and 5G technology open the possibility to connect a larger number of devices and sensors into the urban infrastructure [7].

Block chain technology will allow implementation of paperless contracts. Big data technology will provide citizens and businesses with targeted services that meet the personal needs. Artificial Intelligence automates decision-making based on data analysis. Virtual and augmented reality will affect areas such as tourism and education [7].

3 Public Engagement

Moscow citizens actively participate in various city issues. There are several important websites and applications, that allow efficient public engagement. The website www.mos.ru is used by citizens to receive housing, communal and utilities services. The website and mobile application with the same name ”Our City” www.gorod.mos.ru actively engages citizens in submitting requests about various issues and problems online. The requests are then being transferred to applicable

agency. For example, it is possible to submit complaints regarding irregular waste removal, unlawfully parked cars etc. There are currently more than a millions users registered in this system [8].

Another important website is www.ag.mos.ru (“Active citizen”), where citizens can vote on a problem or issue; express their opinion on different topics, such as new public transportation routes, speed limits, creation of new parks etc. One of the major projects, where citizens can electronically vote, provide feedback and express their opinion, is called “My street”. Various major Moscow central streets are being renovated and partially rebuilt according to this project.

Website www.gosuslugi.ru (“State services”) allows citizens apply for various government services online. The services range from car registration to passport application.

Website www.crowd.mos.ru is dedicated to crowdsourcing, which is a new information technology that allows gathering of citizens and interested parties in one place to discuss a certain topic and provide own ideas. It is a technological open platform working in the following cycle:
idea - expert choice - discussion - vote - realization [6].

4 Conclusion

The program "Smart City 2030" is a comprehensive strategic document which defines the goals and objectives for the development of Moscow as an innovative smart city of the future. This program and its predecessors create a significant change in the way of citizens’ lives, bring it up to date with the latest technologies and accomplish more advanced and efficient systems of urban planning and management with active public involvement.

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Afro-Mobitecture as a Catalyst for Resilient Community Development in Sub-Saharan Africa

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Abstract: The efforts by many sub-Saharan Africa (SSA) countries to meet the Sustainable development Goals (SDGs) (especially: 2- Zero Hunger, 3-Good Health and Well-being, 4- Quality Education, 9-Industry, Innovation and infrastructure, 11- Sustainable Cities and Communities) seems daunting and challenging because of the absence of basic community infrastructures and amenities that serve as the pivot for development. As an attempt to help provide appropriate home grown solutions to improve the quality of life for the people in marginalized communities in Ghana, the Department of Architecture of Kwame Nkrumah University of Science and Technology (KNUST) embarked on an applied research called Afro-Mobitecture: Architecture on the move for community development. From a pragmatic worldview using a qualitative approach based on epistemological analysis of mobile structures and its details, conceptual proposals based on an integrated approach was realized. Knowledge from the fields of Engineering, Architecture, Sociology and Anthropology as well as community health were utilized in the proposal that tries to solve a continental problem from a local perspective.
Mobile Architecture is a new movement, with literally prehistoric roots, which is exploding and expanding in popular culture, lifestyle, art, and architecture that is, paradoxically, about reducing, compressing and simplifying the objects of its interest. This movement which is always on the move could also be called Mobitecture. This architectural concept was invented by our nomadic ancestors when it became clear that

the supply of habitable spaces ought to follow them as food, water and trade was not static but geographically dynamic. The study sought to apply the concepts of minimalism, upcycling and Mobitecture as well as provoke creative design principles which are local African Context.
It came out from the study that the nomadic spirit of our hunting and gathering ancestors is very much alive in the modern world. Afro-Mobitecture shares adaptable, lightweight, responsive to local conditions characteristic. In addition, it has the ability to travel almost anywhere with ease as its intrinsic inherent qualities, which is the opposite of our usual stationary, brick-and-mortar-bound existences. Mobile structures for food, health, education and training, emergency relief, and housing were realised as part of the focus for this study. Consequently, the proposed structures were water and energy selfsufficient. The various Afro-Mobitecture proposals were also realised from the study to be a handy solution for the perennial problem where experts shy away from being posted to serve in marginalised communities. Above all, this could be useful for developmental and relief missions, educational tours and outreaches in marginalised communities to help improve the quality of life of the inhabitants.

Key Words: Mobile, Architecture, Infrastructure, Resilience, Sustainable, Upcycling

1 Introduction

Over the centuries, many semi-nomadic and nomadic cultures have inhabited the sub Saharan region in the African continent. Pastoral people continue to live in these harsh habitats. Their inventive architectural responses reflect timeless, sophisticated thought processes and involve cultural strategies: spatial mobility which is the key to their viability (Prusson, 1997). The disposition of their traditional technology of transport interfaces with the technology of building (Carlisle, 2005). Their knowledge of the physical properties of wood and aerodynamic design results in the creation of geodesic and tensile structures (Prussin, 1995). Mobile architecture is design that interprets the current condition of a modern man, who is constantly on the move. For Wright (1932), the nomad is not the man who fights the cave-dweller, they are, after all, brothers in their humanity, and accepts the cave-dwellers' presence even while he rails against their fixity; the nomad embodies an alternative. Wright is interested in the present. His question is: What can we do now? Wright’s largest architectural goals were in the social realm: he wanted to help build a society with nomadic values (Allen, 2005). This would make people's constant movement continually re-orient themselves to the changing demands of life.

1 Theoretical Framework

2.1 Community Infrastructure and resilience

Infrastructure is core to our quality a life, a fact that explains the prevalence of infrastructure, both implicitly and explicitly, in the Sustainable Development Goals (SDGs) (Casier, 2015). Population growth, migration and urbanization trends demand an increase in infrastructure development, especially in emerging economies and developing countries (Ahmed & Dinye, 2011). For instance, energy-related infrastructure

and an expansion of the electricity grid are necessary to provide energy access to urban and rural areas. Also, transportation infrastructure such as roads, railways, ports, airports is key for people's mobility from home to work, and for connecting rural areas to domestic and regional markets, contributing to a country's economic development (Casier, 2015; Seonwook & Miyoung, 2012). A community's resilience is its social capital, physical infrastructure, and culturally embedded patterns of interdependence that gives it the potential to recover from dramatic change, sustains its adaptability, and supports new growth that integrates the lessons learned during a time (Ungur, 2011). Resilience can be achieved by enhancing the ability of a community's infrastructure lifelines and structures, to perform during and after a hazard, as well as through emergency response and strategies that effectively cope with and contain losses and recovery strategies that are required to alleviate the situation at hand. (McDaniel et al., 2008). The US National Institute of Standards and Technology (NIST) in 2015 states six effective measures of planning and improving community infrastructure. It involves forming a collaboration (identifying leaders, forming team members, key stakeholders), understanding the social dimension, built environment and link social functions within these communities, determining goals and objectives, developing plan and implementation strategy, review and finalization of strategy and planning implementation and maintenance.

2.2 Historical review of Mobitecture as a metamorphosis result of nomadic architecture

According to Aristotle (384-322 BCE) as cited by Arc Space (2012), there never was a time when there was not motion, and never will be a time when there will not be motion. In recent times, society is increasingly fluid yet architecture can be more responsive than ever before; given the improvements in materials, production techniques, experience and technology (Siegal, 2003). Architectural form can cope more than adequately with the variety of different stylistic, contextual and political demands placed upon it. Today, the modern dynamic citizen finds himself in dynamic, ever changing environment. By its nature, mankind has always been transient to varying degrees through history (Roke, 2017). In order for modern architecture to serve the contemporary society, it must embrace and respond to the state of constant transfer, exchange, relocation and adaptation; the qualities evolved by contemporary and changing societies in a globalized world (Acharya, 2013). The optimism required for such an undertaking (nomadic lifestyle) was certainly a lingering result of the conclusion of the World War I, an event which had invigorated the avant-garde with the feeling of being given a second chance. The war made certain traditional practices (in governance, State politics, building, etc.) appear flawed, thus undercutting the authority of tradition in architecture as well (Allen, 2005). The ageless logic of classical economics defined the 'masters' would have been at the heart of a new architecture that would eventually construct a new world. Before the future arrived, architects would be the designers of standard prototypes and the managers of mass-production of housing; either in conjunction, as with Gropius' goal of the standardization of entire houses, or separately, as with Le Corbusier's insistence on the standardization of types using mass-produced parts in slightly different (Allen, 2005). In "Universal Architecture, Essay No.2", Fuller (1932) begins the discourse by illustrating the adapta-

bility of humanity to changing conditions by using Hungarian birth rate statistics. As people adapt to the conditions of a global urbanization and migration and physical need, humanity will adapt by transcending the 'logic' by "abandoning the land" and losing their "property sense." However, Fuller (1932) sees this state of 'loss of logic' as one of total freedom.

Nomadic architecture deals with 'unconventional architecture' outside the dictates of planning and the questioning of dwelling which is an alternative to an untenable architecture of stability and permanence (Acharya, 2013). Nomadic architecture started from movable tents and dwellings and has eventually metamorphosed in the new architecture termed 'Mobitecture' (Roke, 2017). Generally, humankind possesses the greatest values that allow defining it as dynamic. These are the systems that pass on the accumulated knowledge from one generation to the next, to embrace and solve the problems; it entails the natural curiosity to explore, the restless energy, and uncontrollable desire to achieve new goals. Moreover, all the historical and cultural events that happened in the world and all that are to happen are based on these qualities (Acharya, 2013).

Vladimir Lenin (1870 -1924), a Russian communist and political theorist said: "To live in a society and be free from a society is impossible". Truly, societies form the networks of countries, where citizens are organized into certain way of living, framed by set of rules and laws. But, if we compare the dynamic type of citizen to the static one, we could say that the static type is content to live in a changeless environment. Traditions determine the way of his living, his beliefs, his production techniques, social and cultural activities. Such societies can be remote tribal societies that are ignorant to any kind of innovation and actually have no need or desire for it even though there are other societies that adapt to change (Allen, 2005).

Today, the modern dynamic citizen finds himself in dynamic, ever changing environment. By its nature, mankind has always been transient, to varying degrees through the history. What has changed with the time, and what we can witness today is the speed and scale at which the increasing restlessness occurs. In order for modern architecture to serve the contemporary society, it must embrace and respond to the state of constant transfer, exchange, relocation and adaptation; the qualities evolved by contemporary societies (Acharya, 2013). Wright (1932) explored a range of concepts under the myth of the nomad and the cave-dweller. According to Wright (1932), in past times, Mankind was divided into cave-dwelling agrarians and wandering tribes of hunter-warriors; moving from one place to the other. While the more 'static' one for safety is hidden in a cave. Here we have a myth of origins. Onwards, the cave-dweller, who "lives in the shadow of the wall," protecting himself with a club, becomes in modern times, the "city dweller." Conversely, the "nomad," who finds his dwelling-place in the "folding tent" becomes the modern citizen, a man of the land, the adventurous "democrat" (Allen, 2005).

Historically, one can therefore discern several types of nomadic dwellings common in Eurasia and Northern Africa but are not exclusive those regions. They include:

- Tents with a load-bearing inner structure
- The yurt (Turkic) or ger (Mongolian), a trellis tent with a load-bearing inner structure and felt covering

- Horses and donkeys drawn with tents attached to them
- The straw tent
- Tuareg tents
- Different tents, usually for very temporary purposes and not intended for permanent dwelling (Zámolyi, 2016; Prussin, 1995)

According to Rogers (1997; 163), modern life can no longer be defined in the long term and consequently cannot be contained within a static order of symbolic buildings and spaces. Buildings no longer symbolize a static hierarchical order: instead, they have become flexible containers for use by a dynamic society. Thus, there is the need to embrace the evolution of humanity's existence.

2.3 Understanding Afro Mobitecture

Drawing from age old tradition yet unmistakably on-trend, the notion of the 'nomadic home' is increasingly a symbol of spontaneity and simple living (Siegal, 2003). Thus drawing from the ancient lifestyle and roots which employ African influences in mobile architectural design denotes the term 'Afro'-African Architecture. Generally, mobile architecture is an architecture that represents physical movement, architecture that changes places within a time range. "Mobility" refers to buildings that can physically relocate from one place to another (Friedman, 1960). Kronenburg (2011) defines mobile architecture as an architecture that "rolls floats or flies".

In reality, there is nothing new about mobile architecture. Currently, there are still plenty of nomadic communities who take their dwellings in nomadic structures such as Mongolian yurts, Bedouin tents and trailers amongst other examples (Siegal, 2003). Many demountable buildings that are produced commercially today are used widely in a number of fields which comprise commerce, industry, military, education, health care, housing, where they fulfill their unique roles. The advantage of such temporary buildings lies in the flexibility and diversity of their purposes, as well as the fact that they can be reused and therefore regarded as non-disposable (kronenburg, 2017). The unique characteristic that makes these mobile structures reusable implies that it involves cost effective use of materials and resources. Thus must be designed with lot considerations which make it relevant-'reusable'. Also, these Mobile structures are tuned to a specific need and not necessarily to a specific location. The recycling potential provides the opportunity to experience changes in accordance to needs (Roke, 2017). Primarily exemplified by the mobile home, mobile architecture presents a courageous effort in promoting movement, and flexibility of place. The mobile home however embodies some shortcomings that often overshadow its advantages. Marketed as a low-income housing option, mobile homes are typically equated with low standards of living. As evidenced by the typical consumption method of the mobile home - prefabrication, delivery, permanent placement - just because something can move, does not mean it will. Thus, mobile architecture that remains static is ultimately immobile and permanent (Acharya, 2013).

Mobile architecture is also linked with the possibility of establishing temporary lodgings in acute and emergency situations; for example in war and conflict areas or in relation to natural disasters. This new direction within architecture, focused on creat-

ing futuristic living spaces in unusual environments, often affected by climate change, has the potential to incite projects and ideas that have been unimaginable until now (Acharya, 2013; ArcSpace, 2012; Center for Public Interest Design, 2015).

Yona Friedman, one of the leading architects and theorist in the 1950s and 60s, identified flexibility as a key concept in architecture. In 1958, Friedman published his first manifesto called 'Mobile Architecture', which proposed a new kind of mobility, which he called “general theory of mobility”. His concept of “mobile architecture” implies mobility not of the building, but for the inhabitants, who are given freedom (Friedman, 1960).

Subsequently, the desire also to break free from urban living is facing a resurgence and portable architecture is being developed to reflect the eventual ‘cultural change’. Shelters and other structures that are easily moved, allow for consumers to explore their desire for a nomadic life. Abodes like portable compact homes and other similar structures can easily be shifted to another location. However, Mobile lodging has increased in popularity because of developments in technology and increasing property prices (Lam, 2013).

2.4 Afro-Mobitecture as essential catalyst for resilience

Resilience in design refers to integrating features into a design of a building; that enable the building to perform its envisioned uses, presently and in the future (Alfraidi, et al., 2015). In summary, Fehrenbacher (2013; pg1) defines resilient design as “the intentional design of buildings, landscapes, communities, and regions in response to vulnerabilities to disaster and disruption of normal life”. Resilient design pursues buildings and communities that are shock resistant, healthy, adaptable, and regenerative (Wholey, 2015). Building resilience to shocks, includes adaption to the effects of climate change, strengthening institutional response mechanisms and sustainable development that enable countries to deal with disasters and address insecurity more effectively through the promotion of AfroMobitecture. The promotion of mobile structures will be required to promote resilience, as well as for public service delivery, such as education, healthcare or access to water and energy (UN, 2017).

2.5 Afro-Mobitecture as an essential catalyst for providing Basic Infrastructure and Amenities

Basic infrastructure as the term suggests are the fundamental facilities and services that are required to support the livelihood of people within an area. They include simple but very essential facilities such as school, heath centres, and worship centres among others. Basic infrastructure is seen as a very important component for the growth and sustainability of people in an area, yet many rural areas, especially in Africa lack access to these infrastructure not only in terms of availability but also in term of physical accessibility. While government may be challenged by the cost of providing infrastructure within multiple rural areas only to serve a few people, there is also the regular desire of rural people to move from one location to another within the rural setting. Consequently, using Afro-Mobitecture, basic infrastructure including school, health facilities, libraries, and worship centres could be provided for rural areas at low cost because their design employs using basic environmental materials. In

addition the movable, dissembling, and assembling characteristics of Afro-Mobitecture designs allows the easy transportation of these basic infrastructure from one area to another, hence addressing the challenge of infrastructure provision associated with the continuous change of location by the rural people. Subsequently, Afro-Mobitecture also provides the access to the basic infrastructure within close proximity. Thus, because of it movable characteristics, people would not have to travel longer distances to access basic infrastructure and amenities as they could be transported to a location close to their place of residence. Also, the use of local environmental materials by Afro-Mobitecture design allows an easy fitting into the built and natural environment, which further triggers a sense of belonging and an acceptance by the local residents. This therefore further encourages the use of these basic infrastructure, thereby increasing access to them.

2.6 Afro-Mobitecture and the Sustainable Development Goals

Afro-Mobitecture seeks to provide flexibility and diversity of the various purposes of mobile structures. In the long run, it addresses and provides sustainable solutions to facilitate the reality of the Sustainable Development Goals (SDGs). In promoting the Afro - Mobitecture agenda, it achieves the objectives in the Sustainable Development Goals. The post-2015 development agenda “Transforming Our World: The 2030 Agenda for Sustainable Development” includes 17 Sustainable Development Goals, each with their respective targets and indicators, and a plan for implementation. The advent, education and pushing the afro Mobitecture agenda in sub Saharan Africa and Africa as a whole will promote an implicit impact to implement and achieve the SDGs.

2.6.1 Goal 1: No Poverty

This goal relates to access to basic services, building resilience and reducing vulnerability to climate related extreme events, and other economic, social and environmental shocks. The promotion of mobile structures is required to provide public service delivery such as education, healthcare or access to water and energy. Furthermore these services will also be provided in close proximity, hence cutting down the cost of physical accessibility that impedes the poor from accessing certain services and facilities.

2.6.2 Goal 2: Zero Hunger

Despite progress made over the past few decades, about 767 million people globally continue to live in extreme poverty, with half of them in sub-Saharan Africa. The majority of the world’s poor and hungry live in rural areas and depend on agriculture for their survival. However, their livelihoods are often constrained by limited access to resources, services, technologies, markets and economic opportunities, lowering their productivity and income. Fast population growth, increasing conflicts, civil insecurity and climate change exacerbate the situation, as the poor are invariably the most vulnerable (UN, 2017).

This goal endeavours to end hunger in all its forms by 2030 and to achieve food security. The promotion of mobile structure facilitates greater investment in agriculture.

It also facilitates the spread of equipment and materials, while educating farmers and other relevant stakeholders, in the use of appropriate agricultural methods and increased agricultural productivity, through higher levels of irrigation, technology and value addition (Food and Agriculture Organization of the United Nations, 2018).

2.6.3 Goal 3: Good Health and Well being

The target of this goal is to ensures healthy lives and promote well-being for all at all ages. It focuses on access to quality essential health-care services for which the development of health centres and hospitals in urban and rural areas will be essential (Casier, 2015).

2.6.4 Goal 4: Quality Education

This ensures inclusive and equitable quality education and promotes lifelong learning opportunities. The progress of mobile structures will allow dissemination of educational materials and minimize the use of schools under trees which is prevalent in sub Saharan Africa (Casier, 2015).

2.6.5 Goal 5: Gender Equality

The goal mainly empowers all women and girls. This point at the need for provision of public services through the use of mobile structures to educate and provide, the necessary framework for social protection of the vulnerable.

2.6.6 Goal 7: Affordable and Clean Energy

SDG 7 ensures access to affordable, reliable, sustainable and modern energy for all. The use of mobile structures advances the use of affordable and sustainable energy sources since they are self-sufficient structures and reusable and in disposable (Alfraidi, et al., 2015).

2.6.7 Goal 8: Decent work and Economic growth

The use of mobile structures provides a vessel and platform to allow unemployed and entrepreneurial minds to start and grow their businesses.

2.6.8 Goal 9: Industry, Innovation and Infrastructure

Goal 9 explores not only opportunities to build and improve resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation. It also calls for increased investment in sustainable infrastructure. But, implicitly, infrastructure development is part of advancing the popularization of mobile structures in sub Saharan Africa (Casier, 2015).

2.6.9 Goal 11: Sustainable Cities and Communities

The goal advances the cause of safe, inclusive and sustainable cities and human. Pertaining to mobile structures, it addresses issues relating to waste management, transportation, climate change mitigation and adaptation, and resource-efficiency, both in rural and urban centres (Eskew+Dumez+Ripple, 2014).

2.6.10 Goal 13: Climate Change

This takes urgent action to combat climate change and its impacts: it fosters the role and use of adaptable and resilient architecture which mitigates the impact of climate change as well as provides an avenue to protect the poor and vulnerable groups (Fehrenbacher, 2013).

2.6.11 Goal 17: Partnership for the Goals

The means of implementation of the SDGs and post-2015 agenda involves the collaboration of other stakeholders to fulfil the SDGs. Public-private partnerships (PPPs) will become increasingly important as a way of delivering infrastructure (Casier, 2015).

3 Case Studies

3.1 Portable Adaptive Dwelling - PAD

PAD is a prototype for affordably-built, secure and transportable housing for the homeless community (Sustainable Design for the Built Environment, 2018). PAD is part of the various design options for the Partners on Dwelling (POD) Initiative which is aimed at using architecture and appealing design community to apply their skills and experience in shaping the built environment toward housing Portland's most vulnerable population- the homeless. This is intended to ensure those without homes can remain in their communities, while setting a nationwide precedent for how municipalities help those living on the streets transition into safe, stable homes (Center for Public Interest Design, 2015).

In 2016, Sustainable Design for the Built Environment (SERA) built their proptype PAD in portland, Oregon as part of design contribution towards the Center for Public Interest Design and the Village Coalition.

Figure 1: Portable Adaptive Dwelling

Figure 2: Portable Adaptive Dwelling

SERA's PAD was built for durability, with a wood-framed construction and steel-framed folding walls, and cedar cladding to withstand heavy Portland rains. Its folding assembly allows for expansion on site, with exterior walls designed for modification; where residents can attach tarps and other materials to increase privacy, hang clotheslines, tapestries, etc., to add to their feeling of safety and ownership.

The interior is heated by a wood stove. There's a sink for washing, a desk for meals and tasks, and secure storage for valuables under the bed. Its thoughtful design illustrates that houseless communities can be safe, beautiful, and valued contributions to the neighbourhoods they are set in. The cost of materials for a PAD is under $4,500.

Figure 3: Portable Adaptive Dwelling

The POD Initiative is a joint effort of the Center for Public Interest Design and the Village Coalition. At the end of the year, each POD will become a home for a member of the community.

3.2 GRID by Carter Willamson Architects

GRID is a sustainable housing prototype that can be assembled quickly and transported cheaply to diverse and remote locations. GRID was originally conceived as a response to the tsunami in Banda Aceh. The strategy was to devise both an 'ideal' and a 're-use' system that could operate interchangeably; where in disaster zones the materials would comprise materials retrieved from debris. In less compromised circumstances, the shelters, pre-fabricated off-site, can be transported 'flat-packed' by either road or rail to remote communities.

GRID houses eight to ten people with a mezzanine level for sleeping and privacy. In community contexts, GRID can be configured to respond to the specific contextual and administrative requirements of family, culture or work. GRID is able to operate using either local municipal services or independently off-grid. The ultra-fit, fully insulated, steel-frame structure utilises photovoltaic cells and a roof-mounted solar hot water system; rainwater tanks collect roof water; and barn-door windows ensure the building is thoroughly ventilated. Sanitary amenities, comprising a composting toilet system and a shower along with gas bottles for cooking, are located on two external perforated metal decks.

Figure 4: GRID (Boardman, 2015)

4 Methodology and Data Analysis

This section highlights the methodological approach used in the research. The study adopted a qualitative approach using applied research method. The research explored theoretical framework encompassing and sustaining the advent of mobile architecture through literature review.

The research also employed a case study approach which was exploratory in nature. Desktop analysis of archival documents as well as secondary data from university was obtained. An architecture class of eighty one (81) students were engaged to design sustainable, adaptive, movable Afrocentric structures in relation to eight themes to mitigate pressing issues in the rural communities: clinic, pre-school, pharmacy, library, house of five (5), artist and architects design studio, eatery/restaurant, and rural evangelism. Jurors from the related design categories were invited to grade the various designs. Miniature models were made by the students as well as A0 posters were designed to be used as exhibits.

An exhibition was also held on the KNUST campus to solicit the public's reaction and perception of Afro-Mobitecture in Ghana, using KNUST as the focus community. A random survey was taken amongst the public that attended the exhibition. The methodology used drew out themes in the design exercise in solidarity with its needs, strengths, and challenges.

4.1 Profile of Study Area: Kwame Nkrumah University of Science and Technology (KNUST)-Kumasi, Ghana.

Kwame Nkrumah University of Science and Technology (KNUST) is an academic centre of excellence located in Kumasi-Ashanti region, Ghana. The University is the second public university established in the country, as well as the largest university in Kumasi Metropolis and Ashanti (Ulzen 1952). The university was established by a Government Ordinance on 6th October, 1951 and started out as the Kumasi College of Technology. However, it opened officially on 22nd January, 1952 with 200 Teacher Training students transferred from Achimota-Accra, to form the nucleus of the new College.

Once established through successive creation of academic colleges and systems, the last college to be established was in 1957, the School of Architecture, Town Planning and Building. Its first students were admitted in January, 1958, for professional courses in Architecture, Town Planning and Building. As the College expanded was adapted into a purely science and technology institution. In pursuit of this policy, the Teacher Training College, with the exception of the Art School, was transferred in January, 1958, to

the Winneba Training College, and in 1959 the Commerce Department was transferred to AchimotaAccra to form the nucleus of the present School of administration of the University of Ghana, Legon. Over the years the university has grown into having about six colleges with over fifty Departments; of which include the department of Architecture. The figure 5 below shows the KNUST Campus.

Figure 5: The KNUST Campus, Kumasi.

4.2 Profile of Department of Architecture - KNUST

The Department of Architecture forms part of the College of Art and Built Environment of the Kwame Nkrumah University of Science and Technology, Kumasi, Ghana.

It offers an array of teaching, a research and outreach service programmes in the key disciplines of the art and built environment which includes Architecture, Building Technology, Planning, Land Economy, Communication design, Painting and Sculpture, Rural and Industrial Art and Publishing studies.

The Department has as its ethos a pedagogue which encapsulates the requisite skills and perceptions necessary to comprehensibly effect the analysis, planning and implementation of both rural and urban design projects of varying complexity and scale based on the demands of Climate, Culture and Construction (the three Cs) within the tropical sub-region. As in most Architectural Schools globally, the Studio Programme (Architectural Design Studio), remains the pivotal course (core-course) around which the Theoretical courses are structured and taught in the Department. The mission of the Department is to develop excellence in the practice of architecture through quality education, training, research and the provision of community service to meet the changing and future needs of our society.

4.3 Afro Mobitecture in Department of Architecture, KNUST

Rural areas in Ghana cover a greater portion of the country's land area and currently accommodate a majority of the country's population. These areas also provide more than sixty percent of the Gross Domestic Products (GDP) earned annually; however these areas face socio-economic and infrastructural challenges. There have been several approaches in tackling these issues and developing these rural areas in Ghana. Some of these interventions include the establishment of the Department of Social Welfare and Housing Development in 1943 with most of its effort directed at construction of community centres, social clubs and youth centres as the basis of welfare work. As part of the Department of Architecture effort's to increase its visibility, relevance and contribute to the growing challenges in the rural communities, a studio exercise and exhibition was organized and as dubbed 'Afro Mobitecture: African architecture on the move for Rural Development' was put together by the Third Year Architecture class. This programme targeted developing innovative design solution to address challenges in rural areas within Ghana and Africa. Also, it is geared towards bridging the gap between academia and industry through pragmatic solutions to solving the nation's problems. The programme is a collaboration between the Department of Architecture and Architects Registration Council and was supported by Spaysis Architecture, Engineering & Planning Limited and CLEAN - AFRICA.

The students were engaged to translate the idea of 'Afro-Mobitecture' into designs that incorporate concepts pertaining to African architecture, minimalism, multipurpose spaces which facilitate varied spaces. Also, upcycling and recycling were areas taken into consideration during the design process. All designs developed were to be placed within a rural setting to solve accessibility issues relating to basic needs. Ingenuously, the students found ways to transport their structures; through collapsible and retractable technologies.

The design exercise comprised schemes of eight thematic areas designed by third year students of the Department of Architecture. The scheme was drafted by the third year studio staff as studio assignment. As a response to the assignment, the students produced creative and innovative designs based on their ideas and concepts of

what they feel encompass the term ‘Afro-Mobitecture’. The scheme was categorized into eight themes for mobile architecture. These included mobile pharmacy, mobile clinic, mobile studio, mobile preschool, mobile rural evangelism, mobile house, mobile restaurant and mobile library.

5 Results and Discussions

5.1 The Design Responses

Ivana Frimpong Yvette Annang

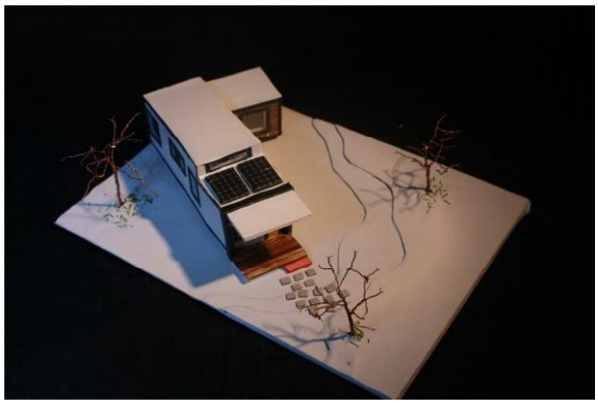
Figure 6 and 7: Mobile Clinic and their respective designers

Baffour Konadu Owusu Raymond Ofori-Tetteh

Figure 8 and 9: Artists studio and their respective designers

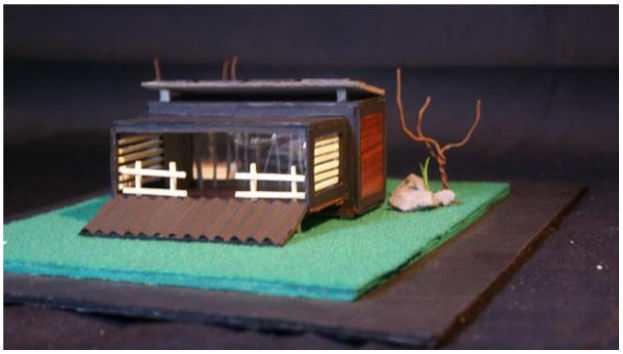
Othniel Baah Ennum Kwabena Adonu

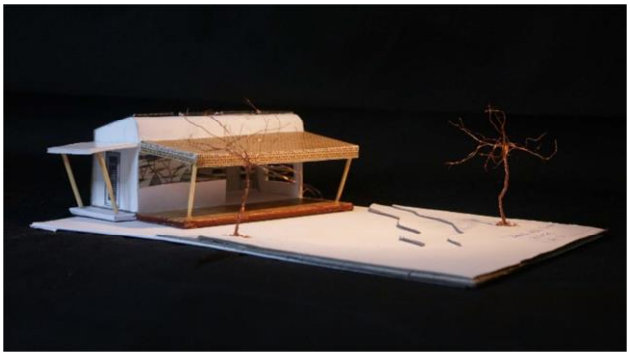
Figure 10 and 11: Rural Evangelism and their respective designers



Oduro Baah Roberta Kukubor

Figure 12 and 13: Rural Evangelism and their respective designers





Adel Maria Henry Onwona

Figure 14 and 15: Restaurant and their respective designers

Gideon Nuamah Maryse Madzouka

Figure 16 and 17: Mobile Pharmacy and their respective designers

Naa Koshie Hagan Francis Adjartey

Figure 18 and 19: Mobile Pre-school and their respective designers

Baako Godwin Daniel Obiri -Okae

Figure 20 and 21: Mobile Library and their respective designers

At the end of the exhibition, a survey was taken among the public present at the exhibition. The survey was to find out their reaction, perception and viability of Afro Mobitecture in Ghana using KNUST as the focus community. The figure 22 and 23 shows a graphical representation of responses and Feedback from public respectively. 58% of the public thought the design responses of the students were sustainable but 23% were skeptic about the cost and performance within our society's framework. 9% of the general public felt the design responses by the students could have been more innovative, while 10% considered the design to be aesthetically pleasing. As to the feedback from the public, generally the public felt it was a great cause and revolution for our society and more options of mobile architecture should be explored.

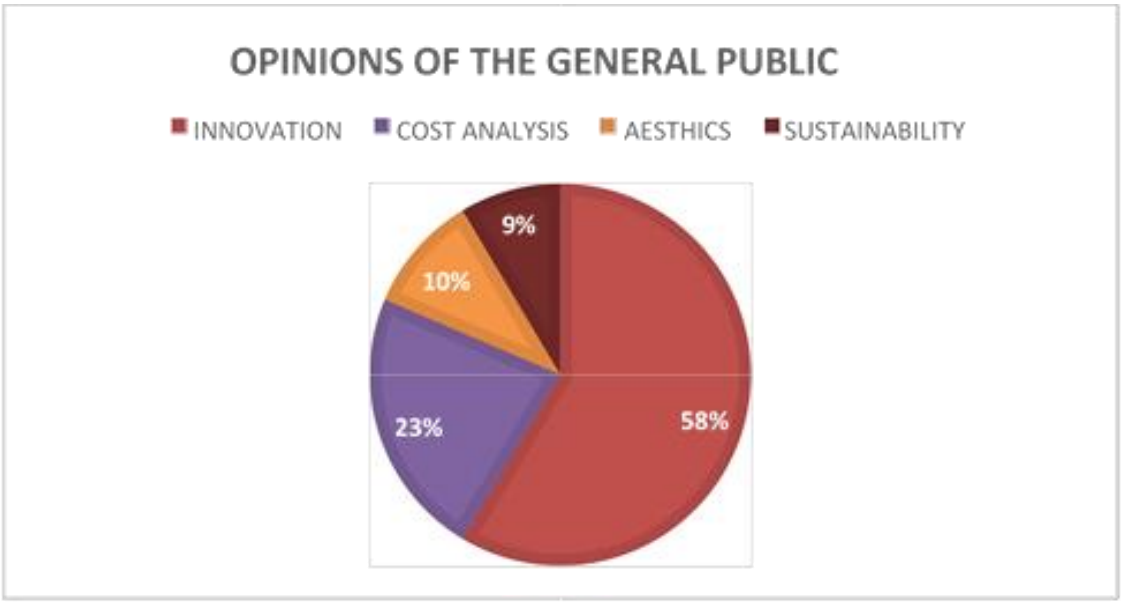


Figure 22: General public reaction of exhibition design responses.

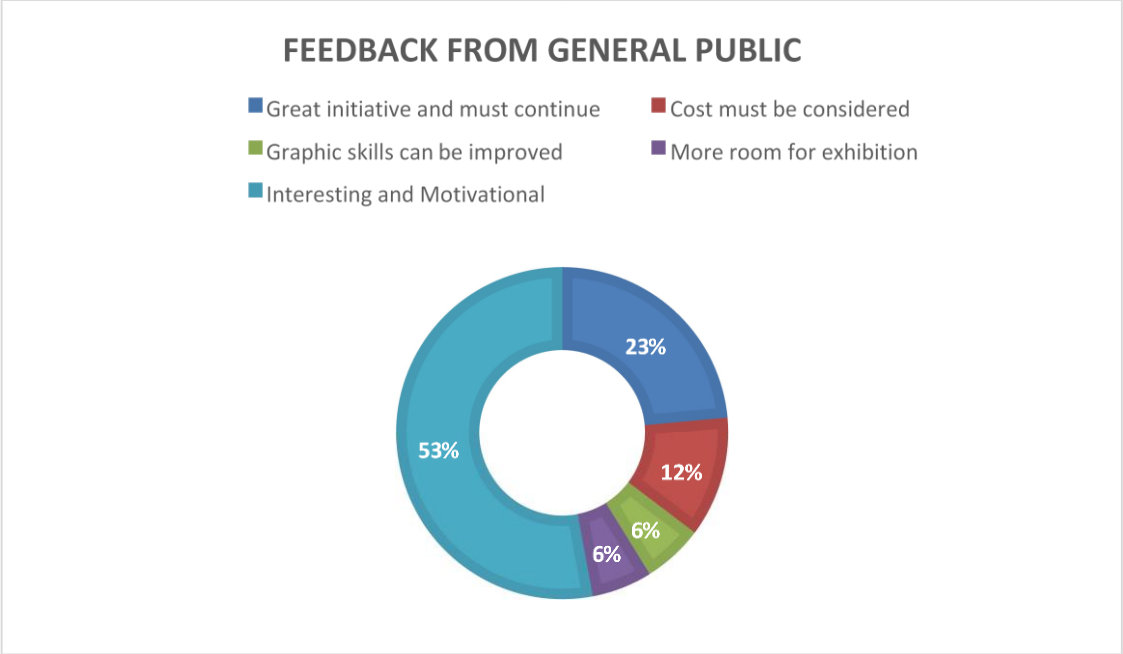


Figure 23: General public reaction of exhibition design responses.

5.2 Application in the Industry

As a result of the discussions and exhibitions some industrial players expressed interest in the usage of the Afro-Mobitecture products customised for the use of capacity building and education, health delivery and political education in the rural areas where basic infrastructure is missing. Moreso, interest has also been expressed for similar solutions for the urban areas to meet peculiar needs for targeted industries. A typical example is the GHACEM Mobile cement academy for the various rural areas in Ghana as shown in figure 25.

Figure 24: Example of Results of Afro-Mobitecture being adopted by Cement industry for rural areas

6 Recommendations and Conclusions

Per the discussions had in the literature review and field work carried out, the following points were highlighted.

- Mobile architecture is the new future of humanity; as mankind would be returning to its roots of nomadism.
- In the face of rapid urbanization and migration, mobile architecture is key to the economic and social development of Sub Saharan Africa as a whole.
- The concept of sustainability in Africa should be explored more seriously to fit in the local context.
- The Public needs to be educated on the use of these building concepts in the rural areas. Where government officials can be made aware of these building typologies which are cost efficient.
- Creation of platforms where some of these innovations can be exhibited both locally and on the international level which can be used in the educational sectors, health sectors and industrial sectors respectively.
- Improvements should be made on how mobile the structures can be, with reference to movements on distances.
- Cost analysis should be factored for the user to have a general idea of the cost involved.
- There should be improvement on the finishing details with regards to student craftsmanship.

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