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Norsidah Ujang · Tomohiro Fukuda ·
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Resilient and Responsible Smart Cities

Volume 1

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Resilient and Responsible Smart Cities

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Foreword

The global phenomenon that is rapid urbanization, coupled with population growth and concentrations in countries in the low-income category, has naturally been accompanied by an unprecedented increase in consumption of food, water, building materials, energy and resources. The world is now left with a pressing demand for pollution control measures, waste management and improved efficiency, productivity and quality of services. Since new ideas and innovation often start with a "need," the world is now motivated to turn to smart and resilient solutions.

Despite a shared primary motive, which is to respond to the sustainable development needs of society, the application of the Smart city concept may differ from one country to another. In developing countries, a smart city may be defined as one providing adequate infrastructure to meet increasing demands in the face of rapid urbanization, whereas in developed countries, the maintenance of existing infrastructure systems is the main challenge. Smart infrastructure is the foundation for key elements and themes related to a Smart city and that includes smart mobility, smart economy, smart governance, smart building and a smart environment. These elements, operating individually yet contributing to a whole that is a smart city, need integrated approaches as tools for multiple disciplines and key players.

Now that Smart building and Resilience in planning have become a primary goal and their importance has become established, the question of "how can they be achieved?" remains a topic of deliberation and research among architects and city planners. Can old and already developed cities take advantage of new sustainability opportunities and become resilient or is it too late? What is certain, on the other hand, is that new cities can learn from the mistakes of old ones. By taking a resilient approach to city planning and management, cities can withhold the ability of coping with climate change shocks, energy crises, food and water shortages and more.

Because smart and resilient cities involve dealing with built structures, infrastructures, institutions and individuals, the proposed approaches and solutions must originate from multidisciplinary discussions in a multicultural environment. By promoting communication and exchange of knowledge, this book represents the perfect platform where the current requirements and advances are investigated and analyzed. It is the resulting work of experts, researchers and city planners, from different parts of the world, coming together to interact, exchange ideas and work on solving mutual problems.

This volume offers real-life examples from current realities in hopes of allowing the reader to establish an understanding of the essential components of resilience and adaptation to change and shocks. It is meant to, both, showcase and stimulate discussion on the rising challenges faced by cities and why becoming intelligent and harnessing innovation is imperative to tackling those challenges and making our cities more livable. Research authored in this volume takes advantage of emerging technologies to build sustainable programs and

enables decision-making to predict and meet social, economic and environmental outcomes. With an emphasis on the interaction between the natural environment, infrastructure and society, the book represents a valuable contribution toward the future and welfare of our society.

Mourad Amer Ph.D.
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Preface

Cities are complex systems that are becoming more and more intricate as the needs of their citizens' increase. As a way of meeting those needs, every city currently aims to become the new Shanghai or New York as a result of a deeply rooted belief that urbanization is the solution. However, there is a price to be paid. A threat caused by urbanization has emerged over the years in the form of infectious diseases, natural disasters, extreme weather events, exploitation of natural resources and agricultural practices, all of which demonstrate how poorly managed urbanization has been. However, its effects are not merely limited to that but extend to the remaining rural and less fortunate populations. Realizing it is a double-edged sword with powerful future implications such as traffic congestion, pollution, spreading of diseases, water and sanitation problems, poverty and more, policymakers are now our only hope for implementing the necessary change to harness the economic and social benefits of urbanization.

This volume does not merely discuss the concept of a smart city as separate from that of a resilient city. The former focuses more on governance and IT solutions where the disaster component is not outright pronounced whereas the latter emphasizes the need to reduce the future impact of economical and physical disasters through the involvement of governments, communities and stakeholders. The resilient city's focus further regards factors of governance, risk assessment and management, disaster response and education. However, ideally, resilience cannot be limited to disaster management but further entails energy consumption, water consumption, waste management, transportation and more. With clear linkages detected, a smart city must be built for resilience at all times.

Nonetheless, the concept of a smart city itself is still emerging and the work defining and conceptualizing it is still in progress. Furthermore, identified challenges have further stimulated discussion and research. The five main challenges of implementing smart and resilient infrastructure can be summed up in (a) localization, (b) skills gap, (c) lack of finance, (d) inclusivity and (e) application of a governance model. Research presented in this book comes together with the purpose of underlining the primary role played by science, technology and innovation (STI) in guiding the development, planning and governance of smart and resilient cities. It also contributes to providing key design principles and approaches for tackling those challenges.

This book contains five parts with four to five chapters within each. It is comprised of an amalgamation of international case studies that offer comprehensive knowledge on the topic. It consists of carefully selected research papers prepared for and submitted to the second edition of the International Conference on Future Smart Cities and the second edition of the international conference on Resilient and Responsible Architecture and Urbanism, both held in Sepang, Malaysia in 2019 and organized by IEREK.

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Contents

Gaining momentum over the last few years with digitization as a key component, the rising approach that is a smart city is the way to mitigate challenges produced by rapid urbanization, population growth, polarized economic growth, increased green house emissions and decreased budgets. These issues as well as other related challenges can be alleviated through the adoption of scalable solutions, namely, the smart cities concept, that utilize ICTs (Information and Communications Technology) to enhance the quality of life and lessen the burden. Many theoretical and technological discussions have been stimulated over time, however, with little implementation due to a number of barriers. The main barrier to adopting such solutions is the multi-dimensional and complex nature with which cities are financed, regulated and operated as stakeholders' needs determine the built environment. However, the physical infrastructures within a city such as services, transportation and utilities can be further integrated through smart city frameworks that will enable cities to establish a system for recording, measuring, assessing and collating city data. As a result, lack of consistency, clarify and reporting will no longer be an issue to effective implementation and management of smart city solutions.A clear example can be seen in the Chapter titled "Are the New Towns really smart?" where the authors analyze twenty-first century new Chinese towns that represent an "identity model" inspired by European Cities. They start by pointing out the rapid transformation of contemporary cities, their consequent need for new ways of living and technology systems, then proceed to show how the eco-city term has been used to identify urban development processes and how sustainability principles have prevailed despite the existence of ambitious eco-city projects. In this chapter, the authors show how the smart technological paradigm approach has been applied along with the ecological paradigm in order to provide a basis for a model that could be replicated at different scales while using the "New Songdo City" as an example. By presenting case studies of new towns developed using smart city principles, their research provides an analysis of the objectives, those realized and those neglected, in order to understand the possibilities of building a smart city from scratch today. Similarly, and in another chapter or rather Study on the Planning of the Characteristic Town which Undertake Function Spillover of Big Cities, China's main strategy to promote its new type urbanization and industrial transformation, known as Characteristic Towns, is analyzed and compared with other types. The authors take the Butterfly Island Outlets Town Program in Harbin New area Sanjiawan Tourist resort as a case study. In Residents' Satisfaction towards Transformation of Klang River in Klang District, Selagnor, the authors shed light on a rehabilitation and redevelopment project of the Klang River in Malaysia implemented to transform a polluted river into a clean source for water and economic growth in Selangor. The research adopted and its findings are an attempt at measuring the level of satisfaction of the residents toward the transformation in hopes of developing strategies that would result in improvements and transforming it into a better place for the public.Moreover, and in this part of the book, the authors challenge conventional stereotypes about the concepts and perceptions that impede smart cities. First, smart cities should be Citizen rather than Technology-Centric. They should be quality of life and process directed rather than just one-touch does it all oriented. This chapter is more concerned with the connected management of resources, the economy and the environment, as much as with the connectivity of all databases. To avoid a failed Smart Cities Framework, it deems a national prioritization study necessary to identify which existing cities need to be smart within proper KPIs and roadmap before embarking on building new ones from scratch, especially in resource-stricken developing countries. Cities differ in terms of size, population, demographics and economic base. Accordingly, there is no "one size fits all" smart city transformation plan. In Chapter "Localizing the Globalized - How not to Fail in Smart Cities Frameworks",

the authors present somewhat of an anti-globalized thesis, which may seem in tune with the emerging post- COVID-19 world paradigms, using data from an 18-month-long in-depth analysis of four global case studies and detailed interviews with a state-of-the-art expert. Their findings answer a number of key questions as well as challenge many of the conventional stereotypes that impede the development of smart cities today.

Residents' Satisfaction towards the Transformation of Klang River in the Klang District of Selangor, Malaysia

Huay Ying Ong and Xiao Ying Meng

Abstract

A project known as "Rehabilitation and Redevelopment Project of Klang River (PPPSK)" had been implemented to transform Klang River, considerably the most polluted river in Malaysia, into a beautiful and clean river which can be a new source for economic growth in the state of Selangor, Malaysia. Therefore, it is essential to review the considerations from the public, especially residents who live along the river towards the transformation project. The research objective was to study the residents' satisfaction towards the Klang River transformation. With the aim to develop strategies to improve residents' satisfaction with the Klang River transformation, the research adopted both qualitative and quantitative methods (mixed method) to generate results and findings. Qualitative data were collected through a structured interview with two experienced government officers from the Town Planning Department. And, quantitative data were collected by distributing questionnaires to the residents from ten villages along Klang River. Findings demonstrated that residents are still dissatisfied with the transformation of the Klang River in the aspect of water quality, recreation uses, and flood protection whereas, enhancement of residents' satisfaction needed to develop from the integration of residents' expectations and government's development concepts on the river restoration project. In conclusion, this research can be a reference for the local government to transform the Klang River into a better place for the public.

Keywords

Residents' satisfaction • River restoration • Klang River

1 Introduction

Klang is one of the oldest cities in Malaysia that has been occupied since over 2,000 years ago. It is a royal town and former capital of the state of Selangor , Malaysia. Klang is divided into North Klang and South Klang, which are separated by the Klang River. The Klang River is approximately 120 km long, under the territories of five local governments in the state of Selangor and Kuala Lumpur City Hall (Abdul Rahman 2010). This research focused on the Klang River at the district of Klang, Selangor, which is under the administration of the Klang Municipal Council (MPK). It is 21 km from Port Klang to Kampung Bukit Jati. It is the heart of the development and growth of Klang City as the river mouth is the main exit for foreign traders to the Klang Valley area. Therefore, the Klang River was the catalyst for the development in Selangor state in the early age. Besides that, the importance and roles of the Klang River will highly impact the property development and future development of Selangor (Abdul Rahman 2010).

Unfortunately, the Klang River as the Selangor's iconic river, is one of the dirtiest and most polluted in Malaysia. According to the Department of Environment (2019), the water quality of Klang River lies between the category of slightly polluted and polluted. The pollution was caused by industrial discharge, improper sewage treatment, residential discharge, land development, and soil erosion. This pollution had affected the quality of public life due to the unpleasant sight and smell of the river (Rajan 2011). It also endangers public health as dengue cases are caused by mosquitoes breeding in clogged drains (Perumal 2015).

In 2010, the Selangor government initiated the "Rehabilitation and Redevelopment Project of Klang River (PPPSK)" with the goal to transform Klang River into a beautiful and clean river as well as a new resource for generating the economy of the Selangor state. The mission is to preserve and enhance the water quality of the Klang River with the involvement of all the stakeholders in a sustainable,

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holistic, and integrated way. After working for 7 years, the image of the Klang River full of dirt and rubbish is now changing into a cleaner river. Since then, there are people fishing, bringing children for sightseeing, and jogging around the bridge. The surrounding areas of the river is decorated with mural paintings. Besides that, there is a "key love" attraction like in Paris which has become a photo shooting place for married couples (Ibrahim 2017a). With the transformation of the river, the Klang Municipal Council promoted Klang River as a "Visit Klang 2017—City of Heritage" program meanwhile achieving the goal of making it become one of the tourist attractions (Ibrahim 2017b). Currently, this project is still in progress. Hence, continuous public commitment is crucial for supporting this program. Residents who are residing along the Klang River play a vital role in this on-going transformation project.

The research aim is to study the residents' satisfaction towards the transformation of the Klang River. The main respondents for the study were government officers who were involved in the PPPSK and villagers from ten villages along the Klang River in Klang area as shown in Fig. 1. Then, from the result of the study, strategies were developed for the development of the river and to improve residents' satisfaction towards the transformation of the river.

2 Literature Review

2.1 Necessity of Residents' Satisfaction in Transforming a City

Transformation of a river in a city area always needs to consider the satisfaction of residents. Therefore, residents' satisfaction should be implemented in urban research (Zenker and Rütter 2014). Every place, like a city, with the target to satisfy the needs of its place customers whether it is resident or other customer groups like tourists. By doing research on resident satisfaction, it was beneficial to identify alterations and issues in residence development from a customer's point of view and to further improve the area itself. Besides that, the accomplishment of expansion such as urban regeneration projects can be monitored as well. According to the report by WWF with the title "Water Restoration", social expectations can be a significant encouragement. Communities' dissatisfaction with the poor state of their rivers lead to political inspirations to take action (Speed et al. 2016). Responses can be ideas at improving the aesthetic qualities of a river system, reducing odour, or improving water quality to allow swimming or fishing, or creating riparian recreational areas.

Residents' satisfaction is the overall satisfaction of users based on their perception of the features of green spaces (Gozala et al. 2018). Chan et al. (2003) clearly stated that beautifying the riverine areas with a view to provide and upgrade recreational facilities within the city is one of the objectives of a river restoration project. According to Martinez et al. (2015), several areas near to Klang River were flooded on 15 March 2016 which was caused by excessive rain, blocked drainage, and river flow. River restoration projects for enhancing flood protection are required to deliberate ecological aspects that gain acceptance among local residents (Seidl and Stauffacher 2013). Hence, residents' satisfaction undeniably needs to be considered in a river restoration project for a city.

2.2 Measuring Satisfaction of River Restoration

Seidl and Stauffacher (2013), conducted an evaluation of river restoration through residents' feedback by focusing on ecological aspects such as "naturalness" and biodiversity with the intention to provide better flood protection. In order to investigate the opinions of residents about the restoration project at Thur River, which include the enquiry of whether the restoration was perceived as reasonable and accepted. The questionnaire comprised of questions covering the perception of ecological diversity, flood protection, and aesthetic aspects, as well as personal attitude towards nature.

While in the study by Chang and Huang (2011), in the context of waterfront development in Singapore, reclamation was used in aspects such as functionality, accessibility, and community, for instance, reclaiming functionality, designed at infusing the waterfront with new land uses; reclaiming access as a way of opening up the landscape to more people; and reclaiming the community by commemorating local cultures and histories. This could pursue Singapore to be a world city without becoming an immoderation of global urbanism and the closed-mindedness of traditional development.

According to the book "Ecological Riverfront Design: Restoring Rivers, Connecting Communities", restoring a river into a riverfront project may have to overcome physical, political, social, and economic barriers to increase community usage and pleasure towards the resource. Many successful projects conducted previously were designed to include spaces that specifically accommodate parks, walkways, docks, and special events such as concerts and festivals. A good riverfront design should consider the needs of all neighbourhoods, ages, and cultures in the community. They allow community members to experience the river up

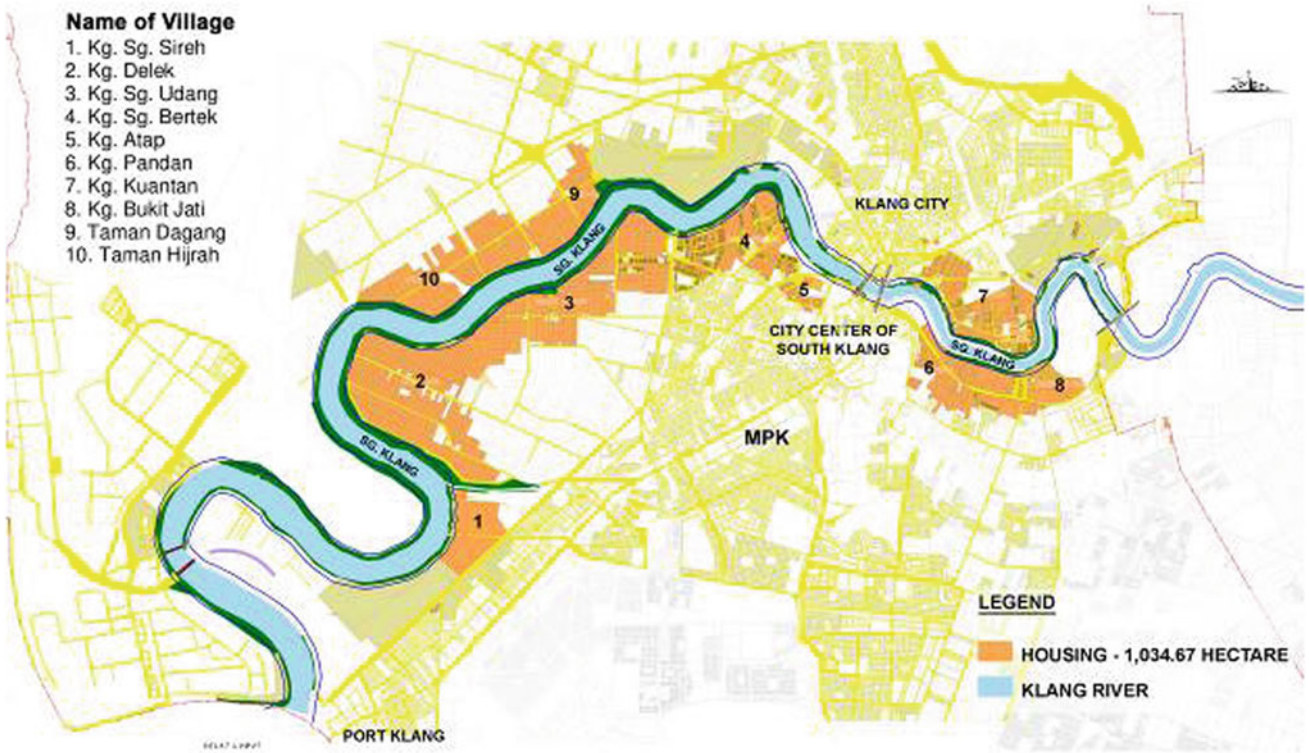

Fig. 1 Study areas of the research

close. In turn, this physical and visual access helps create lively, diverse places that encourage a sense of community and an appreciation for nature (Otto et al. 2004).

According to City of Portland Bureau of Planning (2001), there were five (5) goals of the river renaissance vision. The first goal is to make the river clean and healthy for fish, wildlife, and people by highlighting riverbank restoration, removal of combined sewer runoffs, and better flood management. The second goal is to preserve and improve the working harbour where its infrastructure as the port is a fundamental economic asset. Thirdly, the river should be embraced as Portland's front yard to make the river more accessible to residents. Next, vibrant waterfront districts and neighbourhoods that add the value of those places by creating attraction spots and interesting activities should be enhanced. Lastly, partnership, leadership, and education for strong involvement and collaboration should be promoted.

Rivers are recognised as living systems where river restoration supports and enhances biodiversity, water quality and flood management, and also supporting economic and social benefits for people and industry (RESTORE Layman's Report 2013). According to Langford and Shaw (2014), there are assorted concepts that have been utilised for post-restoration assessment with considerations such as public safety (flood protection), economic priority, amenity, restoration of physical processes, and ecosystem enhancement.

2.3 River Restoration Projects

River of Life was one of the Malaysian government's Economic Transformation Programs. This project was divided into three main components known as river cleaning, river master-planning, and beautification. It covers three city rivers with a total area of 781ha and 63 ha of water bodies. This project is established to fully transform the river and bring the community "back" to the river. The river is to be transformed into a vibrant waterfront with high economic and commercial value, revitalising the city's river and reconnecting it to the surrounding urban stuff (AECOM 2018). It had successfully improved public accessibility by constructing bridges, bicycle paths, and pedestrian sidewalks.

Besides that, the Kuching Riverfront was one of the successful river restoration projects in Malaysia. It was transformed into an oasis of leisure, recreation, and discovery. The structures and facilities at the Kuching Waterfront revealed a combination of existing historical buildings and supplementary modern facilities. Besides that, the features also showed integration of local culture and modern technology. "Perahu tambang" or "water taxi" was an icon of Kuching. It was alternative transportation for kampung folk across the river and it boosted tourism in the city as well.

Bishan-Ang Mo Kio Park at Kallang River is a river restoration project in Singapore. According to Ng (2012), a

2.7 km straight concrete drainage channel had been transformed into a sinuous and 3.2 km long natural river that flows through the park. This transformation was not only as a shield from flooding, but it also built new recreation opportunities for the city. It provided three children's playgrounds which include water, adventure, and inclusive. Spaces for traditional recreational activities, likewise practicing tai chi and walking on a "foot reflexology path", had been preserved in the redesigned park (Hattam 2012).

The Chicago River had a similar background as the Klang River which was polluted with garbage, animal carcasses, and waste in the 1890s (Bosman 2018). It was thought of by locals as an unattractive, dirty, and nasty hazard. According to ArchDaily (2016), the Chicago Riverwalk project was an initiative to reclaim the Chicago River for the ecological, recreational, and economic benefits of the city. A series of piers and floating wetland gardens provided an interactive learning environment about the ecology of the river; it provided chances for fishing and identifying natural plants. Besides that, kayak rental and docking for individual boats provided physical connections to the water through recreation. Restaurants, outdoor seating, sculptural staircase, and boardwalk improved the accessibility of people to the river.

3 Methodology

3.1 Data Collection Procedure

First and foremost, the research was carried out by identifying the problem statement. Subsequently, the decision was established in the objective of the research. The first objective of the research is to determine the residents' satisfaction towards the transformation of Klang River. The second objective is to develop strategies to improve residents' satisfaction of the transformation of Klang River. Related information was reviewed to support the research objectives. A mixed method was used to achieve the objectives. For the first objective, qualitative and quantitative data were collected at different phases while both data were collected at the same phase for the second objective.

For the first objective, the research was first carried out by interviews, then a questionnaire survey. This is because there were some unknown variables and insufficient information regarding the restoration project. Thus, interview sessions with the purpose to ensure the questionnaire surveys can be developed within the scope of the research and to determine the current conditions of the Klang River's restoration project. Two experienced Town Planning Department's government officers who are a local government officer and a state government officer had been selected as interviewees. Data collected was analysed and used to construct questions in the survey. The survey was conducted by random distribution to the villagers living along the Klang River. A ratio method was implemented to determine the target sample for each village. For the second objective, interview and questionnaire surveys were carried out concurrently with respective analyses. To achieve this objective, a questionnaire was prepared with the purpose to understand the opinions and perception of government officers and residents towards the future development of residential areas along the Klang River with regards to the river transformation.

For the interview session, data obtained was the government's analysis report towards potential development along the Klang River whereas questionnaire survey displayed the ranking result on the significance of each aspect to improve the village. Then, the results from these two data sets were merged, compared, and related. The most appropriate strategies were developed after the interpretation. At last, results were concluded by providing strategies that integrated the expectations from the residents and the government.

Based on Krejcie and Morgan table, the target sample for this research was 383 respondents from a total of 167,020 residents in ten (10) villages. SPSS software was used as a tool to interpret the data. Index mean was implemented to obtain the range for the level of perception and commitment of the respondents. The aspect of flood protection was analysed according to each village while river water quality and recreational use were analysed according to each indicator. Then, results were concluded for each aspect.

There were several obstacles and limitations which restricted the data collection and analysis for the completion of the research. The constraint was the availability of government officers who were involved in the river restoration project to be interviewed. And also, respondents who were unable to respond to the questionnaires due to other committment and the difficulty to obtain an AutoCAD file of drawings with clearer photos.

3.2 Measurement Criteria/Indicators

Data collected through interviews with Town Planning Department's government officers was analysed and the information was used to further develop a set of questionnaires. The questionnaire consists of three main aspects to assess river restoration successfully which were (1) ecological condition of the river; (2) flood protection, and (3) recreational use. From these three aspects, there were a total of 35 items that have been questioned to the respondents. A five point Likert scale was used to measure residents' satisfaction levels from "most dissatisfied" to "most satisfied".

To achieve the second objective which was to develop a comprehensive strategy, questionnaires were prepared to

understand the opinions and perception of government officers and residents towards the river transformation and future development of residential areas along the Klang River. The research focused on eight important aspects: (1) ecological condition of the river; (2) flood protection; (3) aesthetics; (4) accessibility; (5) cleanliness of the environment; (6) economy; (7) value of place; (8) facility and amenities.

4 Result and Discussion

4.1 Residents' Satisfaction towards the Transformation of the Klang River

For the first objective, data collected from interviews was in three sections, Sections A, B, and C. Section A was the respondents' information. R1 was a senior officer who had 15 years of working experience at Klang Municipal Council Town Planning Department while R2 was a senior officer who had 22 years of working experience at Department of Town Planning in Selangor State. They were chosen because of their long service period. They were involved in the river restoration project since the beginning till now. Section B was general information on the Klang River restoration project. Five questions had been asked to ensure the questionnaire can be developed in the scope of research which included the main factors to restore Klang River, development concept and government plans in the river restoration project, involvement of the public in developing plans, and their opinions on the role of residents for the transformation of Klang River. For Section C, seven questions had been asked to determine the current conditions of Klang River in the restoration project, so that more precise questions can be developed in the questionnaire and to ensure the objective can be achieved. After receiving the response from the respondents, variables were specified and the questionnaire was developed.

A total of 315 questionnaires were collected through social media, head of village, and by hand. According to (Survey Monkey 2019), the survey had a 5% margin of error and it was acceptable. The majority of the respondents were female (64.13%). Most of the questionnaire surveys were replied to by the Malay respondents (69.84%) and the majority of the respondents were in the range of 45 to 54 years of age (37.14%). More than 90% of the respondents were living in their respective villages for more than 11 years. This indicated that the findings presented in this research had been carried out with the residents who know the area very well. Questions in Section B and C were designed to achieve this objective. Section B was regarding respondents' opinions on changes of Klang River which included their awareness of cleanliness, importance of Klang River, and their exposure to the transformation of Klang River. All respondents were aware of the factor of pollution and benefits of the river restoration project, but minority respondents were not aware of their roles in river protection. This consequently showed that the frequency of visits decreased. The majority of respondents didn't notice that the river had become a better place to visit although the government had organised activities to increase the exposure of the restored Klang River. 93.7% of respondents disagreed that mosquitoes nearby the river had been reduced after the change. This result showed that the problem of disturbance of mosquitoes was not solved.

Section C revealed results of residents' satisfaction towards the transformation of the Klang River. There was a total of 35 items in the questionnaire designed to determine the satisfaction levels of residents. Cronbach Alpha Test was used to indicate the internal consistency reliability of the collected data. The result indicated the value of Cronbach's Alpha was 0.849. Based on the data regarding assessment of overall changes on the Klang River, it showed that 234 out of 315 respondents (74.3%) were dissatisfied with the transformation of the river. For more details on the aspects investigated, the data was organised and analysed according to three main factors of residents' satisfaction measurement for the transformation of the Klang River which were the ecological condition of the river, recreational use, and flooding protection. Ecological condition was examined by the water quality of the river and its physical factors.

Table 1 depicts that majority of the respondents were dissatisfied with the water quality of the Klang River as all the indicators fall into the "dissatisfied" category except for "aquatic habitat" which was "neutral" (M = 3.13) because there were many people who enjoyed fishing there. "odour" and "colour" were the most dissatisfied items (M = 2.19) as the smell of the river was very strong and its colour was dirty during the ebb tide period. The water looked dirty because of the mud and impurities silted on the river bed. Although picking up rubbish activities had been practised, there was some rubbish found floating on the river and at the river bank. Therefore, the cleanliness of the water was dissatisfactory (M = 2.23).

In this research, the recreational use of the Klang River was measured in Pengkalan Batu Park. Table 2 reveals the mean value and satisfaction category of recreational use in six main factors with a total of 27 indicators. The majority of the respondents were dissatisfied with "public transport" to access the recreational park which had the lowest mean score (M = 2.15) since no public transport was provided for direct access to the park. However, the majority of the respondents were satisfied with the indicator of "availability of trash can" which had the highest mean score (M = 3.74). This was due to the effort of the Klang Municipal Council in providing many trash cans at the park.

Table 1 Residents' satisfaction of the ecological condition of the river

Indicator	Mean	Category
Odour	2.19	Dissatisfied
Colour	2.19	Dissatisfied
Cleanliness	2.23	Dissatisfied
Mud and impurities	2.24	Dissatisfied
Rubbish	2.47	Dissatisfied
Aquatic habitat (Fishes)	3.13	Neutral

Three indicators in the aesthetics factor, "architecture" (M = 3.22), "flora" (M = 3.20), and "landscape" (M = 3.21), were in the "neutral" category. The park had beautiful architecture, flora, and landscape. However, the public didn't take care of the structures; they were destroyed due to vandalism with no proper maintenance. Thus, the overall aesthetics of the park was still unsatisfactory. As mentioned earlier, the majority of the respondents were dissatisfied with the accessibility of "public transport" as no public transport was provided to reach the park. Respondents were satisfied with the accessibility of "parking area" because it had sufficient car parks. Accessibility of "pedestrians" and the "handicapped" was considered `neutral'. The condition of the pedestrian was good, only some of

Table 2 Residents' satisfaction of the aspect of recreational use

Factor	Indicator	Mean	Category
Aesthetics	Flora	3.20	Neutral
	Landscape	3.21	Neutral
	Architecture	3.22	Neutral
Accessibility	Public transport	2.15	Dissatisfied
	Handicapped	3.06	Neutral
	Pedestrian path	3.10	Neutral
	Parking area	3.57	Satisfied
Environment factor	Cleanliness of toilet	2.14	Dissatisfied
	Cleanliness of park	2.27	Dissatisfied
	Cleanliness of parking area	3.45	Satisfied
	Available of trash can	3.74	Satisfied
Safety and security	Activities in park area (criminal cases)	2.84	Neutral
	Condition of pedestrian path	3.07	Neutral
	Safety in using the facility of park	3.60	Satisfied
Value	Educational	2.22	Dissatisfied
	Historical	2.22	Dissatisfied
	Cultural	2.22	Dissatisfied
	Attraction varieties	2.86	Neutral
Facilities and amenities	Public toilet	2.25	Dissatisfied
	Direction boards	2.26	Dissatisfied
	Street lights	2.43	Dissatisfied
	Shades	2.55	Dissatisfied
	Recreation space	3.08	Neutral
	Shelter (Gazebo)	3.52	Satisfied
	Jogging track	3.52	Satisfied
	Seats and chairs	3.56	Satisfied
	Children's playground	3.69	Satisfied

the paths in the parks were not well connected. Accessibility of the handicapped was provided, but it was not comprehensive. There was no special path for blind peoples.

There were four indicators used to measure the environment factors for the recreational park comprised of "cleanliness of park", "cleanliness of parking area", "cleanliness of toilet", and "available of trash can". A majority of respondents were dissatisfied with "cleanliness of park" (M = 2.27) and "cleanliness of toilet" (M = 2.14) while "cleanliness of parking area" (M = 3.45) and "available of trash can" (M = 3.74) were considered to be satisfied. Although the park provided sufficient trash cans, there was trash thrown everywhere in the park. Therefore, the cleanliness of park was not satisfactory to the users. The public toilet is in a poor condition due to the lack of cleaning and maintenance.

Besides that, "safety in using the facility of park" was considered satisfied by the majority of respondents. Measured on "activities in park area" and "condition of pedestrian path" for safety and security factor were reflected as neutral. However, respondents were concerned regarding their safety at the park as it does not have CCTV and there were fewer police patrols at the park. The pedestrian path was safe and well-maintained but some motorcyclists were using the pedestrian path causing danger to pedestrians.

There were four indicators used to measure the factor of value, which involved "attraction varieties", "educational", "historical", and "cultural". The indicator of "attraction varieties" (M = 2.86) revealed the satisfaction level was "neutral" as the local government had created attraction places near the park such as mural paintings and "key love" attractions. However, it was not sufficient. "Education", "historical", and "cultural" had the same mean value, 2.22, that was in the category of "dissatisfied". We could hardly see any education, historical, and cultural values within the park.

For the facilities and amenities factor, the result indicated that respondents were dissatisfied with "shades", "public toilets", "street lights", and "direction boards" in the park. Respondents' feedback was that no shades and direction boards are available at the park. And, the far distance between the public toilet and the park resulted in inconvenience for usage. Furthermore, the street light was stolen. Nevertheless, they were satisfied with "shelter (gazebo)", "jogging track", "seats and chairs" and "children's playground". The satisfaction of "recreation space" was "neutral". There was a recreation space for the public without the provision of exercise equipment or any activity functions.

For flood protection, the analysis had to be done on every single village as all places along the river had a diverse condition of flooding. Figure 2 revealed that among the ten villages, half of them were in the "satisfied" category which meant that majority of the respondents were satisfied with flood protection in their villages. Respondents said that since the floodgates were installed and the drainage system was improved, there were no flooding issues. However, the majority of respondents from Kampung Sungai Sireh and Kampung Delek were dissatisfied with the flood protection in their villages. According to Bernama (2018), Kampung Delek was hit by flash floods in October 2018 due to heavy rains. Kampung Sungai Sireh was the village neighboring Kampung Delek, thus the flood affected the villagers as well.

4.2 Strategies to Improve Residents' Satisfaction of the Transformation of Klang River

To achieve this objective, the perception of government officers and residents towards the future development of residential areas along Klang River were significant in developing the transformation strategies. Through the interview sessions, the state government officer provided the most useful data to accomplish this objective which was the government's analysis report. This government's analysis report stated the potential development of areas along the Klang River was determined based on (1) inventory and land survey study along the Klang River under the territory of the Klang Municipal Council, (2) proposed land used according to the Local Plan of Klang 2015, and (3) current data and information from the relevant agency or department. However, the data collected from the questionnaire presented the top three most important aspects to improve in the transformation of the Klang River at each village (Fig. 3).

During the data analysis, some villages were grouped and interpreted together as they had close distance and high similarity results. Based on the government's analysis report, the government concluded the potential development of Klang areas that are close to each other. Besides that, the questionnaire results revealed that those villages had a very similar selection of the top three aspects to improve in the river transformation project. Therefore, a joint display comparison data, from qualitative and quantitative, were tabulated according to villages (Table 3). Based on the interpretation, the most appropriate strategy had been developed to improve each aspect in the transformation of the Klang River.

4.2.1 Strategy to Improve Flood Protection

Kampung Sungai Sireh, Kampung Delek, and Kampung Sungai Bertek chose flood protection as the top three aspects to be improved. These areas were surrounded by a mangrove forest along the Klang River. According to the government's analysis report, the mangrove forest along these three villages should be well preserved. By considering the preservation of the mangrove forest, Low Impact Development (LID) is an ideal solution to improve flood protection. Low Impact Development (LID) is an ecologically based flood management approach choosing soft engineering to manage

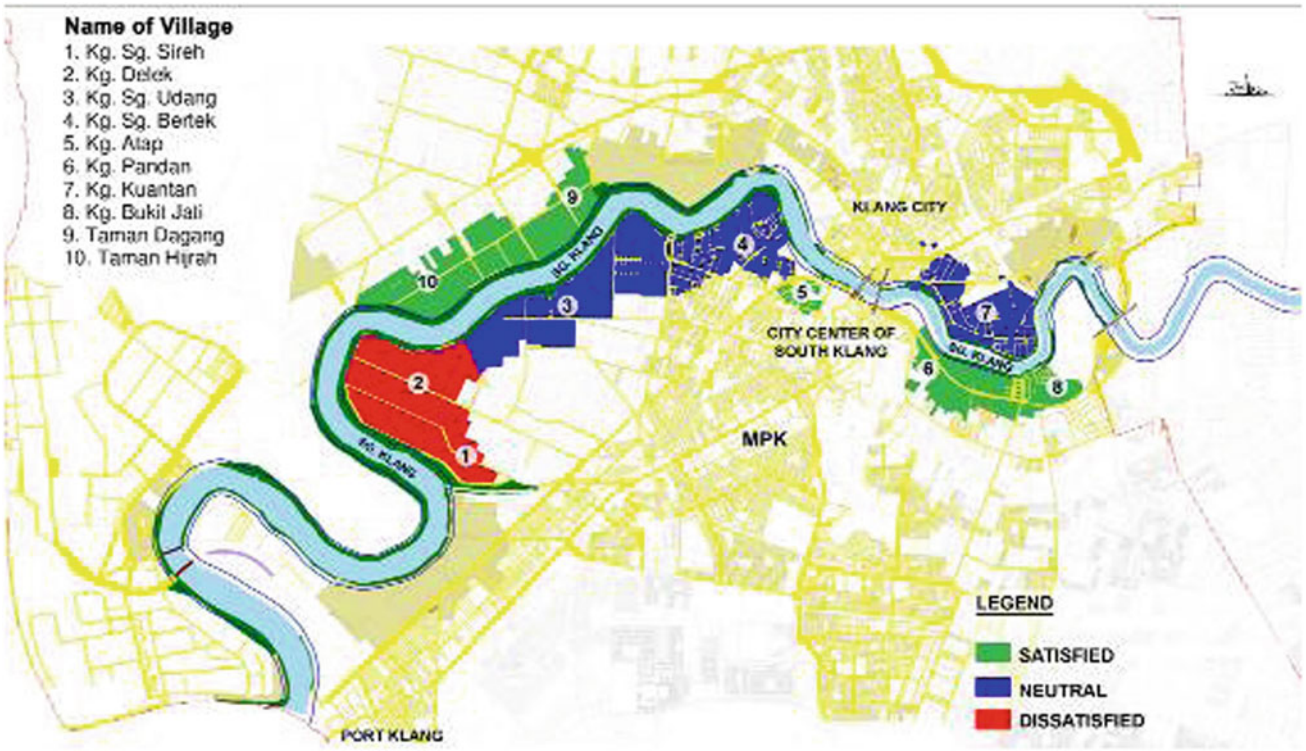

Fig. 2 Satisfaction level of flooding protection for villages

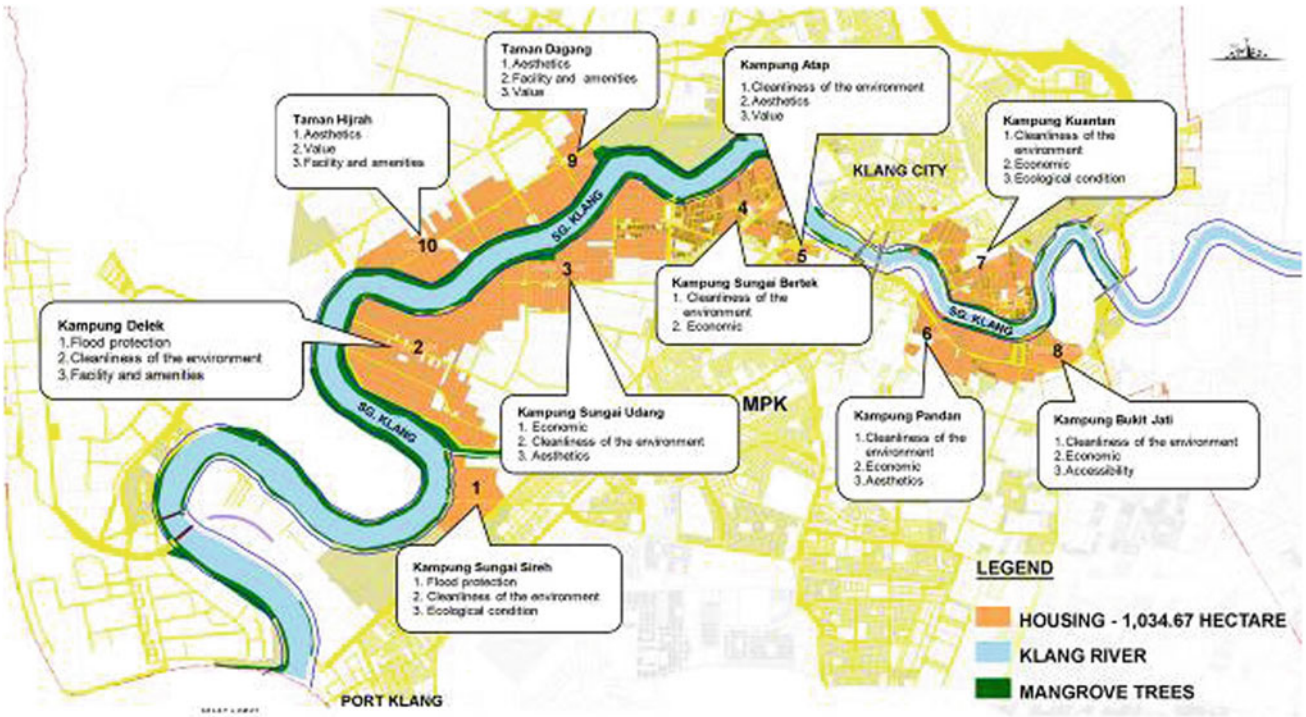

Fig. 3 Top three most important aspects to be improved for each village

Table 3 Comparative analysis of quantitative and qualitative data

Villages	Qualitative data	Quantitative data
Kampung Sungai Sireh and Kampung Delek	• Potential to promote local food and village cultures such as beverage made from sugarcane, traditional dance, and cultural show • Mangrove forest must be well preserved and has potential for R&D and to develop eco-tourism	***Kampung Sungai Sireh*** 1. Flood protection 2. Cleanliness of the environment 3. Ecological condition ***Kampung Delek*** 1. Flood protection 2. Cleanliness of the environment 3. Facility and amenities
Kampung Sungai Udang and Kampung Sungai Bertek	• Cultural and eco-tourism zone through activities such as cultural, homestay, and food • Product of small and medium enterprises (SME) to boost the economy of residents	***Kampung Sungai Udang*** 1. Economy 2. Cleanliness of the environment 3. Aesthetics ***Kampung Sungai Bertek*** 1. Cleanliness of the environment 2. Economy 3. Flood protection
Kampung Atap	• Heritage and historical zone, "Little Indian", "Klang Royal Palace" and "Royal Gallery" • Commercial centre, residential, hospitality, tourism, recreation, and public transport • Maintain Pengkalan Batu Park and promote the concept of "Linear Park City" • It is seen as a positive alternative to integration as it is located near to the city centre	1. Cleanliness of the environment 2. Aesthetics 3. Value
Kampung Pandan and Kampung Bukit Jati	• It has the potential to redevelop as it has a vacant land owned by the government • Is suitable to become a tourism place	***Kampung Pandan*** 1. Cleanliness of the environment 2. Economy 3. Aesthetics ***Kampung Bukit Jati*** 1. Cleanliness of the environment 2. Economy 3. Accessibility
Kampung Kuantan	• Is located near to Klang City Center • Has the potential to become a heritage and tourism zone	***Kampung Kuantan*** 1. Cleanliness of the environment 2. Economy 3. Ecological condition
Taman Dagang and Taman Hijrah	• Reserves mangrove forest • Has the potential to develop into an R&D and eco-tourism	***Taman Dagang*** 1. Aesthetics 2. Facility and amenities 3. Value ***Taman Hijrah*** 1. Aesthetics 2. Value of place 3. Facility and amenities

rainfall on-site through a vegetated treatment system (UACDC 2010). In this research, two examples of LID models can be implemented for flood protection in the transformation of Klang River in Klang District. A stormwater treatment park was proposed to be located at Kampung Sungai Sireh as it has a vacant open space in the housing area and it is far away from the recreational park. The LID block design model was proposed for Kampung

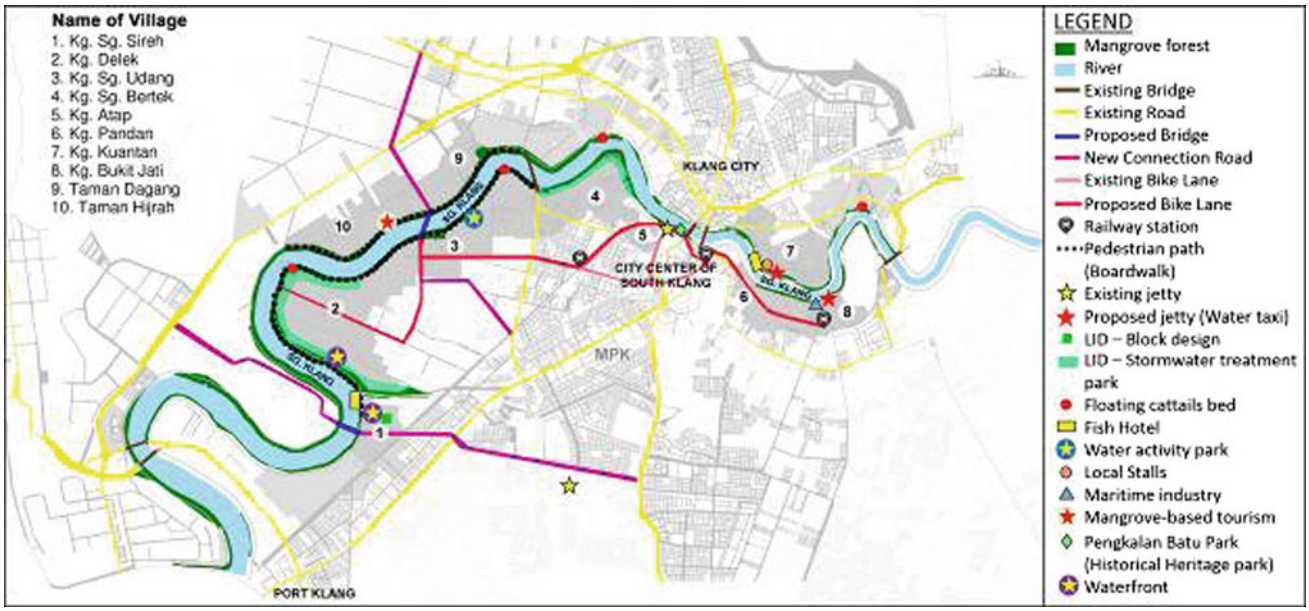

Fig. 4 Map of the proposed strategies to improve residents' satisfaction of Klang River transformation

Delek and Kampung Sungai Bertek. They lacked open spaces and had higher density development. Therefore, the block design model could be utilised to integrate the shared conservation areas with the property through LID easements.

4.2.2 Strategy to Improve the Cleanliness of the Environment

Environment cleanliness was ranked as the top or second most imperative aspect by most of the villages. Through the interview with the government officers, lack of awareness of residents was the main factor that caused the environment to be dirty. Respondents understood the need to take care of the environment but nobody really took action. Thus, success factors generally need strong cooperation among public administrations and other stakeholders, raising support and creating public awareness. Awareness of cleanliness can be raised through education and by creating more opportunities for community access to the river. Besides that, the government should enforce environmental laws especially at Kampung Kuantan because illegal factories caused the pollution and it was upstream of the Klang River in the Klang district. The government should make sure every factory has installed qualified waste treatment equipment. This can reduce river pollution from factories.

Conservation on the cleanliness of river water by nature was a great alternative. There's no doubt to use natural cattails to eliminate the excess phosphorous and nitrogen from rivers. However, planting cattail rooted in the soil of the river is not a good idea as the water level was deep and it may affect the local ecosystem if it grew uncontrollably. In this case, a floating cattail bed is the most effective and suitable method. Figure 4 illustrates there were four points proposed to install a floating cattails bed to eliminate the excess phosphorous and nitrogen from the Klang River. The floating cattails beds were proposed to be located at the riverside of the curve stream where the speed of the water stream is relatively slow.

4.2.3 Strategy to Improve the Ecological Condition

Results demonstrated that residents who are residing in Kampung Sungai Sireh and Kampung Kuantan were more concerned about the ecological aspect. A fish hotel, an idea used in Chicago Riverwalk for ecological enhancement, could be a good idea to be implemented along the Klang River. It was a project by Friends of the Chicago River to rehabilitate the river into a more vibrant ecosystem (Dahlman 2008). The fish hotel does not require hard engineering work. Thus, it will not affect the landscape of the environment. Figure 4 showed that fish hotels can be installed at the existing jetty at Kampung Sungai Sireh and proposed jetty at Kampung Kuantan. By setting up fish hotels, it can help to cultivate small fishes and increase aquatic life in the river.

4.2.4 Strategy to Improve the Economy

Many respondents chose economy as one of the top three important aspects. They hope that the government can create more business opportunities for them. The strategy to improve the economy of Kampung Sungai Udang and Kampung Bertek was to provide sport recreation activities. Sport recreation activities were conducted as special interest tourism. These activities can be set up at the existing fisherman jetty at Kampung Sungai Udang without the needed

large-scale or even greatly expensive development of facilities and infrastructure. For instance, the jetty can transform into a water activity park where local people and tourists can seek some water activities similar to Taft River in the Philippines which introduced kayaking and paddleboarding (Amazona 2018). Respondents generally look for new experiences which can be obtained from the sport, culture, and adventure activities in the field of nature.

Kampung Pandan and Kampung Bukit Jati are suitable to be developed with the concept of the "Maritime Industry" where the vacant land is owned by the government, and there were necessities to enhance accessibility between Southern Klang and Northern Klang. Water taxi that takes commuters across the Klang River could be a good alternative for this concept. Kampung Pandan and Kampung Bukit Jati which are located at the right end of the Klang River bank are also strategic to support the "Maritime Industry" concept, for example, organising workshop repairing boats or an individual yacht terminal. Besides that, villages can also develop market stalls similar to Chatuchak Market in Bangkok for economic growth. This strategy not only could boost the economy, subsequently, the place but also create a more vibrant place. Hence, local market stalls that are selling clothes, bags or shoes and food stalls, can be set up near the proposed jetty at Kampung Kuantan.

4.2.5 Strategy to Improve Value and Aesthetic

Klang owned a valuable history contextually and a big mangrove forest zone that surrounds along Klang River. Mangroves are one of the potential sites for sustainable tourism development at Taman Dagang and Taman Hijrah. Moreover, this development was supported with the concept of government—"Conservation and Preservation". Therefore, mangrove-based definitely could be a naturally friendly attraction spot for tourism and also stimulate the community involvement. Besides, economic growth could inspire research and development (R&D) from researchers like educational ecotourism programs in the Bedul area at Alas Purwo, Indonesia (Hakim et al. 2017). Whereas, Kampung Atap can presenting the same concept as Eager Park in East Baltimore, a successive recreation park that located in historical zone (Barber 2018). Kampung Atap had a good geographical location where it was near to the historical tourism zone together with some symbolic places in Klang. Furthermore, it was the place where Pengkalan Batu Park was located. Therefore, the value of the river and area could be enhanced by maintaining Pengkalan Batu Park and integrating Kampung Atap into the heritage and historical tourism zone. Pengkalan Batu Park can be maintained and developed as a "linear park city" by redeveloping abandoned historical shops and existing open spaces . With all these strengths and opportunities, Kampung Atap is feasible to develop with the concept of "Tourism and Recreation". In short, the historical contextual mangrove forest and the recreational park (Pangkalan Batu Park) are beneficial features in boosting the village value and the aesthetic in terms of architecture and landscape design.

4.2.6 Strategy to Improve Accessibility

Kampung Bukit Jati was the only village that selected "accessibility" as its top three (3) most concerned aspects. A strategy was proposed to enhance this aspect focused on the people's mobility and the ways the public exploit the river with the city. To enhance mobility , two bridges were proposed at mid-stream of Klang River where the bridges were built at the upstream and downstream parts of Klang River in Klang. Besides that, it was discovered that residents faced difficulty reaching the riverbank from their homes. Hence, a pedestrian path of the boardwalk was proposed to be constructed along Klang River. Simultaneously, many mangrove plants were found planted at the riverbank which had the potential to develop eco-tourism. This boardwalk could bring people close to nature.

There were many cultural, heritage, and historical buildings surrounding Klang River with 1 km distance from it. Hence, the idea to construct the bike lane lines was proposed. This idea can promote Klang as a City of Heritage for tourism attraction as well as ease people to reach the tourism area. In addition, the usage of public transport could be maximised where people can travel by bus or commute to the attractive spots, simultaneously accessing the river. Chan (2010) mentioned that transport services such as *sampan*, boat, and ferry services were available at Kuching, Sarawak. In this research, water taxi service is suggested as an alternative transportation mode to cross the river where jetties were available along Klang River. Figure 4 indicated the overall connectivity of Klang after adding the proposed bridge, pedestrian path, bike lane, and water taxi.

4.2.7 Strategy to Improve Facilities and Amenities

From the data collected, Kampung Delek had ranked "facilities and amenities" as one of its top priorities in the transformation of Klang River. From Fig. 4, the nearest recreational park was Taman Panglima Batu but the location caused inconvenience for residents to access this park. Hence, it was proved that there was a necessity to enhance the facilities and amenities of this village. In terms of facility and amenity necessity consideration, this research discovered that there were animal farms and fisheries available in Kampung Sungai Sireh and Kampung Delek, respectively, and a mangrove forest surrounded nearby Taman Hijrah and Taman Dagang. Furthermore, Kampung Sungai Sireh and Kampung Delek revealed the potential to be developed as eco-tourism that could promote local food and village culture in the government's analysis report. Thus, the

Table 4 Summary of strategies to improve transformation of Klang River

Aspect	Villages ranked as top 3 aspects	Strategies of improvement (proposed location)
Flood protection	• Kg. Sungai Sireh • Kg. Delek • Kg. Sungai Bertek	– **LID—Block Design** (Kg. Sungai Sireh) – **LID—Stormwater Treatment Parks** (Kg. Delek and Kg. Bertek)
Cleanliness of the environment	• All villages except Tmn. Hijrah and Tmn. Dagang	– **Raising awareness of cleanliness** (All villages) – **Installing floating cattail bed** (Kg. Delek, Kg. Sungai Udang, opposite Kg. Sungai Bertek) – **Enforcing environment law** (Kg. Kuantan)
Ecological condition	• Kg. Sungai Sireh • Kg. Kuantan	– **Fish hotel** (Kg. Sungai Sireh & Kg. Kuantan)
Economy	• Kg. Sungai Udang • Kg. Sungai Bertek • Kg. Pandan • Kg. Bukit Jati • Kg. Kuantan	– **Water activity park** (Kg. Sungai Udang & Kg. Sungai Bertek) – **Maritime industry** (Kg. Pandan & Kg. Bukit Jati) – **Local market stalls** (Kg. Kuantan)
Value and aesthetics	• Tmn. Hijrah • Tmn. Dagang • Kg. Atap	– **Mangrove-based tourism** (Tmn. Hijrah & Tmn. Dagang) – **Historical heritage park** (Kampung Atap)
Accessibility	• Kg. Bukit Jati	– **Bridge** – **Pedestrian path** – **Bike lane** – **Water taxi**
Facility and amenities	• Kg. Delek • Tmn. Hijrah • Tmn. Dagang	– **Waterfront** (Kg. Delek)

integration of both the strength of the village with the ecological theme should be carried out. Waterfront can be considered as a fishing platform, and open spaces for performances and recreational activities for residents. This waterfront concept is able to expand mangrove-based tourism with broadwalk and canoeing services in Taman Hijrah and Taman Dagang besides developing eco-tourism at Kampung Sungai Sireh and Kampung Delek. This development was proposed as shown in Fig. 4.

5 Conclusion

It could be concluded that the transformation of Klang River for these 9 years still needs more effort to accomplish the goal and missions. Based on the results, the majority of the respondents didn't notice Klang River which had become a better place for them to visit, and consequently no improvement in the frequency of visits after the change. From the study, the result revealed that the majority of respondents were dissatisfied with the transformation of Klang River, especially the water quality, recreational use at Pengkalan Batu Park in the aspect of accessibility, cleanliness, value, facilities and amenities. For the water quality, "odour", and "colour" of the river were the most dissatisfied criteria because of their very strong odour and filthy water appearance during the ebb tide period. For the aspect of recreational use, 10 out of 27 indicators were in the "dissatisfied" category which included accessibility of public transport, cleanliness of toilet and park, educational, historical and cultural value, availability of public toilet, direction boards, street lights, and shades. After the restoration of the Klang River, flood protection was enhanced indicating only two villages' residents were dissatisfied with flood protection due to the recent flooding in their villages. Lastly, appropriate strategies had been developed in the transformation project to fulfil the perception and expectations of the government and residents along the Klang River. The overall proposed strategies can be referred to Fig. 4 and Table 4. Besides that, challenges faced in the river restoration project were studied. The budget was the main problem that caused the project unable to be implemented smoothly. Moreover, local government also faced internal and external problems where it is troublesome in seeking cooperation from other local governments at upstream areas of the Klang River and lacking communication and interaction with the public. Through this research, the government was able to have a better understanding of residents' needs with a set of proposed strategies as a reference for continual transformation and development of the Klang River into a better place for the public.

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Are the New Towns Really Smart?

Giuseppe Marino and Lorenzo Massimiano

Abstract

In the twenty-first century, a lot of New Towns projects have been announced, due to the increase of the world population and its relocation in urban centres. This phenomenon has made it possible to conceive new approaches to urban planning, many of them related to smarter and eco-sustainable strategies. Today, the list of brand new towns is wide. We can consider them as examples—more or less concrete—of the current state of the art on these issues. The paper wants to speculate on these questions by dealing in the first part with the phenomenon of New Towns, focusing above all on those that claim to be "Smart Cities". In the second part, we will analyse in depth a case study that embraces both the concepts of *New Towns* and *Smart Cities*: *Masdar City* in the United Arab Emirates. As we argue at the end of the paper, the concrete development of Masdar City has not brought the expected results. Nevertheless, we can look to Masdar City as an interesting case study that adds an extra piece to the construction of the smart city of the future, an experiment that served to push the boundaries of research on these issues further.

Keywords

New Towns • Smart cities • Environmental sustainability

1 Introduction

It can be a difficult and controversial operation to give an exhaustive definition of what a New Town can be as evidenced by the different positions and visions taken by the scholars in this field. For Ervin Galantay, New Towns are "planned communities consciously created in response to clearly stated objectives" (Galantay 1975); for Pierre Merlin and Françoise Choay, a New Town is "a planned city whose creation was decided by administrative means" (Merlin and Choay 1988); in Piero Pierotti's words, "A city problem exists when the creation of a new settlement has the exclusive or predominant purpose of establishing a new urban organism, conceived in its specific constructive and functional articulations"; and finally, Bernardo Secchi writes, "Probably at the origin of every city there is an act of foundation, most often unaware of its own destiny". The creation of a city as an act of will presupposes the existence of an authority or organization sufficiently effective to protect the site, to introduce resources for its development, to exercise control until the city reaches vital dimensions. The New Towns also have an identifiable date of birth, which may be the day of the designation of their site or the day of a formal foundation act that establishes the legal existence of the new community. The "idea" of the city is formalized in a project drawn up before the site which is modified by the arrival of the first new residents. A design response that responds to very well-defined temporal needs leads to bringing together many of the new cities regardless of the historical moment to which they are linked and in this regard a definition that well summarizes this aspect is the one proposed by Rachel Keeton: "New Towns are cities or towns that are designed from scratch and built in a short period of time. They are designed by professionals according to a Master Plan on a site where there was no city before. This distinguishes New Town from a "normal" city that gradually grows and evolves over time. Also, New Towns are the result of a political (top-down) decision. The building of a

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new city "from scratch" is a heroic enterprise that challenges the architect or planner to find the ideal shape for the urban planning according to the state-of-the-art planning ideas. A New Town is always a reflection of one moment in time and the ambitions of that moment. What does a "City of the Future" look like? Which are the main features that characterize this city? And which differentiate it from the cities of the past?

Historically, New Towns were built on the basis of a unitary project and often for political decisions such as, for example, that occurred for the cities of New Delhi and the new British cities of the twentieth century. Contemporary New Towns tend to have fluid boundaries, extremely variable dimensions and varying degrees of autonomy (INTI 2007). The demands of contemporary living, as well as global settlement strategies, lead to a redefinition of the reasons that drive governments to establish new cities. In the twentieth century, up until the seventies, the reasons that led to the need to build New Cities programs lay in not only progressive social development models, such as Garden City by Hebenezer Howard or in functionalist models (Ellis 2014), such as La Ville Radieuse of Le Corbusier, and utopias but also replicable city models. More often there were strategic needs such as creating new cities dedicated to trade (Jubail, Saudi Arabia); city for scientific and technological research (Irvine in the USA and Novokuznetsk in USSR); colonization, for example, of African countries by some European nations (Eritrea, Zaire, Morocco and Ethiopia); a need to give a capital to new states or redefine political geographies within the same countries (Brasilia in Brazil and New Delhi in India); and new cities dedicated to controlling urban and demographic growth (Great Britain, Sweden, France and the United States). The new contemporary cities gather much of these functional specificities, often hybridizing them.

1.1 The New Towns of the Twenty-First Century

The twenty-first century is characterized by an exponential and irreversible increase in the inhabitants of the planet, affecting lifestyles and urban environments. According to United Nations estimations (United Nations 2017), the world population will increase from the current 7.69 billion people to 9.7 billion in 2050 and 11.2 billion in 2100. 2050 represents the year in which it is assumed that Africa will see continued growth in its population as a contraction in Asia will begin. Moreover, if we consider the first 40 megalopolises in the world, most of them are in Asia and Africa, and about 24 in the least developed areas of the planet. Only two are in North America (New York and Los Angeles area), two in Japan (Tokyo and Osaka), and two in Europe (London and Paris). If in 2030 it is expected that 60% of the world population will live in the city, compared to the past, the phenomenon of growth in Asia and Africa takes on new and urgent characteristics, as well as accepting the needs of industrial and technological modernization. The mentioned numbers are inextricably linked to the transformations of the territory where the traditional tools of urban planning see the methodologies and the consequent technologies change, and in the cases in which the numbers presuppose new ways of living, a transformation occurs also in the idea of the city itself. The utopias of the early twentieth century, the modernist ones and the relative avant-gardes, hypothesized a sort of revolution in the way of living, with the idea of replacing the cities as we knew before. However, today there is a consolidation of the existing urban structures with the related long-term actions (Cities from scratch, 2009), making the new city models remain limited and historically circumscribed episodes.

New types of interdependence with the mother cities have been and still are the satellite cities, originally conceived to be dependent by a nucleus from which they were only a few kilometers away. Over time, many of them have often been incorporated and reached by urban expansion: the English New Towns, as well as the Swedish ones, are in fact self-sufficient and the reason for their birth depends above all on the need to control the phenomenon of the growth of large metropolitan areas. The new capitals, the colonial cities, were instead often actually built on substantially virgin territories. The contemporary New Towns, on the other hand, tend to be triggered in more structured contexts by making the border between a satellite city and consolidation of an existing nucleus more nuanced, where the greater complexity of structuring urban functions can be considered an index of the greater complexity of the new settlements (Mittner 2018). In some cases, the relationship between the old and the new nucleus has led to a distance extension relationship of the existing as we can see in Zhengdong district founded in 2003 and its original core Zhengzhou in China or New Songdo, founded in 1996, and the existing Incheon in South Korea or Tianjin Eco-City, founded in 2007, and its original Tianjin.

Particularly in China, where the overcrowding of the old towns required the rapid planning and construction of new cities, the phenomenon ended up incorporating and absorbing small villages and traditional cities (Shepard 2015). The new settlements, often separated by natural elements such as mountains and hills, were larger than the old towns from which they originated, thus creating a new relationship between past and present, as happened around Shanghai with some of the "One City Nine Towns" (Den Hartog 2010) (strategic plan of decentralization of Shanghai, started in 2001). The result is a hierarchical and polycentric system, structured in a complex way, in which they tried to create new identities as models of European cities on paper. Some

examples are Luodian, founded in 2010, inspired by the Scandinavian city model; Fengjing, founded in 2004, a North American model; Gaoqiao, founded in 2001 inspired by the Netherlands model; or the new Qingpu District, founded in 2002, related to the old core of Zhujiajiao.

2 The Eco-City Model and Smart Cities in Contemporary New Town

While some of the new contemporary cities are born with a hybrid connotation (the so-called mixed-use cities where there are no prevailing functions and no greater specificity is given), many others adopt the key themes of contemporary urban design literature often using the suffixes *Economic*, *Smart*, *Eco* and *Cyber* to identify the main vocation of the new city project in progress.

2.1 Ecological New Towns

"Eco" clearly refers to sustainability and the environment. Eco-city is a term used to identify urban development processes in which the principles of sustainable development are predominant. It is a common feeling that there is a need for cities that are more respectful of the environment, but what happens when the motto of eco-sustainability is applied to New Towns? There are many contemporary New Towns that adopt the Eco-City suffix in their same names such as Hacienda Eco-City (Kenya), Changchun Jingyue Ecological City (China), Tianjin Eco-City (Fig. 1, China), Dongtan Eco-City (China) and Caofeidian International Eco-City (China). Many of these mentioned "eco-cities" are thought in China not by chance, a country that has been suffering significant environmental damage to its territory due to the unbridled race of its development over the last 30 years. One of the ways used to remedy the damage in that country was to include a sustainable design on all scales, even though it was often a political proclamation: by observing the cities created with this intention, the results are often disappointing but this does not exclude that it is necessary to maintain this approach in wider urban projects. In fact, many of these ambitious eco-city projects are frequently disconnected from the territory in which they are located (Keeton 2011).

2.2 Smart New Towns

Starting from the visions by Francis Bacon with the hypothesis of a technological society as described in "New Atlantis" (1626), continuing with the visions of the Italian futurists about the city, as well as in the playful visions of Archigram's Walking City, designers and planners have been constantly pushed to design cities of the future.

Among the most recent concrete examples as a development strategy focused on the use of IT (Information Technology), we can mention the Technopolis program in Japan to promote the Hi-Tech industries, started in the early 1980s and ended in 1998. In that context, some new cities were created by the Ministry of Trade and International Industry (MITI), combining industrial parks with high technology with research institutes. Similarly, in China in the 1980s, Special Economic Zones (SEZ) were introduced, a model replicated later in various other countries, including India in 2000 (Bonino et al. 2019).

In some cases the smart technological paradigm approaches the need to diversify a prevailing economy as in the case of King Abdullah Economic City (Saudi Arabia) or Binh Duong (Vietnam), which is part of a project called *Binh Duong Urban Service Urban and Industrial Complex* which aims to become the most advanced technological centre in the country, providing the basis for a model that can be replicated at different scales.

The Smart and Cyber suffixes presuppose a vision of the city that improves everyday life by increasing technological standards, for example, with low energy consumption

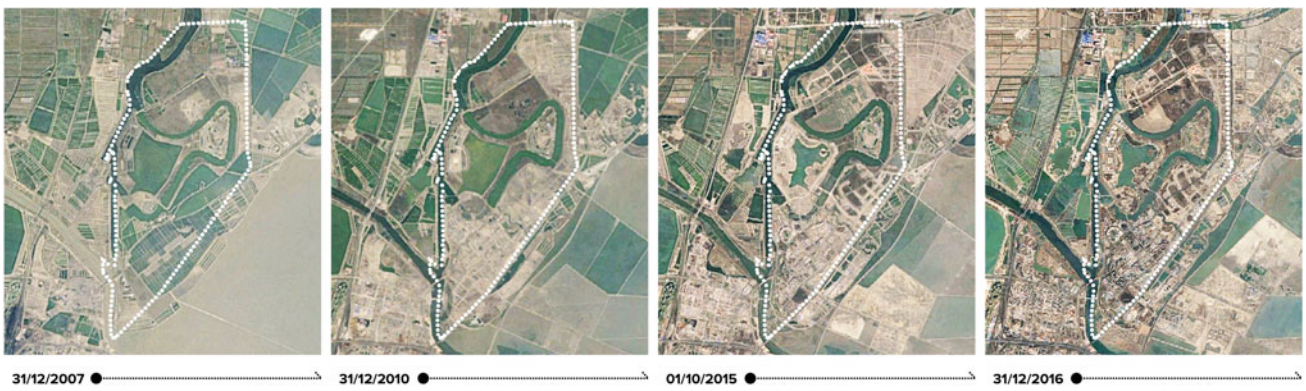

Fig. 1 Tianjin Eco-City, satellite view, evolution from the foundation in 2007–2016, image of the author

targets, optimized transport infrastructure networks, broadband networks for residences, facilities and businesses along with economical progress. Therefore, technological rhetoric is combined with technological settlements according to the growing awareness that the boundary between technology and environmental awareness is increasingly blurred. Among the most extreme examples of this phenomenon, we can also include the "U-Cities" of South Korea, Hwaseong-Dongtan U-City, Future-X and Busan City which aim to provide an example of how cities could look in the future.

New Songdo City (founded in 1996) (Fig. 2), located at the gates of Incheon, is a city that originates mainly from the private initiative and follows the SEZ strategy model integrating research and IT sectors, using specialized tax incentives and simplified licences to attract foreign investors (Ooosterma et al. 2012). The city embraces the competitive technological culture of South Korea and was one of the first in which residential, medical and corporate information systems are integrated into the network thus forming a system of total connection: in this city, citizens can thus manage and control their homes and offices from anywhere in the city. Many of these technologies are linked to personal communication and allow the inhabitants to live the rather dubious dream of "total connectivity". If we look at the design of the grid of the urban streets, it does not seem to be an innovative formal model: the urban fabric of Songdo is based on famous urban elements of previous centuries. A revisited Central Park, Savannah neighbourhood squares and a Venice-inspired canal system all appear on the city plan.

Cyberjaya was founded in 1997 under the initiative of the Malaysian Ministry of Finance and is located 50 km south of Kuala Lumpur, in Malaysia. Cyberjaya is called "the smart city of Malaysia". The city is home to some of the country's largest universities, research and development institutes, government agencies and various multimedia industries. The city aspired to become the "Silicon Valley of the East" but the financial crisis of the early 2000s slowed its development process.

What identifies the new smart cities, the vanguard proclamations and the visions on the future of a high technological infrastructure offer us the opportunity to verify how much the technology, so strongly integrated in every component of the city, from the walls to the streets, can resist the evolution of technology itself, risking instead to

Fig. 2 New Songdo City. *Source* https://pxhere.com/en/photo/398710

Fig. 3 Dimensional comparison of some contemporary New Towns: Masdar City, Saadiyat Island, Cyberjaya, King Abdullah Economic City, Naypyidaw

accelerate the process of obsolescence of the city: A paradox that drives these new cities to always be at the forefront in order to compete in the global scenario.

We see how the population increase is leading to the birth of new towns to satisfy the growing demand for space in our cities. Most of these projects strive to make the most of the potential offered by contemporary technological innovations in order to achieve better performance. The spread of digital technology, thanks to its increasingly low cost, has allowed us to accumulate a quantity of data from the city that was unthinkable up until a few decades ago. This allows us to acquire an ever greater knowledge of the territories in which we live. So now we are in the phase of imagining how to exploit this potential to improve the quality of life of citizens, increase the competitiveness of cities and optimize the use of resources and energy. Masdar City is just one of the examples of a "new town" where all this is being attempted (Fig. 3).

3 The Case Study of Masdar City

The announcement of the birth of Masdar City was launched in 2007, with the promise of quickly becoming one of the most sustainable cities on the planet (Masdar 2018a). The idea of building a new city was born from the desire to increase the Masdar Initiative's portfolio, one of the companies owned by Mubadala, which is the investment company of the government of Abu Dhabi focused on renewable energy. The main objectives of Masdar Initiative are mainly four, and it is useful to list them to understand many of the choices made for this project. They can be summarized as follows: (1) to diversify the economy of Abu Dhabi, until then largely focused on the export of fossil fuel and therefore destined to become extinct; (2) to maintain and subsequently expand the position of Abu Dhabi in the global market of energy; (3) to make the UAE a leader in the export of clean technologies; 4) to give a contribution to sustainable development in the world (Embassy of EAU 2010). This is therefore the humus from which the idea of the new city is born. The task of transforming it into a real masterplan was entrusted to the architectural firm Foster + Partners, recognized as one of the best in the world precisely because of its ability to create highly eco-friendly projects. The cost of the project has been estimated at between 15 and 30 billion dollars and consists of a vision of the city that combines environmental sustainability, innovative technologies and sensitivity to local tradition. From the beginning, the masterplan adhered to the principles of One Planet Living (Bioregional, 2018), a chart written by Bio Regional and World Wide Fund for Nature (WWF) to build an effective action plan in favour of environmental sustainability and people's well-being (Jensen 2014). But how were these goals transformed into the Masdar City plan? First of all, it is fundamental to define the geographical area in which the project is located: Masdar City is located in the southern part of the Persian Gulf, 30 km from the centre of Abu Dhabi and 140 km from Dubai, in the heart of the Arab Emirates. Given its location, the city is characterized by a typical desert climate, predominantly hot and dry throughout the year, with temperatures that can touch extreme peaks during the hot season. The site on which the intervention is located

has an area of 6 square kilometres, within which the part for construction is distributed according to the following proportions: 62% of the surface is for residential use, 10% for the common services, 10% for companies, 4% for shops, 7% for research and development centres, 4% for light industries and 3% for receptive buildings (Masdar 2018b). According to the estimates of the promoters, the city will be completed in 2030 and will host 50,000 residents plus 40,000 commuters, including professionals and temporary students. To welcome them, there will be buildings with high energy performance that meet very strict construction criteria. Each of them, in fact, uses low carbon cement, as well as 90% recycled aluminium and is designed to reduce energy and water consumption by at least 40%. These standards derive from compliance with the LEED parameters (Leadership in Energy and Environmental Design) and Estidama, an evaluation system recently developed by the same Abu Dhabi Urban Planning Council specifically for those projects that are located in arid and desert areas such as this. By adhering to these protocols, all buildings can have high energy efficiency, as well as a low ecological footprint, both during construction and afterwards. The buildings are then equipped with sensors through an Internet of Things (IOT) system which, on the one hand, serves to manage the home automation systems that regulate the climate inside the structures and, on the other hand, allows the city to become a "real-time" laboratory, through which to monitor the behaviour of the urban organism. The Masdar Institute of Science and Technology (Fig. 4) is an example of a building of this type. It hosts the first independent university dedicated entirely to the challenges of environmental sustainability, currently involved in experimental research together with the prestigious Massachusetts Institute of Technology in Boston. The presence of the MIST in Masdar City is central also from an economical point of view. As exposed by the informative materials that promote the project, Masdar City was born with the intent to be a hub where companies that deal with technologies related to sustainable development can find the most favourable conditions to establish their research centres, develop their ideas, and then implement and test them on the city. The advantage that derives from such a model is mutual, since on the one hand, the city periodically obtains the latest generation technological equipment, which ensures that the city is always at the forefront in terms of "smartness", and on the other hand, it allows companies to make use of the city as a test field, transforming it at the same time into a 1: 1 scale showroom, always open.

The theme of environmental sustainability clearly does not focus only on the scale of buildings but has also been applied to the entire urban layout. To try to reach the ambitious goals requested by the Masdar City promoters, Foster + Partners has devised an action strategy based on wide exploitation of passive methods of climate control—

Fig. 4 The Masdar Institute of Technology. *Source* https://www.flickr.com/photos/rimcreation/26401733803/in/photostream/

some of which result from the construction tradition of that geographical area—then enhanced in performance, thanks to the implementation of "green" technologies. They therefore started from the orientation—north-east/south-west—to obtain the optimal exposure at these latitudes: this means to have maximum shading during the day and at the same time favour the movement of air, thus lowering the temperature of the city in a natural way. The city layout, then, takes up the classic orthogonal grid system, considered the most performing from the organization's point of view; however, it has been declined in a more free and articulated way, in order to overcome the rigid scheme of Abu Dhabi. It is useful to recall here the analysis that Kherdeen does on the urban form of Masdar City, suggesting a reading that distinguishes between *physical form* and *functional form* (Kherdeen 2016); as for the first, the current masterplan's road system uses the following hierarchy: at the highest level there are the "boulevards", large arteries that surround the city and cross it in its centre; then there are the "avenues", intermediate roads that distribute the flows in a capillary way, forming a loop inside the urban perimeter; and finally the "alleyways", narrow and pedestrian streets that delineate the different blocks of buildings (see Fig. 5). The blocks have been conceived in a homogeneous but variable way, according to the number of buildings that compose them, as well as the way in which they are aggregated; all of them, however, have a constant element, the internal courtyard, according to the model used by Cerdà for the city of Barcelona. Two large green corridors cross the city longitudinally, creating two linear parks; the choice of the narrow and long shape for these spaces is not accidental: their proportions are chosen so as to generate corridors that serve to channel the wind and to avoid having too large open spaces. Regarding the *functional form,* the original masterplan envisaged a mix of functions that should have ensured a reduction in travel within the city and a constant activity throughout the entire 24-hour period. However, commercial choices have led to a concentration of offices and shops in the city centre (a sort of downtown) and to place the residential area at the edges. Certainly a makeshift choice, which if on the one hand supports the lifestyle of the locals—who are used to always moving with their own car—on the other hand could lead to generating sprawl and traffic congestion in the long run. On this last issue, great attention has been paid by the designers, with the aim of providing a sustainable type of mobility. In this regard, it is useful to report a definition of sustainable transport system: "A sustainable transportation system is one that: allows the basic access

Fig. 5 Masdar City Masterplan. *Source* https://www.flickr.com/photos/eager/5122240951/in/photostream/

needs of individuals and societies to be met safely and in a manner consistent with human and ecosystem health, and with equity within and between generations; is affordable, operates efficiently, offers choice of transport mode, and supports a vibrant economy; and limits emissions and waste within the planet's ability to absorb them, minimizes consumption of non-renewable resources, limits consumption of renewable resources to the sustainable yield level, reuses and recycles its components, and minimizes the use of land and the production of noise" (Geurs and Adams 1999). The Foster + Partners studio has therefore designed a diversified system of "low carbon" transport vehicles with which to completely replace the use of private vehicles: personal rapid transit, electric buses, Metroline, Light Rail Transit and Group Rapid Transit are the ways to move within Masdar City. However, it must be said that currently only the personal rapid transit, which connects the city with the airport, is in operation.

A hierarchy regulates its use: large public transport vehicles have the task of serving the connecting routes between the cities around Masdar City; the personal rapid transit, on the other hand—consisting of a single cabin reserved for a few passengers—should be the main mean of transport to circulate within the city, through a network that includes 74 stations. Its peculiarity is to customize the routes, directly selecting the stops to be made and thus avoiding unnecessary stops. Once you leave the personal rapid transit, you are pushed to move on foot: public spaces, shops, offices, greenery and transport stops are distributed at a maximum distance of 150 m from any point of the city, thus favouring journeys on foot. According to the initial project, the whole city had to lay on a base about 7 m high, which had the dual function of capturing desert breezes, cooling the temperature of the ground above, and at the same time hosting the circulation of the various means of transport, without cross pedestrian flows: an idea that has illustrious precedents, including the "vertical city" of Hilberseimer and before that, in the Renaissance, the ideal city of Leonardo da Vinci. Norman Foster said in this regard, "Disneyland is attractive because all services are located below ground level. We did the same here; it is literally a walled city. Traditional cars are stopped at the edges" (Ouroussof 2010). Another key issue is energy supply. The energy consumed by the city comes largely from the solar power plant located in the peripheral area, which is capable of producing up to 10 MW of clean energy, while 1 MW comes from the solar panel system distributed over the buildings. According to the estimates reported in the dossiers produced by the company, the plant is able to produce 17,500 MWh per year by diverting 7,350 tons of CO_2 emissions each year. The energy produced by the sun therefore constitutes 80% of the total, while the rest is drawn from the wind and from the conversion of waste material. In addition to this, there are also heat pumps for cooling and in the future, they want to build a hydrogen plant to help sustain and diversify the energy sources. The goal is to get 100% of the energy from renewable sources, even if it has recently been considerably reduced. Given the geographical position of the city and its desert climate, water is considered a very valuable asset and therefore great efforts have been made to manage it efficiently and sustainably. Masdar City acquires all the water it consumes through a desalination plant located on the outskirts of the city, also powered by solar energy. The water network, then, is designed to reduce water consumption by 60% and to recycle 80% of the water used, putting it back into circulation for domestic use or for irrigation (Masdar 2018c). As we said at the beginning, Masdar City tries to combine not only environmental sustainability, technologies, but also local tradition; the Foster + Partners studio, before starting with the design of the masterplan, has in fact conducted an in-depth study of the vernacular architecture of this region, in order to combine new technologies with indigenous forms and construction methods. As Foster himself admits: "With Masdar we began by looking at the regional vernacular—the 'architecture without architects' that existed historically—and then aimed to build for zero carbon and zero waste, with the least amount of embodied energy" (Jenkins 2008). The shape of Masdar City therefore reproduces the characteristics of Arab cities, drawing on their ability to control the climate in a passive manner: narrow streets to promote the shading and channelling the winds, compact buildings with high population density, internal courtyards, porches outside the buildings to allow walking in the shade, a mix of functions, short distances, and the characteristic towers of the wind—modern reinterpretations of those that were once built in these regions (Ibrahim 2015). Also construcion details were build according to decorative geometric motifs of Arab architecture: to shield the windows of one of the residential buildings of Masdar City, in fact, a contemporary version of the "mashrabiya" was used, a sort of perforated bay window, here made with reinforced concrete and sand to respect the environment and requires little maintenance. The geometric motifs were created by the artist Jean-Marc Castera, while the undulating shape is the work of Foster + Partners engineers and has the task of capturing air currents and shading the levels below.

3.1 Ten Years Later: The Real City

In the prevoious paragraphs we have seen what were the main principles behind Masdar City; subsequently, we focused to describe how these same principles were translated into a masterplan by Foster + Partners; thus, the question is: how much of the initial vision has actually been

achieved? First of all, we can affirm that the starting project has changed substantially over the years, especially after the economic crisis of 2008, when many projects born in the Arab Emirates were reduced or cancelled. At first, the city went from being "zero carbon" to "carbon neutral", which means that it went from not producing CO_2 at all to compensating for its consumption in other ways. And the same happened for the claim "zero waste". However, today the label has changed again, and Masdar City is considered as a "low carbon" city, meaning that it actually consumes CO_2 like all other cities, but in smaller quantities (Kherdeen 2016: 47). The same happens for the energy supply issue, which—according to the initial project—had to be completely independent and coming from renewable sources, but it was insufficient and therefore it was necessary to resort to keeping energy from outside and also from fossil fuels. Mobility also had to undergo a substantial change: the personal rapid transit, which originally had to serve the whole city, was limited to only 10% of it, and cars, initially banned completely, were gradually reintroduced. To be more precise, in the first version of the masterplan, the city was completely walkable, to reduce traffic problems and to promote a healthy lifestyle and a safer environment; in a second version, however, cars were also allowed, provided they were totally electric; currently, however, waiting for this technology to spread, also normal cars have been allowed to enter Masdar City, thus favouring the widespread behaviour of using private vehicles for each trip. Another change concerns the stratification of the city on two levels: in the first masterplan, the surface of the city was left completely free of transport, placing all the vehicles below the floor. But even this idea of raising the city has been abandoned for a single surface with mixed flows. Therefore, to date, less than 10% of the masterplan has been built and only a hundred people live there, shifting the completion date to 2030 (Cugurullo 2016). According to the company, around 35% of Masdar City is expected to be completed in the next 5 years, and the next 30% has already been commissioned; it will include the development of houses, schools, offices, hotels, mosques, along with new places of leisure such as parks, cafes, restaurants and shops (Masdar 2018a). Therefore, visiting Masdar City today, what we would see would be the skyline of buildings related to the research and sale of technologies (such as Siemens Middle East Headquarters, Irena Headquarters, Incubator Building, as well as the library, residences and laboratories of the MIST), several cafes and restaurants for those who work there and a much reduced version of the personal rapid transit. As regards the results obtained from the point of view of environmental sustainability, they have been evaluated by a research group of MIST and are shown in Table 1 (Mezher et al. 2016).

3.2 Conclusion: Is Masdar a City?

To draw some conclusions about the new town of Masdar City, we must admit that very little has been saved from the first project. The initial idea of an eco-sustainable city has gradually been transformed into a more conventional project, strongly conditioned by the interests linked to high-tech products (Kherdeen 2016: 27). This view is confirmed by Cugurullo, which considers Masdar City a business venture designed to generate profit through a synergistic process of technological and urban development, in which the city is actually a showroom that never closes. This commercial drift is easily understandable considering the motives and the sponsors of this project. If we reread the four objectives of the Masdar Initiative Company reported at the beginning of the text, it is easy to understand that the assumption that originates, models and supports the whole Masdar City is to do business through green technologies, in order to diversify the economy of the region in view of the future time when oil stocks will run out (Cugurullo 2013). For these reasons, it is difficult to speak of Masdar City as a real city, since it lacks all

Table 1 Sustainability objectives achieved by Masdar City

Sustainability coal	Achievements to date
Energy demand reduction	• 51% less energy in residential units
	• 55% reduction in building external heat gain
Renewable energy	• Up to 30% of electricity provided by 1 MW rooftop solar PV
	• Built 10 MW solar PV farm
	• 75% of hot water provided by rooftop solar thermal collectors
Water demand reduction	54% less water consumption in residential units
Waste diverted from landfill	96% of construction waste reused or recycled
Reduction in embodied carbon in materials	Used low-carbon aluminium and concrete mixes in buildings, infrastructure
Intelligent transport system	PRT already in use to transport individuals from parking lot to Masdar Institute

those characteristics—both quantitative and qualitative—which make it recognizable as such. Masdar City can be considered an ambitious experiment to build a real eco-sustainable city, which unfortunately failed. The difficulties met in the creation of this project, however, must not erase the good things that have been put in place, such as the principles and design goals achieved in the master plan created by Foster + Partners, which continues to be one of the most advanced examples of how to organize an eco-sustainable and smart city. Taking up the words of the promotional brochure of Masdar City: "The city [of Masdar] acts as a catalyst for other urban areas in the world, encouraging them to follow its example and embrace its pioneering sustainable development actions" (Masdar 2018a).

Attributions

From **1** to **2.2**, Giuseppe Marino (Author).

From **3** to **3.2**, Lorenzo Massimiano (Co-Author).

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Study on the Planning of the Characteristic Town Which Undertakes Function Spillover of Big Cities

Rui Xue and Songtao Wu

Abstract

"Characteristic town" is one of the main national strategies to promote China's new-type urbanization and industrial transformation. It is a kind of relatively independent spatial aggregation with the development of characteristic industries as its main intention. After several years of practice and exploration, the connotation and coverage of Characteristic towns are in constant expansion. Recently, one kind of Characteristic towns situated in the suburbs which are planned to undertake the function spillover of big cities has received more and more attention. Compared with other types, the Characteristic towns which undertake function spillover of big cities can make full use of the resource radiation of the city centers, form their competitive advantage through the differentiated and complementary growth path, and form compact organization form of urban land use in their fringe areas. We take Butterfly Island Outlets Town program in Harbin New Area Sanjiawan Tourist Resort as an example, analyze the planning model of the Characteristic towns which undertake function spillover of big cities in order to provide some theoretical and empirical reference for the compact and rational development of Harbin's urban fringe areas.

Keywords

The Characteristic towns • Compact city • Harbin new area • Butterfly island outlets town

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1 Introduction

From the 1990s on, Harbin most integrated various resources in its suburb through the form of development zones. But the actual effects were quite different. Through the summary, it is found that without the support of powerful industries and highly competitive large-scale projects, the cultivation process will be very slow, and it is easy to form a relatively loose spatial form, which brings many problems for the development of urban fringe areas. For example, limin development zone in Harbin has formed a certain scale after nearly 20 years of cultivation, but the hinterland areas beyond the two sides of main roads still have not formed a complete and compact urban space, with the disordered industrial spatial layout and lack of service facilities in the living space, showing a relatively loose urban structure.

In recent years, the construction of Characteristic towns has provided a new alternative pattern for the development and construction of urban fringe areas, and the "small but specialized" advocated by characteristic towns has formed a complementary counterpart to the "large and complete" of the core urban areas of large cities. In the urban fringe, the factors of production are relatively separated and the ecosystem is relatively fragile, which make it difficult to form a rapid population aggregation (Zhao 2017a, p. 7). Characteristic towns can promote the endogenous motive force of the development of marginal areas through the cultivation of characteristic industries and specialized division of labor, and form a compact organization of local land use and relatively rapid population introduction through the limited scale of "production-city integration." It is one of the important choices for the rapid and orderly development of some urban fringe areas which lack core competitive advantages.

After the concept of "Characteristic town" was put forward in china in early 2016, a construction climax was formed in a short period of time. In this process, the development mode and path exploration of some

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Characteristic towns have achieved some results, but more Characteristic towns are facing the test of survival. The construction of Characteristic towns in Harbin is still in its infancy, and there are many problems to be solved. In addition to drawing lessons from advanced experience, the key is how to integrate its own characteristics and inject new vitality into the urban development. The planning and design of a series of Characteristic towns represented by Butterfly Island Outlets Town in Sanjiawan Tourist Resort of Harbin New Area have carried on a lot of beneficial explorations.

2 Interpretation of Characteristic Town

2.1 Concept Discrimination

The concept of "Characteristic town" was first put forward by the Zhejiang Provincial Government at the "two sessions" in 2015. The construction of Characteristic towns aims to build a platform of characteristic industries and inject power into the new type of urbanization, and the scope of which is more inclined to non-structured towns (Zhao 2017b, p. 105). In October 2016, the National Development and Reform Commission (NDRC) described the Characteristic town in Guidelines on Accelerating the Construction of Beautiful and Characteristic Small Towns as Characteristic small towns include two forms, one is Characteristic small town, the other is Characteristic town. At the same time, the list of National characteristic towns selected by the Ministry of Housing and Construction also regards the organic towns as the main evaluation object (Shan et al. 2016, p. 23).

In December 2017, the State Development and Reform Commission, the Ministry of Land, the Ministry of Environmental Protection, and the Ministry of Housing and Construction jointly issued a paper entitled "Several Opinions on the Standardization of Promoting the Construction of Characteristic Small Towns and Towns," which pointed out the difference between Characteristic towns and Characteristic organic towns (Li et al. 2018, p. 9). It pointed out that the Characteristic towns are innovative and entrepreneurial platforms that gather characteristic industries on several square kilometers of land, integrate production and living ecological space, and are different from organic towns and industrial parks. The Characteristic organic towns are those with an administrative organizational system, which has more than tens of square kilometers of land, a certain economic scale of population, and distinct characteristic industries.

Generally speaking, although the above definitions overlap with each other, one thing is relatively clear, that is, "Characteristic town" does not belong to the category of administrative organizational system. It is a relatively independent spatial organization mode with characteristic leading industries and other auxiliary functions. The concept of Characteristic town in this paper does not need to be completely separated from Characteristic organic town, which can be either a relatively independent area in the urban fringe, or a small town adjacent to the traffic artery around the city or a larger village.

2.2 Driving Types of Characteristic Towns

According to different driving types, Characteristic towns can be divided into resource-driven, industry-driven, and undertaking function spillover of big cities (as shown in Table 1). Among them, resource-driven towns generally have prominent resource bases, such as natural landscape environment, history and culture, and ethnic features. These small towns rely on the original resources to develop independently into characteristic towns, and their development motive mainly focuses on tourism. Industry-driven towns generally attract entrepreneurs to work and settle down by building characteristic industrial platforms and expanding upstream and downstream industries as the development support of them and attract entrepreneurs to work and settle down through a good entrepreneurial environment and relatively low cost of living. The motive force of their development includes the outward migration of urban industries, the development of innovative industries, and the upgrading of old industrial zones. This type also reveals the core essence of Characteristic towns. Undertaking function spillover of big cities towns generally has prominent location or environmental advantages. Based on the flat and networked development background of urban agglomerations, they carry the function spillovers of big cities. They can carry high-end service functions, leisure, shopping, suburban tourism, and other special functions, and even in order to alleviate the pressure of high housing prices in big cities, set up a considerable number of residential functions.

2.3 Towns Undertaking Function Spillover of Big Cities

The outlets towns this paper refers to which belong to the towns undertaking function spillover of big cities. Outlets as their main function can attract enough popularity. This type of towns and the large cities they rely on often have obvious complementarities, usually located in the suburbs of the city, within 30 km from the core urban areas, and some will be located in the intersection of different urban radiation areas in the dense metropolitan areas, in order to attract more tourists (as shown in Figs. 1 and 2).

Table 1 Classification and characteristics of driving types of characteristic towns

Driving types	Location	Characteristic	Examples
Resource-driven	Resource-oriented, location selection around high-quality resources	Generally, these towns have prominent resource bases, such as natural landscape environment, history and culture, national style and features, they develop independently into Characteristic towns by relying on original resources, and their development motive mainly focuses on leisure tourism	Tourism town, Hot Spring town, Folk town, Film town, Weddingt own
Industry-driven	Industry-oriented, convenient transportation	Through building characteristic industry platform and expanding upstream and downstream industries as the development support of small towns, and attracting entrepreneurs to work and settle down through a good entrepreneurial environment and relatively low cost of living, the driving forces of development include the urban industrial relocation, the development of innovative industries, and the upgrading of the original industrial zones	Light Industrial town, Park town
Undertaking function spillover of big cities	Rely on big cities, located in the suburbs with convenient transportation	These towns have more prominent location or environmental advantages, based on the flat and networked development background of urban agglomeration. They carry the function spillover of metropolis, which can not only carry high-end service functions but also such characteristic functions as leisure, shopping, suburban tourism, and residence	Outlets town, Leisure and Vacation town, Livable town

Compared with the other two types of Characteristic towns, the advantage of towns undertaking function spillover of big cities is that they can make full use of the resource radiation of the core urban areas and form their competitive advantages through the development path of differentiation and complementary advantages. In order to pursue the fairness and diversity of urban development, the service of the core areas must be "large and complete," but it is often limited by the lack of specialization and the low level of specialization on the supply side, which makes more demand impossible to release (Zhao 2017a, p. 6). Therefore, in addition to the scale effect, the pursuit of specialization effect can highlight the advantages of urban fringe areas, and specialization can bring more competitive advantages to the fringe areas. A smaller scale is more conducive to a more detailed division of labor and its professionalism and uniqueness. It is this "small and specialized" is the main advantage of the development of characteristic towns located in the suburbs.

The limited scale of towns undertaking function spillover of big cities in suburban areas is one of the advantages of spatial organization in urban fringe areas. Core urban areas have insurmountable advantages because of their superior infrastructure construction and existing population concentration. However, new industrial towns and development zones in the suburbs of cities, which are large-scale spatial resources integration methods, are difficult to establish sufficient advantages to compete with core areas in a short time, and their population concentration is relatively slow. The small towns can further decompose the larger urban space into a number of flat constituent units through the spatial organization of industrial combination. Small towns are

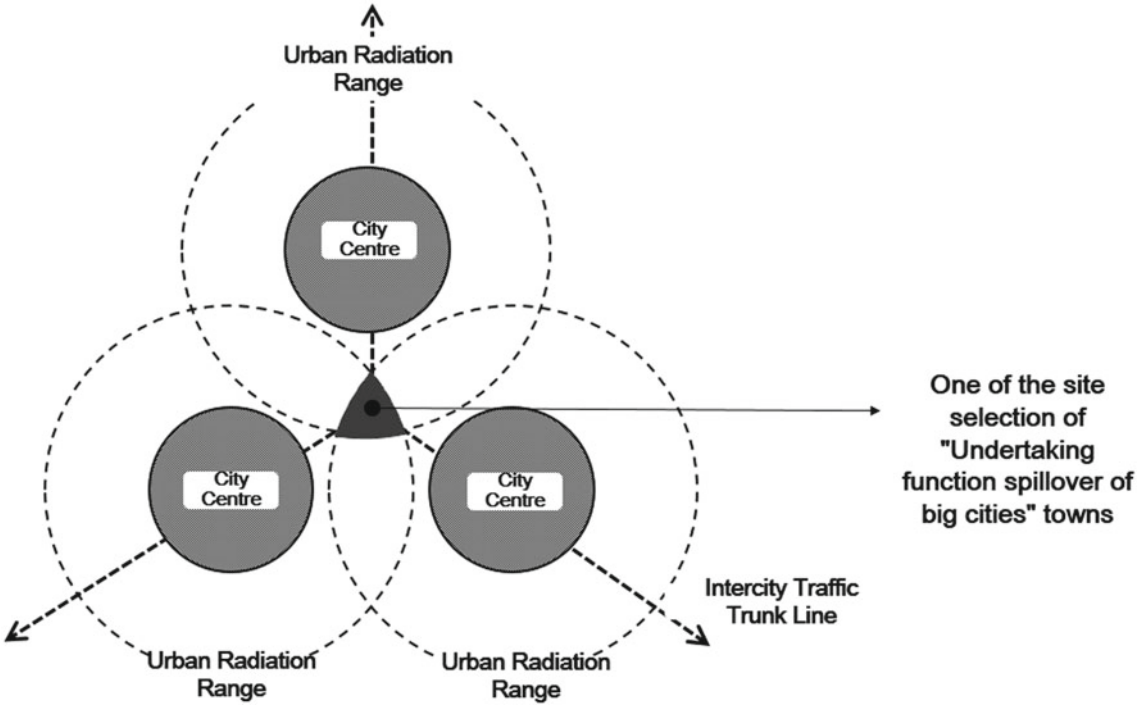

Fig. 1 Location selection of towns undertaking function spillover of big cities

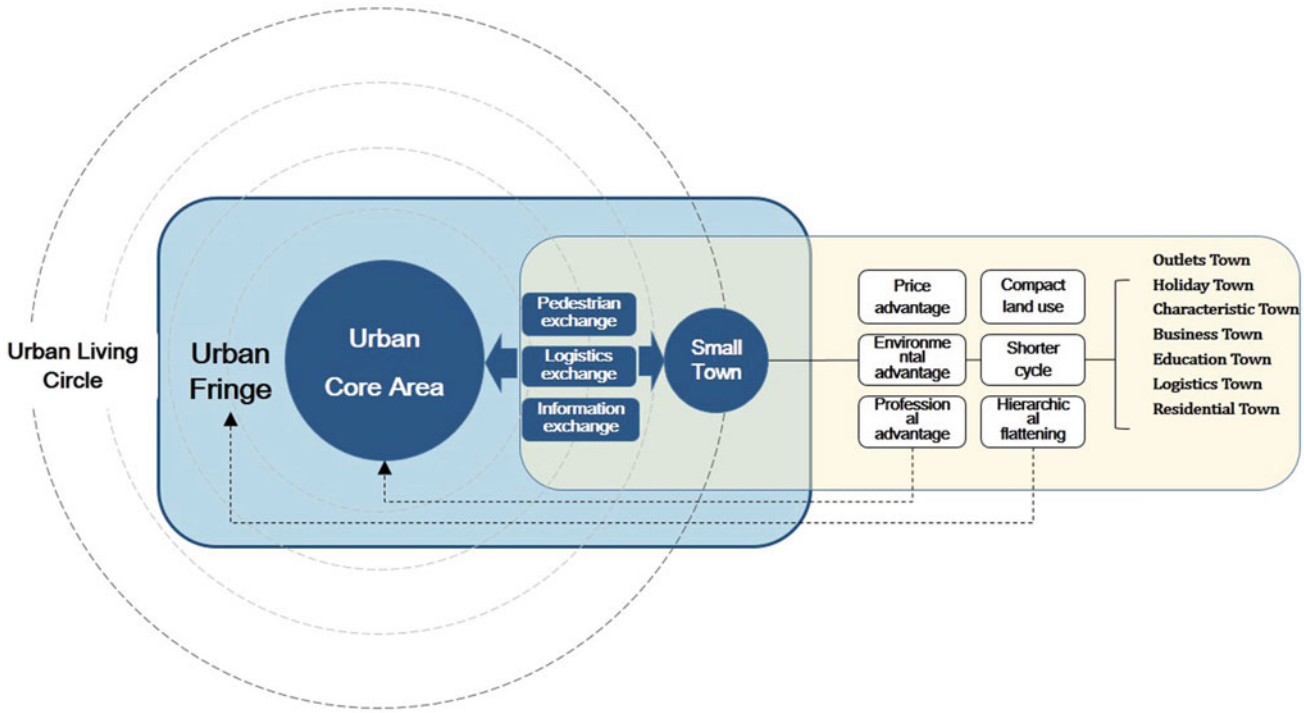

Fig. 2 Driving mechanism of towns undertaking function spillover of big cities

relatively independent and highly related to the surrounding areas and form a relatively compact land use form through the rational allocation of land within a limited range. In addition, the construction cycle is relatively short, which can form a positive attraction to population aggregation in a short time.

3 Form and Characteristics of Outlets Town

Outlets is a kind of commercial retail format that originates from the United States, point to those to sell famous brand goods, especially out-of-season, Off-Shelf, and Out-of-code, and it is also called "Brand Direct Shopping Centre." Outlets was formally introduced to China in 2002, which has been widely recognized by domestic consumers and investors. It has a good development trend when the traditional retail trade is widely hit today. There are many types of outlets in spatial form and site selection, among which "small town-type outlets" located in the suburbs of cities is a relatively mainstream form and site selection mode, which is the starting point and core of the development of outlets towns.

3.1 Classification and Characteristics of Traditional Outlets

3.1.1 Classification by Location

The location of outlets is influenced by many factors, such as transportation, land rent, consumer groups, suppliers, surrounding industries, and the distribution of surrounding population. Most outlets in Western countries are located in the suburbs of densely populated big cities, within 45–90-min drive from the urban core area, and connected with the urban core area and other areas through highway, subway, urban rail, and other transportation facilities.

Located in the suburbs of big cities can effectively balance the contradiction between transportation and land price, effectively reduce the cost of land rent, and have large-scale construction land for selection; located near the city's main road or its key nodes can fully guarantee accessibility and minimize the opportunity costs; located in the suburbs, far from the city regular stores, it can provide the basis for suppliers to open the price gap between outlets products and the same category of regular store products. Some of them will also be located near railway and suburban rail transit stations between several major cities, which can improve the richness of passenger sources and reduce its dependence on motor vehicle traffic. Others will be situated around scenic spots or large-scale tourism projects, sharing human flow and other resources, but will be affected by the scenic spot tour cycle to some extent.

Due to the dependence of Chinese consumers on consumer convenience, a kind of "Urban Outlets" located in the core area of the city emerge after the introduction in China, such as Yansha Outlets in Beijing (2002), which are mostly located in the city's sub-center, but also some in the city's main centers. "Urban Outlets" seek competitive differentiation with the traditional outlets, which are more like shopping malls in form. In terms of brand level, there are not as many luxury brands as traditional outlets but slightly higher than discount department stores in the city center, and the price is more attractive (as shown in Table 2, it is the location, classification, and characteristics of outlets).

3.1.2 Classification by Spatial Form

Outlets can be roughly divided by spatial form into centralized type and decentralized type. Decentralized outlets are usually called garden type or manor type, and they look similar to traditional Pedestrian Commercial district.

Table 2 Classification and characteristic of outlets location

Location	Advantage	Disadvantage	Example
Near the city center	They are closer to the center of customer distribution, the average travel distance of customers is the shortest and bus accessibility is higher. Depending on the mature business circle, they can fully enjoy the advantages of the agglomeration economy	They have high rent and fierce competition, traffic pressure and tight parking will limit accessibility, and their customers are more confined to local residents	Pacific Ocean Outlets in Wuhan (2011)
In the outskirts of the city	Compared with other kinds of outlets, its land price, distribution of passengers, traffic pressure, accessibility, and parking convenience are more balanced	They will be surrounded by the city with the expansion of the city, and become parts of the city, then the various disadvantages of them as the Urban outlets will gradually emerge	Yansha Outles in Beijing (2002)
In the outer suburbs of the city	They are located at the convergence of several expressways, which can radiate more foreign passenger flows; they have lower rent, relaxed shopping environment, convenient parking, and room for expansion; they are far away from regular stores which can make the price lower	They are far away from the main source of passengers and have relatively poor accessibility, and have a high dependence on private car occupancy	Qingpu Outlets in Shanghai (2006)
Around scenic spots or large recreational events	They can share tourists and other resources with recreational projects in scenic areas; they focus on shopping tourism and conform to the development trend of shopping leisure	They are greatly influenced by the tour cycle of scenic spots	Yioulai Tourist Shopping Resort in Shanghai (2016)

Table 3 Classification and characteristics of spatial entities in outlets

Spatial form	Building form	Characteristic	Advantage	Disadvantage	Example
Centralized	Shopping mall-type	Their appearance and pattern are similar to shopping malls, but their goods are different in grades; compared with traditional outlets, they have more entertainment facilities	They have compact layout, clear zoning, easy to manage, rich commercial format, spacious, and bright shopping environment, customers are not affected by the weather	They have higher requirement for capital and longer period of return on investment	Yansha Outlets Shopping Center in Harbin (2006)
	Castle-type	They look like European castles, and highlight the "Castle Culture." They have noble luxury and harmonious shopping environment	They have elegance, heavy appearance and relatively high-end business atmosphere, which distinguish from mass consumption	Their solemnity and sober appearance is not conducive to creating modern business atmosphere	FOXTOWN in Shanghai (2006)
	Warehouse-type	Rebuild warehouses into warehouse type of supermarket model, with no ceiling at the top and fire and air conditioning ducts are exposed	They have large-scale, small-investment, simple, and natural shopping space	Their shopping environment is relatively poor	Phase I of Yansha Outlets in Beijing (2002)
Decentralized	Small town-type (Garden-type, Manor-type)	Their spatial organization are similar to European small towns, and their functions and traffic organization are similar to traditional Pedestrian Commercial blocks	They have flexible and changeable building layout, which combines well with the surrounding environment, they have comfortable, convenient, open, and humanized shopping environment	Their building layout is relatively scattered, which is not conducive to function zoning, customers are vulnerable to weather	Florence Town in Wuqing (2011), Maple Leaf Town in Harbin (2016)

Because of their larger areas, they are usually located outside the urban core areas. Centralized outlets often concentrate a lot of shops in one or several buildings, and the buildings are usually three or four floors. Centralized type can be subdivided into shopping mall type, castle type, and warehouse type by building form (as shown in Table 3).

In addition, as upgraded version of outlets, "Outlets Shopping Parks" and "Tourist Shopping Villages" have gradually sprung up in various parts of China (Li 2013, p. 187), such as Wanhe Outlets Shopping Park in Jiangsu, Yioulai Tourist Shopping Resort in Shanghai and Suzhou (2017). These forms of outlets add the concepts of tourism and vacation to their functions, which expands the connotation of traditional outlets.

3.2 Small Town-Type Outlets and Outlets Town

There are differences in form and connotation between small town-type outlets and outlets towns (as shown in Table 4). The small town-type outlets are relatively decentralized layout patterns of outlets, which are similar in form and organization to the pedestrian business district. Their scale ranges from a few hectares to more than a dozen hectares, with a single internal business format, aside from outlets there are only a small number of ancillary services. Outlets towns are the category of the Characteristic towns which undertake function spillover of big cities, which are comprehensive expansion of small town-type outlets in terms of scale, form, and connotation. Their form and organization are similar to those of comprehensive urban districts with commercial functions, they have relatively clear centers and boundaries and consist of several blocks, the scale is usually several square kilometers, and they have a relatively perfect functional configuration. In addition to the core function of outlets, functional allocation also includes the related formats of upstream and downstream expansion, as well as tourism, leisure, and other peripheral industries, and have the corresponding residential function as the necessary support for the development of the small towns.

4 Planning Practice of Outlets Town in Harbin New Area

4.1 Theme Positioning of the Town

4.1.1. Sanjiawan Tourism Resort area is located in the core of the eastern plate of Harbin New Area. The construction of the area has not yet reached a scale, and it is urgent to inject

Table 4 Contrast of small town-type outlets, outlets towns, and constructed towns

Category	Properties	Core functions	Operators
Small town-type outlets	They have low-density distribution model with scattered formats in the suburbs of outlets, they are small-scale and non-administrative region	Outlets and their related ancillary service facilities	Enterprise
Outlets towns	They belong to the Characteristic towns which undertake function spillover of big cities, which are relatively complete and comprehensive areas with outlets as the leading industry. They are non-administrative regions with moderate scale and certain flexibility	The characteristic retail business of outlets, tourism and leisure functions, residential function	Government, enterprise
Constructed towns	They belong to the administrative divisions of the state, their population and land use scale have clear relevant provisions	Necessary work and life functions in the town	Government

effective endogenous power into the development of the eastern plate of the new area through industrial cultivation. The Characteristic towns provide space and connotation support for the cultivation of the characteristic industries.

The planning determines that the core theme of the town is the retail format Outlets, which is popular among Harbin residents, and it also defines the three main functions of "Outlets + Tourism + Community." Outlets and relevant upstream and downstream functions can effectively gather popularity at the initial stage of the town's development and serve as the initial driving force for its development.

In the case of the extreme shortage of tourism resources in the suburbs of Harbin, the town's beautiful natural landscape and its own cultural landscape, combined with the corresponding service facilities, will create the characteristics strengthening functions of leisure tourism and shopping tourism to strengthen the trend of population aggregation and promote the diversification of the town's participants and participation time. In addition, the construction of an ecological community can meet the low-price and high-quality living needs of some high-income people in urban areas, and also can retain the popularity to the greatest extent and maximize the time span of population aggregation (as shown in Fig. 3).

4.2 Site Selection of the Town

The outlets town is located on Butterfly Island, which is located on the east side of Sanjiawan Tourism Resort. The island got its name from the shape of a flying butterfly. It is about 35 min' drive from the core area of Harbin, and it can be connected with the main urban area through several expressways and main urban roads. It is surrounded by water, of which the east is adjacent to the Songhua River which is Harbin's mother river, and the west, north, and south are adjacent to the water network system. Rich water landscape resources are fully compatible with the natural ecological environment around the design area. As a platform to undertake the characteristic functions of the main urban area, this unique "landscape" provides a competitive advantage for the town to survive (as shown in Figs. 4 and 5).

4.3 Planning and Layout of the Town

"Spatial layout" is a spatial organization means to implement the characteristic theme and functional positioning of the town, and the purpose is to realize the requirements of "fine and beautiful" architectural form of the town (Song et al. 2016, p. 35). The spatial layout of the plan focuses on the overall functional layout, public open-space layout, overall style control, and spatial texture.

4.3.1 Functional Layout

The town takes two horizontal and two vertical cross-border roads as its main development axis, on which four bus stops are located at key nodes. The planning adopts a public transport-oriented functional organization model, taking the bus stop as the center of the circle to form a local circular structure from function to form, and construct four "TOD areas." The radiation range of the circle is controlled by the appropriate walking distance (400–800 m). The core functions of small towns such as outlets, high-end commercial

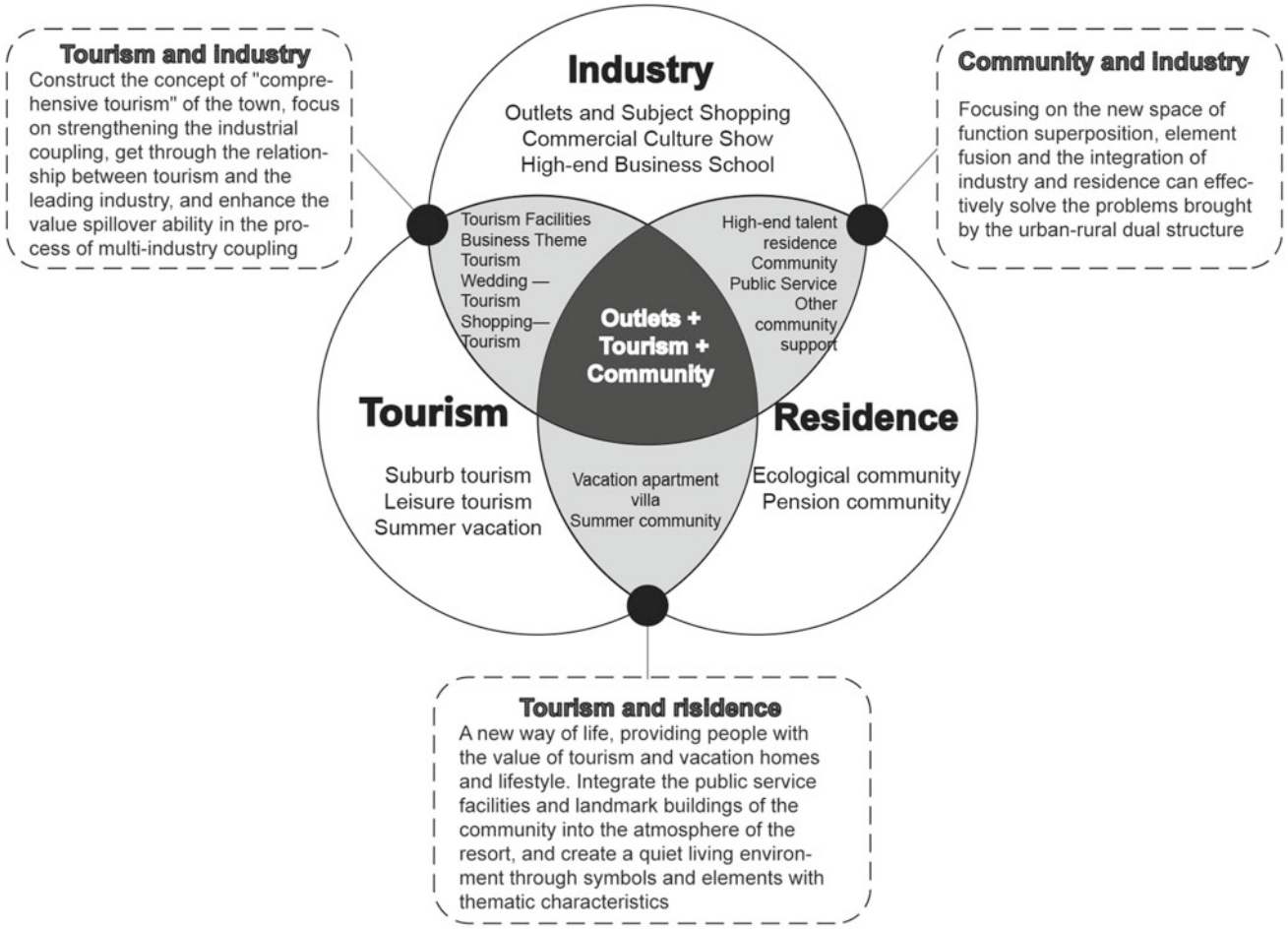

Fig. 3 Analysis of the functional theme of the town

schools, tourist service reception, and enterprise Club areas are centrally arranged near the core of the circle, and the integrated development of high intensity and mixed functions makes it the public core of the town. In the periphery of the circle, with the distance from the bus station increasing gradually, the proportion of living increases continuously, and the building height and development density decrease gradually. This gradient treatment in function and space is more conducive to the intensive development, functional agglomeration, and central enhancement of the town (Liu 2017).

In addition, an east–west landscape axis is set up in the outlets functional area in the center of the town, which leads the core function and landscape to the waterfront square at both ends of the axis. Waterfront Tourism Street is centralized along the inland riverbank and the Songhua Riverbank, forming the characteristic functional framework of "one horizontal and two vertical" on the leading functional structure of circle stratification, which extends the depth of functional development of the small town and gives full play to the advantages of the water landscape (as shown in Fig. 6).

4.3.2 Layout of Public Open Space

In the planning, the layout of public square and green space in the region adopts the strategy of breaking up into parts, avoiding setting up large-scale and relatively concentrated public open space. The uniform distribution pattern of "point + line" is adopted to effectively increase the radiation range of green space and square. In the planning, more attention is paid to the effectiveness of public open space, focusing on strengthening its overlap with important functional areas, structural roads and axes of the small town, and on shaping the integrity of the system. By making the open space system and the whole structural elements of the town close to each other, the permeability and availability of the

Fig. 4 Meso location (Longji Planning Company 2017)

open space system can be strengthened, and it can be built into an important clue of the functional form organization of the town (as shown in Fig. 7).

In addition, the planning also pays great attention to the shaping and excavation of water landscape. There are waterfront squares at the junction of structural roads and strip squares with water surfaces, and they are connected by the waterfront walkway system around the main island. In each large block, there are ribbon public spaces perpendicular to the water surface to introduce the water landscape into the inland space.

4.3.3 Morphological Control

The town adopts the overall low-density development model, combined with the public transport-oriented functional organization model and the hydrophobicity of the area, establishes the overall control principle of the town "Near the water is high, far is low; In the middle is high, in the edge is low; In the middle is high density, in the edge is low density," and according to the partition of their own environment and functional layout for local fine-tuning. Considering the unity of space and function, the circled form of building height and density from inside to outside in each "Tod area" is the main form control principle of the town, while other principles are supplementary. In addition to the positive significance of functional layout, this form of organization of "wedding cake" can also help the town to build a clearer spatial intention. Furthermore, the town will also set up higher landmarks in specific locations along the waterfront, and the contrast formed by this morphological "mutation" can establish the landmark of the town at the key position on the water surface (as shown in Figs. 8 and 9). In order to strengthen the landscape characteristics of the small town and strictly control the building height, all the buildings but the specific landmarks are controlled below 18 m, and the net volume ratio is controlled below 1.1.

In order to create the unique human landscape of the town, the planning gives the corresponding restriction and guidance to the architectural style of the town. Based on the theme of outlets, the specific history and culture of Harbin, and the high-quality natural environment of Sanjiawan Tourist Resort, the planning determine that the architectural

Fig. 5 Micro location (Longji Planning Company 2017)

style of the town is guided by the inheritance and innovation of the historical architecture context of Harbin, and all the buildings are divided into three types: landmark buildings, main style buildings, small-size residential buildings, and public buildings, and they are classified and controlled from the aspects of composition style and implementation method (as shown in Figs. 10 and 11).

4.3.4 Street System of "Large Block + Neighborhood + Small Block + Plot"

The planning adopts the form grading system of "town - large block (area) - neighborhood (group) – block - property plot" in the small town. The main structural roads and spatial axes divide the town into several large open blocks, which are divided into several neighborhoods (groups) by their internal main roads. Neighborhood is the basic development unit of a small town, each of those has its own public service facilities and centralized green space and its internal road network are self-contained, whose scale is controlled below 7 hectares. This approach can better adjust the spatial scale of small towns and avoid the formation of large enclosed blocks. It can also form functional self-balance and compact spatial organization in local areas, which is conducive to building spatial cohesion on the microscale and a better regional vitality.

Neighborhoods can be further decomposed into rectangular blocks with large lengths and widths arranged in fishbone shape, most of the rectangular blocks are formed by a linear arrangement of several property plots back to back. This kind of property plot organization can effectively improve the efficiency and efficiency of land development, and form a relatively pleasant spatial scale of streets and high accessibility within the neighborhood, and can also

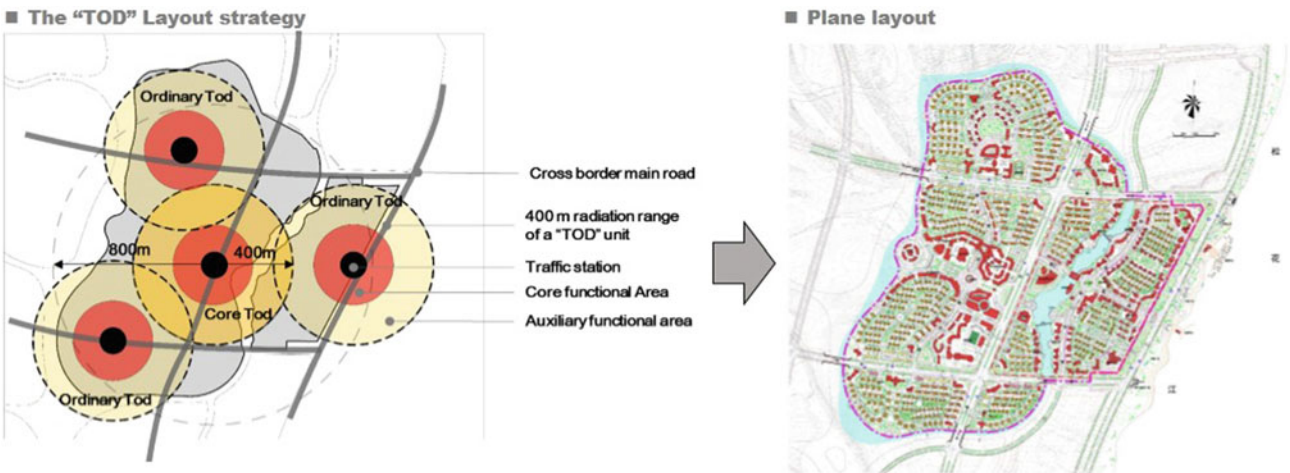

Fig. 6 The "Tod" functional organization strategy

Fig. 7 Layout of public open space of the town (Longji Planning Company 2017)

Fig. 8 Overall bird's-eye view of the town (Longji Planning Company 2017)

Fig. 9 A bird's-eye view of the town center (Longji Planning Company 2017)

meet the needs of different building sizes through the flexible division of plots. In line with this kind of plot organization, most of the commercial facilities in the town adopt a decentralized layout, in which most large complex buildings are replaced by walking blocks, which are consciously arranged along with the public open space in a linear manner to form the interaction and sharing of landscape and people flow (as shown in Fig. 12).

4.4 Planning Compilation and Implementation Plan

The planning of the town based on integrity and continuity integrates the conceptual planning in the early stage and the implementation planning in the later stage, and a comprehensive planning scheme including concept planning, spatial planning, project planning, and fund planning is formulated, formulate a comprehensive solution of multi-planning integration from industrial research, project planning to spatial planning, urban design, building façade, and landscape renovation design. At the same time, according to the implementation of the planning, the late project plan and fund-raising plan are also included in the overall planning consideration.

The planning takes the industrial function as the core and formulates the implementation plan for the first 3 years of the outlets town. The first step of implementation is to develop the business format and supporting service facilities of outlets, aiming at gathering popularity for the town and expanding related service formats on this basis. After a proper period of cultivation, the functions of cultural tourism

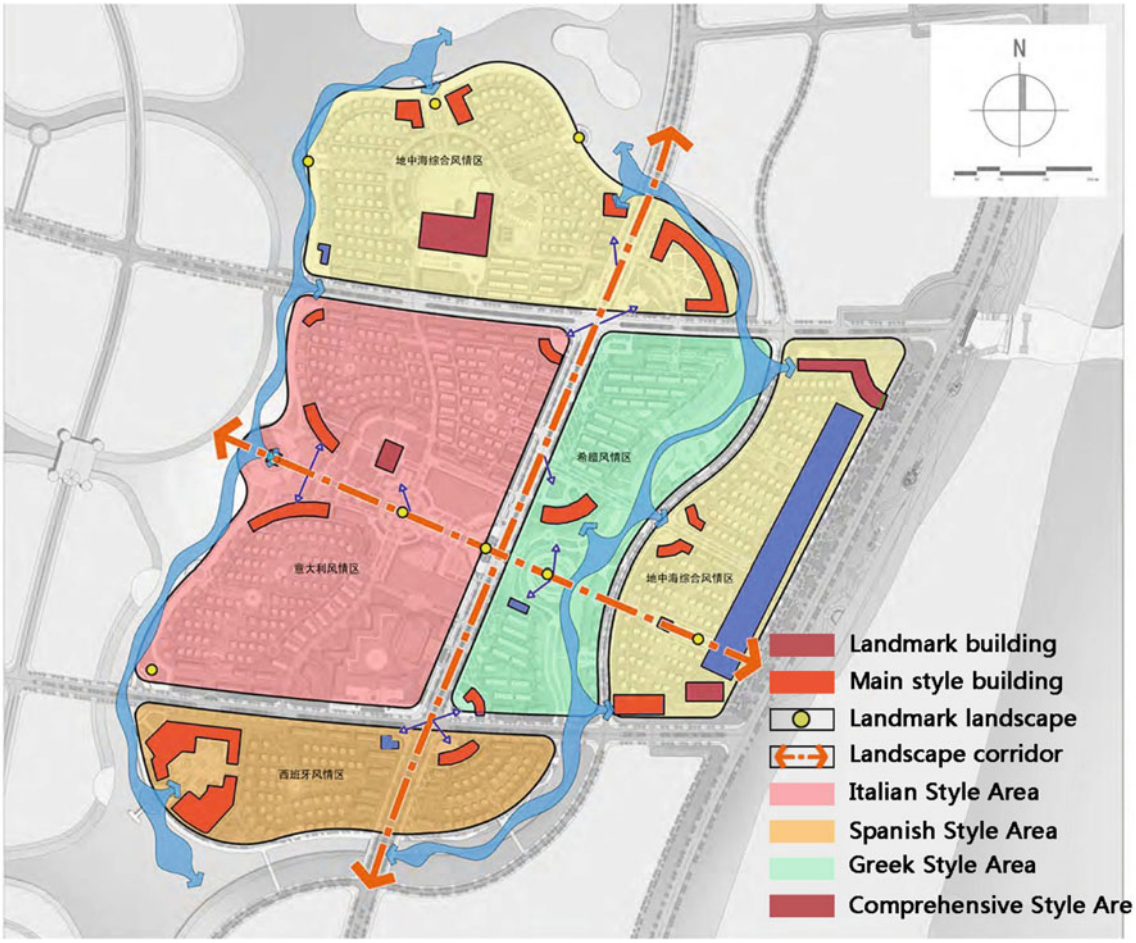

Fig. 10 Distribution of landscape components in the town (Longji Planning Company 2017)

and high-end education should be started to strengthen the main functions of the town, but the core function of the town is still outlets. On this basis, leisure tourism, business services, tourism community, and its supporting functions will be further implemented to continuously improve the characteristic industries of the town.

Fig. 11 Image design of some characteristic buildings (Longji Planning Company 2017)

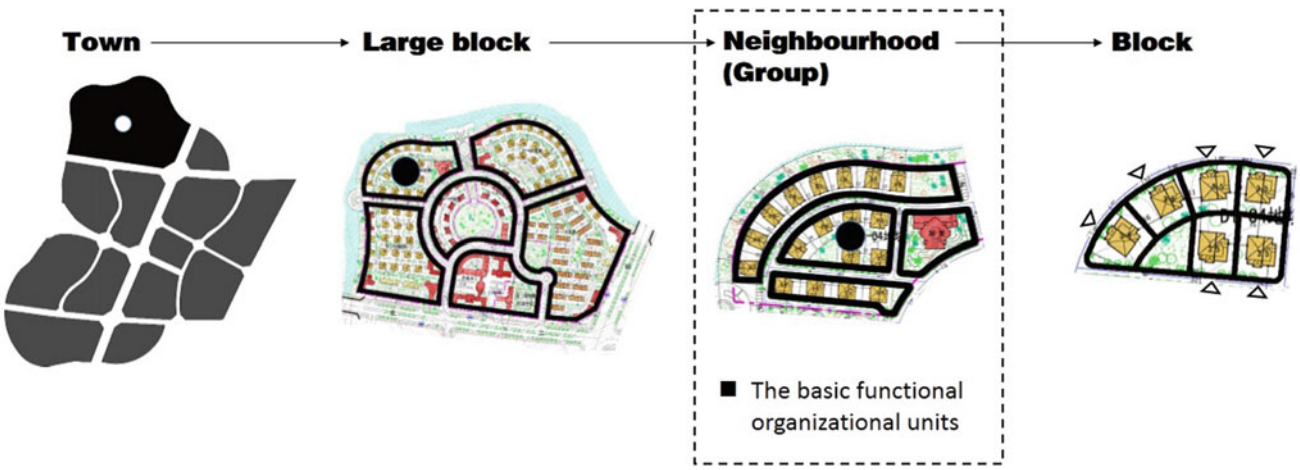

Fig. 12 Hierarchical development system of the town

5 Concluding Remarks

The Characteristic towns which undertake function spillover of big cities are extensions of the development strategy of Characteristic town in China from the connotation to the driving form, they have strong pertinence to many problems in the development of urban fringe areas in our country at present. Their form of industrial innovation can well stimulate the endogenous driving force of urban fringe areas, and make the urbanization process faster and more sustainable, their small and refined characteristics are more conducive to the construction of compact and intensive land use organization form.

The planned Butterfly Island Outlets Town is the combination of Characteristic town and outlets' innovative development, which undertakes some overflow functions of characteristic business, high-end residence, and leisure tourism from the core area. In the planning, the feasibility of the outlets theme and other related functions of the town is discussed, and a detailed planning scheme is made from the aspects of site selection, functional layout, public open space form, and architectural features control of the town. This function-oriented and space-oriented design concept and key points of Characteristic towns have a certain reference significance for the same type of planning but also hope to provide a better driving force for the development of urbanization in Harbin New Area.

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Localizing the Globalized—How Not to Fail in Smart Cities Frameworks

Mostafa Othman, Ayman Ismail, and Mohamed Awny

Abstract

Smart Cities are viewed by a few as a show, by others as a trend, but by many as a necessity. To cope with the growing pressures of urbanization and the complications of citizens' urban needs, an integrated hi-tech solution is needed. After all, many renowned cities around the world are adopting it: London, Dubai, Cape Town and many others. Is there a set-menu to adopt for a smart city approach? Should urbanists seek set standards for quality assurance or develop localized approaches? This research is the findings of an 18-month-long in-depth analysis using extensive case studies and detailed interviews with state-of-the-art experts in the making of Smart Cities around the world. The findings were collaborated by local industry specialists to reach a localized model that adapts the Smart City approach to Egypt. The findings challenge many conventional stereotypes about the concepts and perceptions that impede Smart Cities.

Keywords

Smart cities • Management of technology • Urban planning • Information technology

1 Introduction

The number of urban centers with a Smart City strategy has almost doubled in the past 2 years, rising from 87 in 2017 to 153 in 2019 (Zelt 2019). The trend continues to rise as cities strive to handle more people efficiently. The need is urgent and reflected by most international organizations (UNDESA 2019). Yet, there is no consensus as to the framework or model to adopt. Especially when it comes to the Middle East region, where Gulf and African cities increasingly become metropolis. Different global cases of smart cities were implemented with consideration to a strategy and timeline that follows a smart cities framework (Falconer and Mitchel 2012). Generally, it is believed that the following four major steps are taken; Step 1: Creating the vision; Step 2: building the roadmap; Step 3: Identifying the KPIs; Step 4: Building governance to transform the city's operation model. It is important—as the case for more Middle Eastern smart cities continues to grow—to have a critical look at the model and process by which these cities are created and managed.

In this paper, we will compare the approaches adopted by four different mature Smart Cities from around the globe in order to reach a recommendation on the best course of action.

1.1 Methodology

The main objective of this research is to "To check the validity of appling a global smart cities framework to transform existing cities into smart ones to Egypt'. Will the model overcome structural problems of management in vertical "Silos" into integrated and collaborative management?" This framework considers the social, cultural, economic, and technological factors into account and focuses on a management approach to overcoming the problems of the traditional way of managing cities. Different experts on national and international levels have participated in smart city implementations are approached to assess the preliminary model (Hollands 2008). The interview phase is divided into two steps:

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1. Experts' interviews: The interviews are held to directly talk with the first batch of experts to identify the main steps of the smart cities framework.
2. Survey: The survey targets more experts to collect the most important elements for each step of the smart cities framework developed during the preliminary interviews work.

A total number of 75 experts were interviewed and/or surveyed to tackle different areas of the research. Some experts worked in specific cities and helped in identifying exactly what each city did regarding their smart city initiative. Among the entities interviewed were Honeywell—Dubai, SAP, International Consulting firms, Orange business services, Huawei—China, Dubai Government, WCCD—ISO 37,120. Other experts were from various educational and research institutions. Interviewees discussed their opinion regarding the smart cities framework developed through this research and share their insights about the most important factors to be considered in each step.

For each step, data collected from experts were analyzed to remove redundant wordings and use same keywords for different vocabulary used for the same meaning, etc., in order to generate reasonable and comparable results.

1.2 Proposed Framework

The framework of the smart cities initiatives is considered a strategic planning process that helps cities to address sustainability challenges. Many studies have been made in this area to come up with specific steps that need to be taken in order to build smart cities. Some frameworks tried to address the main pillars and questions that need to be answered before starting smart cities initiatives. The strategic planning process for creating smart cities involves multiple steps that should be taken. These steps are different from one study to another. We choose the model in Colldahl et al. (2013) with six steps for the strategic planning process of smart city initiatives as shown in Fig. 1.

If we looked back at many of the smart cities' frameworks, we will find many similarities in the steps followed. The major or most important steps in the framework are.

- Step 1: Creating the vision
- Step 2: building the roadmap
- Step 3: Identifying the KPIs
- Step 4: Building governance to transform the city's operation model.

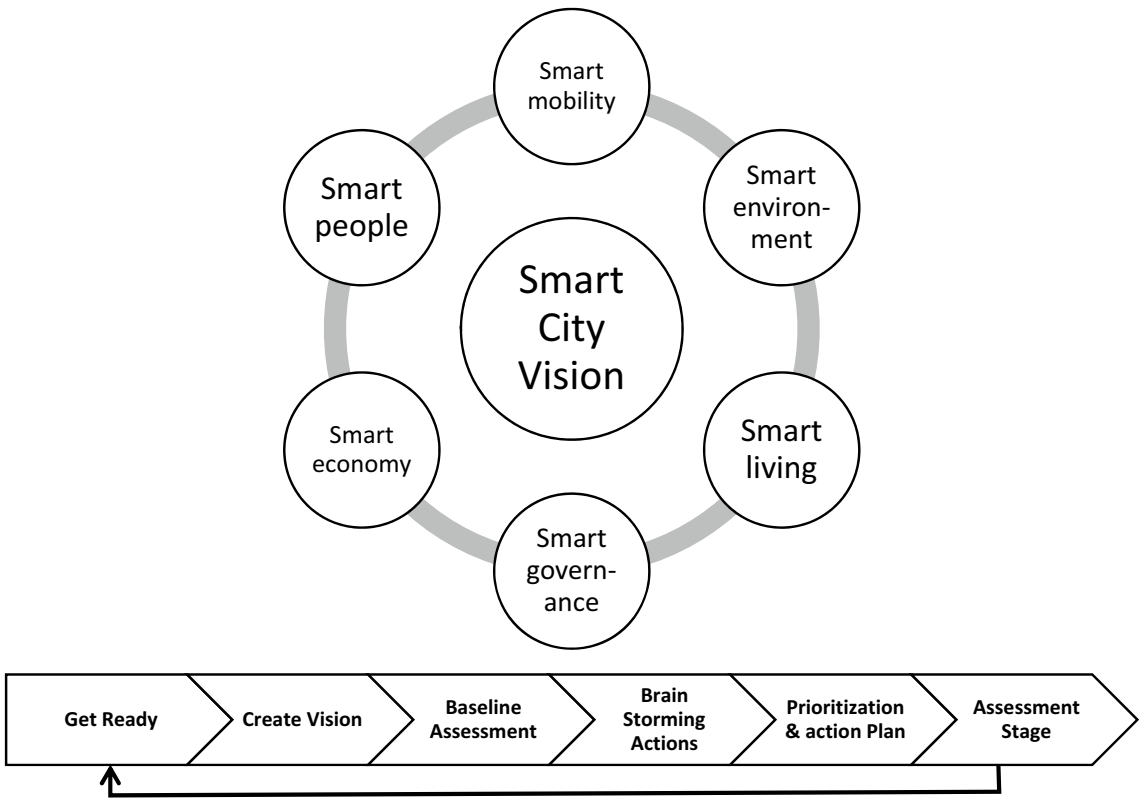

Fig. 1 Strategic planning process (after Colldahl et al. 2013)

1.3 How to Select the Smart City "Smartly"

The challenge that always remains is related to the "How." Since most cities in the region are old enough to require "smart" intervention, the question is *which* city, to begin with.

Initially, in order to build smart cities, national authorities must start with defining which cities are applicable for the transformation into a smart city. The smart city initiatives aim to create sustainable cities with economic development, therefore, cities expect to generate a return on investment from the financing of smart city initiatives.

When choosing a city for a smart city initiative, the officials must put in mind the ability of the city to generate revenues to pay back the financing debt. This can be assessed based on the size of the city, the population, the education level of the people, the city's natural resources, etc.

For example, in India, as part of their vision to have 100 smart cities, they had to nominate some cities to be transformed into smart ones. They used two stages of evaluation.

In stage one, they assessed four major criteria for selection as follows:

1. Existing service levels: including the digital and online existence of the city services.
2. Institutional systems and capacities: this covers the speed and quality of service delivery and improvement in internal resource generation.
3. Self-financing: reflected in the capacity of payment of salaries and generating revenues.
4. Past record of accomplishment: the capabilities of such cities to run large-scale projects.

In the second stage, they assessed six more criteria, which are:

1. Credibility of implementation: to assess improvement in operational efficiency over three years.
2. City vision and strategy: to assess the correlation between the needs and aspirations of the residents and the use of ICT to improve core services and activities.
3. Impact of initiative: to estimate to what extent the initiative will affect the poor and disadvantaged, employment generation, impact on environment, etc.
4. Cost-effectiveness: to ensure the capability of the city to do more with fewer resources.
5. Innovation and scalability: to ensure the applicability of project to the entire city.
6. Processes followed: the extent of use of social media and mobile governance to ensure citizen consultations and participation in the strategy and planning of cities.

Based on the above criteria, a number of cities were selected by the Indian government shown in Table 1.

Table 1 India's smart cities1 after Jog et al. (2017)

Rank	State/Union territory	Selected city	Population
1	Odhisa	Bhubaneshwar	917,766
2	Maharashtra	Pune	6,360,000
3	Rajasthan	Jaipur	3,628,000
4	Gujarat	Surat	6,288,000
5	Kerela	Kochi	2,119,700
6	Gujarat	Ahmedabad	8,160,000
7	Madhya Pradesh	Jabalpur	1,820,000
8	Andhra Pradesh	Vishakhapatnam	3,780,000
9	Maharashtra	Solapur	1,888,000
10	Karnataka	Davangere	1,945,497
11	Madhya Pradesh	Indore	4,160,000
12	–	New Delhi	26,000,000
13	Tamil Nadu	Coimbatore	1,890,000
14	Andhra Pradesh	Kakinada	384,182
15	Karnataka	Belagavi	610,400
16	Rajasthan	Udaipur	474,500
17	Assam	Guwahati	2,052,000
18	Tamil Nadu	Chennai	9,880,000
19	Punjab	Ludhiana	1,976,000
20	Madhya Pradesh	Bhopal	3,300,000

Table 2 Basic data on the selected smart cities (authors)

	Dubai	Cape town	London
Population (2018)	3.1 million	4.05 million	8.8 million
Area	4,114 Km^2	2,451 Km^2	1,572 Km^2
GDP ($)	105.6 billion	58.9 billion	528 billion
Date of establishment	1833	1652	50 AD

As we can see from the table, the selection process of smart cities should be well defined and followed in order to make sure that the selected cities match specific criteria that enable the initiative to succeed regardless of the size.

1.4 Case Studies

The chosen cases were selected to be (1) Globally acknowledged cities. (2) With different objectives (3) In different geographical locations; and (4) With different financial capabilities. Naturally, availability and accessibility of data was a criterion. But since this research is exploratory in nature, constructing a comparative case study is thought to be the most appropriate way to start identifying the key elements of a **Smart Cities (SC)** framework. On one hand, interviews and surveys were held with subject matter experts to get professional and experienced opinions. On the other hand, we will look again at our case studies and elaborate on what each city did in each step of the above. By following these criteria, the number of cities was narrowed down to three cities, namely, Dubai (UAE), Cape Town (South Africa), and London (United Kingdom). The basic data for these case studies is shown in (Tables 2 and 3).

Table 3 Comparison between aims of selected smart cities

	Dubai	Cape town	London
Aim	To make Dubai the happiest city on Earth	To build a city for all, a city in which no-one is left out	To make London exemplary, sustainable, and to excel global cities
Objective	• The people – • The society – • The experience • The place – • The economy – • The government	Everyone is: • Connected • has access to digital information • able to interact with city administration using ICT	Engaging citizens—Providing access to open data—Leveraging research, technology and talent—Infrastructure networks innovation—Enable London to adapt and grow—Better serve Londoners needs—Offering smarter experience for all
Focus areas	• Transportation • Communications • Urban Planning • Infrastructure • Electricity • Economic services	• Opportunites • Safety • Care • Inclusion • Well Run	• Enterprise and Business • Skills and Training • Infrastructure and Environment • Health Care • Transportation

2 Results

The focus of the interviews has been on three points: The Vision Creation, Building the Roadmap, KPI's, and Operation Model. The results were analyzed using word discourse analysis and showed the pattern below:

2.1 Vision Creation

This was reflected in the following questions: Q1: In your experience, what should be the focus of the city's vision? Q2: What are the main elements to consider when developing a city vision? Q3: Who should participate in the stage of developing the city's vision?. This is shown in Table 4.

2.2 Building the Roadmap

This was reflected in the following questions: Q1: What pillars (focus areas) are common for any type of smart city? Q2: How the smart city road map and technologies differ based on the type of the city? Q3: Who should participate in developing the road map? This is shown in Table 5.

2.3 Identifying KPIs

This was reflected in the following questions: In this area, three questions were asked as follows: Q1: How to identify the KPIs for the smart city initiatives? Q2: How can the KPIs differ based on the type of the city? Q3: Should cities follow global standards of KPIs like ISO 37,120 or ITU-T indicators or develop localized indicators based on the type of the city? ITU (2014). This is shown in Table 6.

2.4 Operation Models

This was reflected in the following questions Q1: How do the smart city initiatives affect the operation of the city? Q2: What are the challenges within the managing organization should be taken care of? This is shown in Table 7.

3 Analysis

Answers to the first set of questions in expert opinion (Vision Creation) suggest that the objective of any smart city should be people-centric. People include citizens, visitors,

Table 4 Interviews keywords results (Vision creation)

Question	Most frequent	Frequency (%)	Secondmost frequent	Frequency (%)
Q1	Citizens	20	Quality of life City purpose Technology Data Economy	15 15 11 9 9 Others 21
Q2	Sustainability	13.5	Revenue streams People Resources Collaboration	11.5 11.5 8 8 Others 47.5
Q3	City administrators Residents	18.5 16	Consulting firm Technology providers Urban planners	13.5 13.5 10.5 Others 28*

*Others represent diversified unrepeated answers less than 8%

Table 5 Interviews keywords results (Building the roadmap)

Question	Most frequent	Frequency (%)	Secondmost frequent	Frequency (%)
Q1	Mobility	15	Economy Environment Infrastructure Technology	11 9 9 7.5 Others 48.5
Q2	Resources	16	Demographics Priorities Type	12.5 9 9 Others 53.5
Q3	City management Consulting firms	23.5 20	Technology providers Financial institutions Urban planners	13.5 10 10 Others 23

*Others represent diversified unrepeated answers less than 7%

Table 6 Interviews keywords results (Identifying KPIs)

Question	Most frequent	Frequency (%)	Secondmost frequent	Frequency (%)
Q1	Economic indicators Operations efficiency	27 27	Global Strategic goals	20 20 Others 6
Q2	Strategic goals	42	Operations efficiency	17 Others 25
Q3	Both global and local indicators	67	Global indicators only Local indicators only	22 11 Others 0

*Others represent diversified unrepeated answers less than 11%

Table 7 Interviews keywords results (Operation models)

Question	Most frequent	Frequency (%)	Secondmost frequent	Frequency (%)
Q1	Collaboration Technology People	17 17 17		
Q2	Collaboration People	21 21	Technology Funding	16 11 Others 31

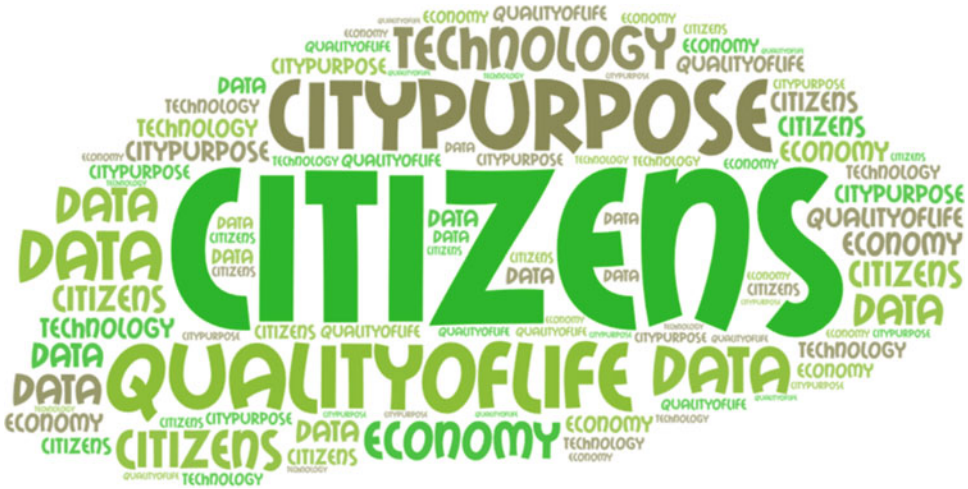

Fig. 2 Word Cloud for the answers to Q1; the supposed focus of city vision

residents, etc. As a service provider, any product or service should satisfy its customer. The quality of life of people and the economic factors are very important for the success of any smart city and it should be improved by technology and data collected (Fig. 2).

These findings are aligned with the adopted definition of smart cities "A city can be defined as 'smart' when investment in information and communication technology (ICT) infrastructure and services fuel sustainable economic development and a high quality of life, with a wise management of city resources." Second, the most important elements to consider in a smart city are sustainability and people. Smart cities should target sustainability whether economic, environmental, operational, or social. Smart cities must ensure there are outcomes that help in the continuous enhancement of these cities. Smart cities should target the optimization of resources and make better use of available resources. Revenue streams were also repeated frequently because this is the main way to ensure the return on investment for such initiatives. Third, building the vision of smart city initiatives should be collaborative between different stakeholders. These stakeholders must include residents, consulting firms, technology providers, city administrators, and can also be extended to include different businesses, universities, financial institutes, or city visitors to ensure the participation of all stakeholders of the city.

Answers to the second set of questions (Building the Roadmap) suggest that any smart city roadmap should focus on improving the environment, enhancing mobility, building solid and strong infrastructure, facing economic challenges, and optimizing the use of energy and water. Any smart city is different when it comes to selecting technologies and building the roadmap. For building a successful roadmap, it should be aligned with the priorities of the cities and driven

from their objectives. It should consider available resources and not overestimate the capabilities of the city. It should also be localized, based on the type of the city. The answers to the third question suggest that building the roadmap of smart city initiatives should be shared by the same stakeholders who participate in building the vision. The only major difference that needs to be highlighted is the introduction of financial institutes as main stakeholders in this step. This can be understood because the financial capabilities and resource availability affect the execution of the roadmap and the phasing of the projects. The type of services and revenue streams can also be affected by the availability of fund.

Answers to the third set of question (Identifying KPIs) suggests that, like any project, smart city projects importantly focus on generating financial outcome for the city and bringing the return on investment (ROI). That is why KPIs should consider the financial performance of smart cities. The efficiency of smart city solutions should also be assessed. This can differ from one project to another based on the type of services offered. The safety of the people is also one critical factor to consider in smart cities. The use of technology should increase the safety of the people. The word global was also mentioned in the context of identifying KPIs because cities don't have to re-invent the wheel and they can rely on global standards to benchmark and assess their performance. KPIs are different between cities because of the possible differences in their visions, roadmaps, and objectives. Each city may have a different set of KPIs or focus on a specific set of KPIs in globally identified indicators. These KPIs can change over time based on the maturity of the city, evolution of its operation, and feedback provided from different stakeholders (Fig. 3).

Interestingly, however, in the third question, most of the respondents thought that it would be better to follow international standards despite the fact that the smart city initiative is a localized one. This shows that the starting point for any smart city initiative should consider first global standards and benchmark with other global cities. Afterward, the indicators should be more localized as the knowledge increases and more exploration is made in terms of changes needed in the organization, regulations, operation, etc.

Answers to the fourth set of questions (Operations Model) suggest that first in any organization there are three main elements that affect the operation of any organization. These elements are technology, processes, and people. In the smart city context, technology is the major factor of enhancement and this typically leads to less number of people to run the organization and different processes to be followed. The respondents also highlighted the importance of using integrated and smart tools requiring a higher level of skilled employees. This shows the importance of building a highly competent operational team to run such complex technologies. Second, that in order to better manage any city; the management should keep an eye on the best combination between technology, people, and improvement of processes. Since any element that is not well planned can ruin the smart city initiative. On the same hand, city officials should consider available funds and financial capabilities to run the city. It should be clear that one of the main goals of a smart city is the economic development and sustainability of services, which cannot be achieved without a financial return.

4 Conclusions

Based on the questions posed in this study; "Is there a set-menu to adopt a smart city approach," the results of this study show that a citizen-centric smart city is highly important to ensure the success of the initiative. Every Smart City Initiative should develop its own proper vision,

Fig. 3 Word cloud for the answers to Q3; the source of KPIs

objectives, and guidelines that are derived from the local stakeholders, not by a politician or for the sake of propaganda. Smart Cities should be "Citizen-centric" to ensure success. The citizen is the beneficiary and should be part of the journey of smart cities from start to end.

As for the second question, "Should urbanists seek standards for quality assurance or develop localized approaches?", cities may and should have global pillars and policies, but other objectives based on local needs stemmed from these main objectives. Quantitative benchmarking on a regional and global scale is important, "What can't be measured, can't be improved." Cities should consider benchmarking their performance with other regional cities in order to make sure of their competitiveness against such cities.

To avoid a Failed Smart Cities Framework, each country should also consider the regulatory and legal framework to enable key stakeholders to work within the new smart city environment. Key elements in any smart city implementation must include collaboration between different stakeholders and the integration of systems and applications with proper governance for data. A national study identifying which existing cities have the highest priority within a proper KPIs and roadmap. Cities differ in terms of size, population, demographics, and economic base. Accordingly, there is no "one size fits all" smart city transformation plan.

Conventional wisdom always assumes technology and technology alone is the key to the success of any smart city. Indeed, technologies are an integral part of Smart Cities, but not as an objective in itself rather used as means to achieve city objectives. Smart city initiatives should include the improvement of quality of life, management of resources, the economy, and sustainability.

Cities must change their traditional operational models to a more integrated model. Cities should keep in mind that process reviews and improvements should be carried out periodically, and training programs and capacity-building plans should be continuously developed and executed.

To avoid huge increases in prices, city management should consider offering new value-added services such as offering parking reservations through mobile applications, providing remote security monitoring.

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Transportation in Smart Cities

Mobility as we now know it is undergoing changes that are already transforming cities and societies and its role in creating smart, world-class cities cannot be overlooked. Innovative transportation, digital connectivity and technological advancements are the root causes of transformation in how we live, work and travel every day. In recent years, socio-economic forces, social networking, location-based services and similar advances in technology are contributing to the growth of shared and on demand mobility. This part highlights smart transportation as one of the main ways in which smart cities can improve the lives of citizens through information systems, collecting data, optimizing and regulating the use of private cars and New Smart City technologies that introduce connected cars, mobile apps, electric vehicle rentals and more.The transportation planning process includes an essential phase known as mode choice. Mode choice is determined by speed, flexibility, cost, safety and quality and more can determine economic condition, comfort and environmental effects on a city. In "Choice of Travel Mode for Work Trips for Dhaka City to Enhance Travel Experience", an analysis of the mode choice behavior of work trips in Dhaka City based on users assessment is undertaken. Cost, trip chains on work-related days, time from one venue to the other are assessed for 1000 respondents. Similar studies are useful for urban planners and policymakers in their pursuit to enhance the user travel experience. By highlighting, the attributes enacting the role of overall mode choice assessment to evaluate public transit ridership and identify alternative modes of transportation. In "Exploration of Urban Regeneration and Design of Characteristic Streets: A Case Study of Chengxian Street", the urban regeneration and design perspective are taken to analyze the evolution of a street in Nanjing, China, by considering traffic optimization, public communication, street landscape and characteristics and street scales. The author presents a case study to strengthen the attention given to street development in China.Cities are considered hubs for culture, business and innovation, which enables humanity to proper socially and economically. However, traffic congestion can often stand in the way of that. There are a number of elements that make up smart city transportation, one of which is Advanced Traffic Management Systems (ATMS). In light of this, the Chapter titled "Integrating Pedestrian Circulation with Proposed Rapid Transit Route: Design Proposal of a Skywalk for Smart Dhaka" tackles one of the most prominent challenges hindering our progress today. The authors conduct extensive field research in Dhaka of Bangladesh to accommodate pedestrian mobility issues in developmental plans before proposing an elevated Bus Rapid Transit (BRT) line and an elevated skywalk below to minimize traffic congestion, ensure the safety of the pedestrians, work toward a Smarter Dhaka and contribute to achieving the Sustainable Development Goals (SDGs) set out by the UN for 2030.Moreover, the challenges posed due to urbanization, congestion and emissions have often been answered with Smart Mobility, where integrated technological advances and mobility management systems can help make transportation more efficient, clean and safe. Similarly, advances in transport monitoring systems and intelligent communication technologies have made it easier to work on reducing congestion and emissions as part of green city initiatives. In this part of the book, the authors pinpoint "The Importance of Green Commuting: A Campus Case Study in Schwäbisch Hall as Contribution to Responsible Urbanism". Proposed in this chapter is an increase in green infrastructure and reduction of emissions to secure healthy living conditions through a shift in mobility and transport to emission-free sources. The authors try to investigate the potential for green mobility at universities in rural areas as a contribution to smart and responsible urbanism.

Choice of Travel Mode for Work Trips for Dhaka City to Enhance Travel Experience

Farzana Rahman, Md. Nasif Rabbi, and Md. Ariful Islam

Abstract

Mode choice and trip chaining behavior of developing cities are gradually becoming more complex due to rapid urbanization and economic growth. The aim of this research is to analyze the mode choice behavior of work trips in Dhaka city based on users' assessment. A face-to-face interview survey was carried out in Dhaka city to 1000 respondents. The result shows that majority of the respondents' monthly household travel cost was 3000–5000 Taka. About half of the respondents said that they make simple home to work; work to home (h-w-(-w-)-h) trip chain on work-related days. Most of the respondents reported that they make only one nonwork (h-nw-h) trip chain on nonwork-related days. About half of the respondents stated that they make more than one nonwork activity (h-nw-(-nw-)-h) trip chain on nonwork-related days in a month. One third of the respondents mentioned the waiting time for a travel mode is 5–10 min and their travel time was 30 min to reach workplace. Respondents use bus, train, or paratransit as their main mode of travel and they are not interested to change it, although half of them considered the mode as uncomfortable. Majority of the respondents did not have a household motorized vehicle, while half of them said that their workplace has no parking facility. This research may be utilized by administrators or urban planners to enhance the users' travel experience and to maximize the utilization of inadequate resources, which would enhance the travel modes.

Keywords

Mode choice • Work trips • Trip chain • Dhaka city

1 Introduction

Mode choice and trip chaining behavior are one of the essential stages in transportation planning procedure bearing a noticeable impact on the formulation of transportation decision. Commuters' trip chaining behavior of developing cities are increasingly becoming popular for the last few decades. The choices of suitable mode may be determined by the costs, speed of transport, flexibility, regularity of service, safety and security, quality of service, capacities, frequencies, comfort, and other considerations of the modes together with the nature of trips and distance of destinations. The mode choice model is one of the fundamental models in decision-making of transportation since it plays a significant role in constituting transport guiding principle (Ortúzar and Willumsen 1994). Nowadays, mode choice modeling is based on utility maximization. It maximizes the utility function by reducing delay, accidents, congestion, and environmental effect. It can also affect positively to maximize utility by increasing economic condition and comfort.

Dhaka, the capital of Bangladesh is a heavily inhabited and extremely overcrowded capital in the world having 122,700 people per square mile in 2018 (Demographia 2018). The percentage of current urbanization level is about 30% and anticipated to increase 50% by 2050 (STP 2005). The profile of Dhaka city is shown in Table 1. The need to study individual trip attributes and choice of transport mode is very important for determining the travel behavior in an area as well as for proper transport planning and decision making. In this research, the type of transport mode indicates respondents' usual travel mode for their every-day work commuting. The aim of this research is to analyze the mode choice behavior of work trips in Dhaka city based on users' assessment.

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2 Literature Review

Travelers' mode choice behavior is persuaded by several factors ranging from social to financial factors and also motivated by travel-related attributes like travel time, cost, waiting at station, and contentment from trip, and a lot more. Zhao et al. (2002) explored that better service of public transport can attract further passengers, while poor service invites more personal vehicles. Trip attributes influence the selection of a specific mode (Racca and Ratledge 2004). Further researches (Strathman and Dueker 1996; Ye et al. 2007) showed that trip intricacy has a significant impact on the choice of a mode. Household position, proximity nature, and other inner-city characteristics demonstrate an eminent role in influencing the preferred commuting mode (Pinjari et al. 2007; Frank et al. 2008).

Habib (2002) established a typical four-step model intended for Dhaka city. Bus, tempo (motorized paratransit), private car, and rickshaw were considered as main modes of travel for the model. The model used three explanatory variables for the mode choice model namely journey period, travel expenditure, and contentment. Result suggests that comfort had a significant impact rather than journey time and cost implying that people are more sensitive toward the comfort provided by the mode than the travel time and expense which is unrealistic (Habib 2002).

A mode choice model for the work trips was established by Aftabuzzaman et al. (2010) for the middle-income group of Dhaka city. The primary data source was the household interview survey of about 200 people. Only three modes, i.e., rickshaw, bus, and auto-rickshaw were considered for developing a multinomial logit model. The research work also presented three policy scenarios in terms of decrease in bus fare, decrease in travel time of bus, and increase in rickshaw fare. All the scenarios resulted in a rise in the modal share of bus and a fall in the share of rickshaw and auto-rickshaw. Tushara et al. (2013) described the significance of choice of a mode for decision-making strategies regarding policies for trip makers. Attributes that affect the choice of housing location are motivated by demographic factors, workplace location, and some most important activities such as education and shop. Hence, to systematize transport and regulate action scheme successfully, mode choice investigation is essential (Cai et al. 2015).

3 Methodology

A face-to-face interview survey was conducted on 7–13 April 2016 between 9.00 a.m. and 4:00 p.m. Questionnaires were handed out at transportation hubs like bus stops, in paratransit paths, to personal vehicle travelers, in taxi lines, or parks areas. The random convenience sampling system was used since the respondents were who were asked to take part in the survey were duly reachable. Random sampling offers a better estimation of the population and ensures that the sample is free of biasness and hence more illustrative than non-probability samples (for example see, Lazerwitz 1968). Abrams (2010) mentioned that, in convenience sampling method, respondents are selected based on their easy access to their location, and availability. Nonetheless, due to the existing conditions and financial limitations, academics in different research areas depend largely on convenience sampling (Randall and Gibson 1990).

The questionnaire had total 19 questions (variables) divided into four major components: The first portion was regarding the socioeconomic information of passengers, the second portion was about employment station features, the third portion was about trip characteristics, and the forth portion was about trip chain employed by the respondents. The variables are respondents gender, age, marital status, educational qualification, monthly household earnings, family size, number of household children, number of household adults, occupation, working hour per day, number of household motorized vehicle, monthly household travel cost, parking availability at respondents' workplace, waiting time of respondents for a mode, number of changing mode to get the destination, home to work trip distance of respondents, trip chain types, mode of travel within a month, in-vehicle travel time to reach workplace, and comfort level

Table 1 Profile of Dhaka city (Demographia 2018)

Parameters	Dhaka
City area (square mi)	119
Metro area (square mi)	11990
City population	14400,000
Metro population	19,578,421
City density (per mi^2)	122,700

Table 2 General characteristics of respondents

Features	Statistics
Gender	Male (96%), Female (4%)
Marital status	Married (71%), Single (29%)
Age	20–30 years—30%, 31–40 years—43%, above 40 years—27%
Educational qualification	Ph.D.—1, Graduate—63%, Secondary—27%, Below secondary—7%, no schooling—2%
Children in a family	Not any—35%, One—31%, Two—29%, Three—3% More than three—2%
Adults in a family	Single—9%, Two—41%, Three—24%, Above three—27%
Total members in a family	One—5%, Two—7%, Three—25%, Four—31%, Five or more—34%
Employment	Job—73%, Business—23%, Other—4%
Office hour in a day	3–5—1%, 5–7—4%, 7–9—54%, above 9—41%
Monthly family income	5000–10,000 Tk.—1%, 10,000–20,000 Tk.—20%, 20,000–40,000 Tk.—43%, >400,000 Tk.—36%
Number of household motorized vehicle	None—69%, One—26%, Two—5%
Travel expenditure of a family per month	Less than 500 Tk—9%, 500–2000 Tk.—19%, 3000–5000 Tk.—38% 6000–10,000 Tk.—23%, above 10,000 Tk.—11%

Approx. 1 US $ = 85 Tk

in a mode. The survey was conducted to have a clear understanding of respondents' trip characteristics and mode choice behavior on work-related days.

Seven experienced surveyors were instructed and appointed to administer the survey. First, they concisely explained the rationale of the current study to the respondents and distributed the questionnaires to them to complete. The filled questionnaires were collected back onsite to confirm better and functional answers.

Fourteen different locations in Dhaka city were selected for the survey having heterogeneous nature of land uses including residential buildings, commercial organizations, and educational institutions. Those locations were chosen because the roads carry heavy and mixed modes of traffic. The survey involved 1025 questionnaires with semi-structured interview questions conducted with car-owning and non-car-owning respondents. A total of 980 samples were employed for analysis after discarding the incomplete one.

3.1 Demographic Information of Users

The sample is categorized by a higher percentage of males (96%) than females' percentages. Female participants are very much reluctant to talk to the enumerators during the field survey; hence their percentage is very low. Seventy-one percent of the respondents are married and 29% are single; 43% of the users are between 31 and 40 years old; and 63% of respondents are graduates. thirty-five percent of the respondents had no children, while 32% had one child and 28% of respondents had two children. Moreover, 42% of the respondents had two adults in his/her family. 34, 30, 24, and 6% of the respondents stated that they had five or more, four, three, and only one family member, respectively. Seventy-three percent of the respondents are service holders and 23% are businessman. Family monthly income is one of the main factors to choose mode of travel. Fifty-five percent of the respondents working hour per day is 7–9 h, while 40% and 5% of the respondents working hour per day is above 9 h and 5–7 h, respectively. Forty-three percent of the respondents stated that their monthly income range is 20000–40000 Tk. Most of the respondents (69%) did not have a motorized vehicle. Thirty-eight percent of users replied their monthly household–travel expenditure range is 6000–10000 Tk. Table 2 shows the general characteristics of respondents.

3.2 Result and Analysis

The result shows that half (50%) of the respondents said that they have no parking facility at their workplace, while 26% and 20% said they have good and moderate parking facility at their workplace, respectively, as shown in Fig. 1. About 34% of the respondents answered that the waiting time for the mode is 5–10 min, while 31 and 27% answered less than 5 min and 10–15 min, respectively, as shown in Fig. 2.

Seventy-nine percent of the respondents reported that they didn't change their mode to reach destination. Eighteen percent, 2, and 1% of them expressed that they change mode once, twice, and thrice, respectively, as shown in Fig. 3. Trip distance of respondents from home to workplace is less than

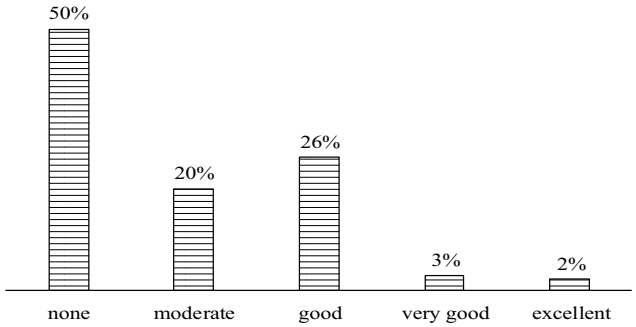

Fig. 1 Parking availability at workplace

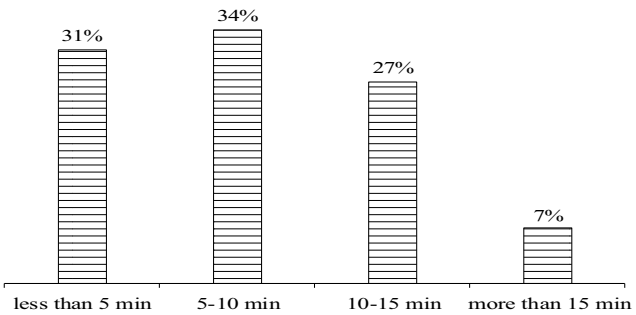

Fig. 2 Waiting time for a mode

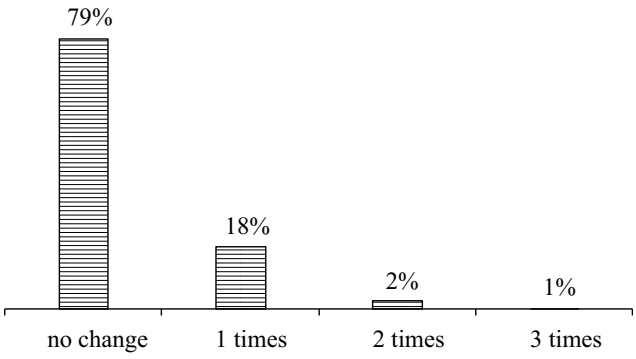

Fig. 3 Number of changing mode to reach destination

1 km, 1–3 km, 3–5 km, and above 5 km as reported by 14%, 36%, 26%, and 24% of them, respectively, as shown in Fig. 4.

Eight types of trip chains are investigated in this study, (Islam and Habib 2012):

Type 1: Simple home to work and work to home (h-w-(-w-)-h) trip

Type II: Single nonwork stop from home to work and one nonwork stop from work to home (h-nw-w-(-w-)-nw-h) trip

Type III: Single nonwork stop from work to home but no nonwork stop while going to work (h-w(-w-)-nw-h)

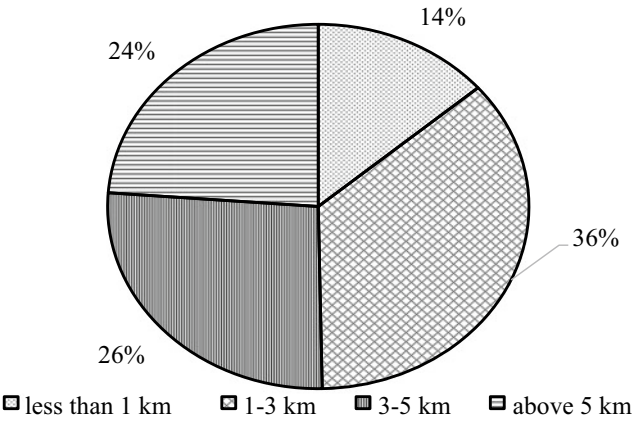

Fig. 4 Home to work trip distance

Type IV: Two nonwork stop from work to home but no nonwork stop while going to work (h-w-(-w-)nw-nw-h)

Type V: Above two nonwork stop from work to home but no nonwork stop while going to work but (h-w(-w-)-nw-nw-(-nw-)-h)

Type VI: Single nonwork stop from home to work and no nonwork stop from work to home (h-nw-w(-w-)-h)

Type VII: Above one nonwork stop from home to work and one nonwork stop from work to home (h-nw-(-nw-)-w(-w-)-h)

Type VIII: others (compound nonwork stops from home to work travel and from work to home travel not mentioned in trip chain pattern I–VIII).

Table 3 shows the number of specific trip chains respondents make in work-related days in a month. Fifty percent of the trip chains were 'Type I' trip chain. Above 15 days respondents made this trip chain for 829 trips and 11–15 days respondents made this trip chain for 41 trips. Respondents made 1–5 days 'Type II' trip chain to make 158 trips and 'Type III' trip chain to make 204 trips in a month.

Fifty percent of the respondents said that they made 'Type I' trip chain during work-related days within a month. Twenty-six percent made 'Type III' trip chain, 14% made 'Type II' trip chain, and 2% made 'Type IV' trip chain in a month. Respondents made 'Type V', 'Type VI', 'Type VII,' and 'Type VII' trip chain as 1%, 2%, 0%, and 5% people, respectively, during work-related days within a month as shown in Fig. 5.

Trip chain comprising only one nonwork activity (h-nw-h) is shown in Fig. 6. Sixty-eight percent of the respondents reported that 1–5 days they did h-nw-h trip chain within a month, while 6% of the respondents reported that they did 6–10 days h-nw-h trip chain within a month in nonwork-related days. Twenty-five percent of the respondents reported that they did not make h-nw-h trip chain on nonwork-related days.

Table 3 Trip chain in work-related days

Trip chain	Number of specific trip chain respondents make in a month				
	1–5	6–10	11–15	Above 15	Percentages (%)
1 Type I	20	30	41	829	50
2 Type II	158	56	19	32	14
3 Type III	204	168	86	28	26
4 Type IV	27	3	6	0	2
5 Type V	11	1	1	0	1
6 Type VI	15	3	0	18	2
7 Type VII	0	1	1	0	0
8 Type VIII	32	16	5	30	5

Elaboration of trip chain is mentioned in the previous section

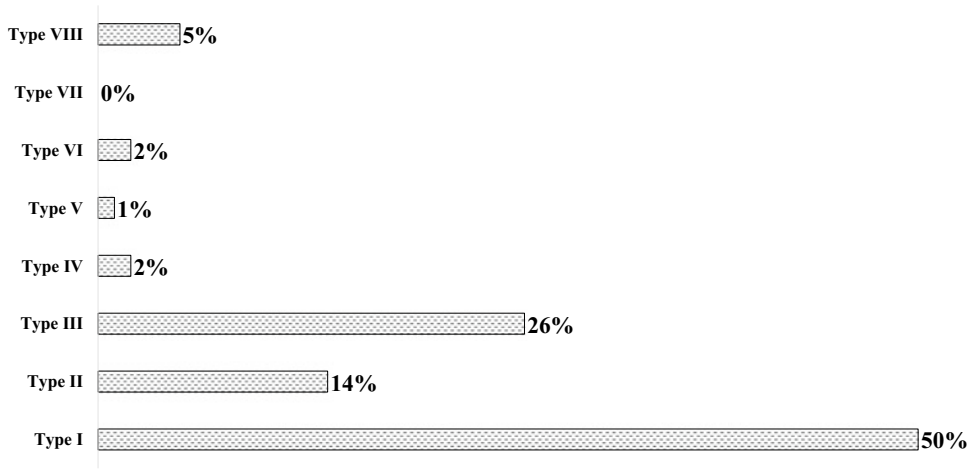

Fig. 5 Trip chan in work-related day

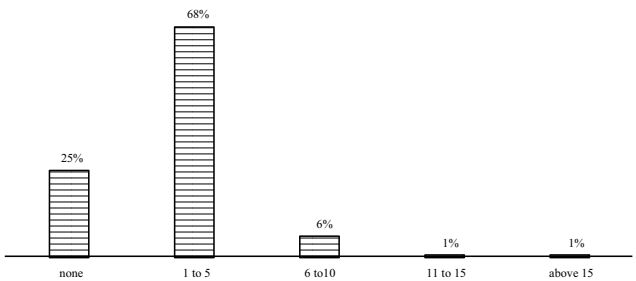

Fig. 6 h-nw-h trip chain within a month

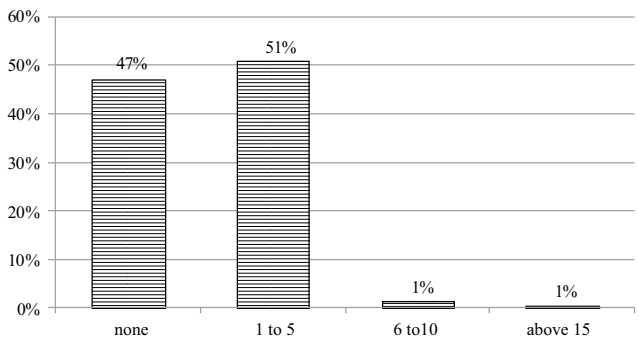

Fig. 7 h-nw-(-nw)-h trip chain within a month

Trip chain comprising above one nonwork travel (h-nw-nw-h) is shown in Fig. 7. Fifty-one percent of the respondents reported that they did 1–5 days h-nw-(-nw)-h trip chain within a month. Forty-seven percent of the respondents said that they did not make this type of trip chain in nonwork-related days.

Table 4 shows the frequency of using a particular mode of travel in a month. Public transport (bus, train, or tempo) is used by the respondents above 15 days for 607 trips in a month. Respondents made 121 trips by motorcycle, 114 trips by private cars, 85 trips by non-motorized paratransit (bicycle or rickshaw), and 32 trips by motorized paratransit auto rickshaw (CNG) in a month.

Figure 8 shows the types of modes used by the respondents. Forty-five percent of the respondents use bus, paratransit (tempo), or train as their main mode of trip. Nineteen percent, 11, and 9% of the respondents use bicycle or rickshaw, auto-rickshaw (CNG), and motorcycle for their trips to work, respectively. Rest of the respondents use private cars (8%), walk (5%), and taxi (2%) for work trips.

Table 4 Mode of travel in a month

Mode of travel	Frequency of using a particular mode in a month				
	1–5 days	6–10 days	11–15 days	Above 15 days	Percentage (%)
Bus, paratransit (tempo) or train	29	17	23	607	45
Auto rikshaw (CNG)	76	33	20	32	11
Private car	3	2	3	114	8
Taxi	26	5	1	3	2
Motor cycle	4	2	8	121	9
Bicycle or rikshaw	115	63	24	85	19
Walk	18	9	4	40	5

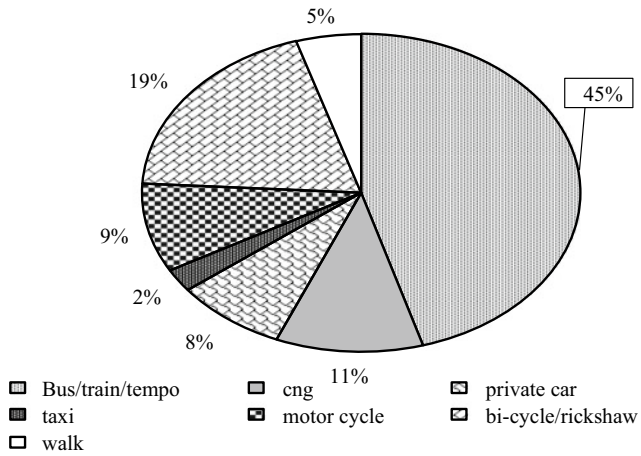

Fig. 8 Types of modes used in a month

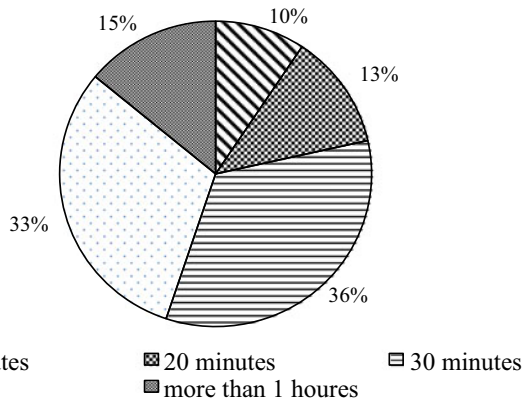

Fig. 9 In-vehicle travel time of respondents

36% of the respondents replied that in-vehicle travel time to reach workplace was 30 min, while 33% said 1 h as shown in Fig. 9. Forty-nine percent of the respondents said that the mode was uncomfortable and 42% said comfortable as shown in Fig. 10.

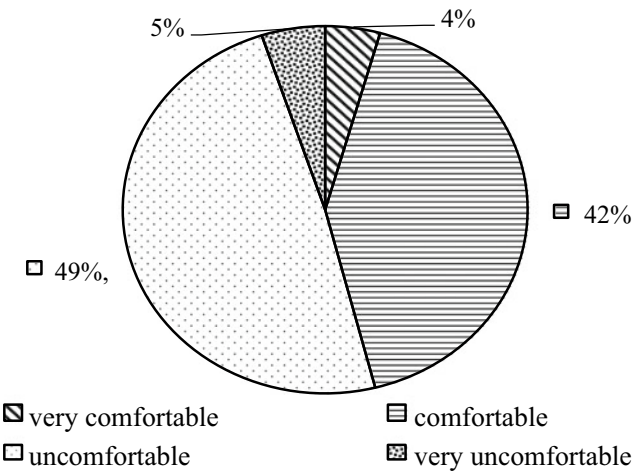

Fig. 10 Comfort level of respondents at a mode

4 Discussions

This research evaluated the attributes influencing the choice of travel mode for work trips in Dhaka city. The study involved an on-site questionnaire survey conducted for trips in Dhaka city. Majority of the respondents were service holders. Half of the respondents said that their workplace had no parking facility. It may be concluded from the result that the respondents are somewhat captive and on occasion choose riders of bus for accomodating the travel expenses with their income level. Most of the respondents make simple 'home to work and work to home h-w-(-w)-h' trip chain in work-related days since trip makers usually do not like to change their mode of transport.

Majority of the respondents use mass transit as their main travel mode. About half of the traveler thinks the mode was uncomfortable. Although bus service in Dhaka city is poor; people have to rely on it heavily since they do not have any other option. Travelers' alternative specific attributes,

including waiting time for a mode, number of modes to reach destination, home to workplace distance, walking facilities to and from bus stop, and in-vehicle time are also important factors for choosing a mode. Certainly, a personal vehicle is deemed to offer better ease and suitability when assessed to mass transit modes that are commonly restrained with regard to uncomfortable sitting arrangement and congestion in roadways. However, it is true that the choice of mode may vary from time to time based on the overall transportation system and infrastructure development of the city.

5 Conclusion

The effectiveness of policies regarding the introduction of a new transit system or improvement of the existing one depends on studies of mode choice behavior. These factors are critical in determining the probability of specific factors, which might influence people to choose a mode or shift from one mode to another. The aim of this research is to explore the constructs influencing the selection of travel mode for work trips in Dhaka city, Bangladesh.

Variables such as monthly income, monthly travel expenditure, and a number of family members influence the choice of travel mode since users need to make a financial plan within their income level. Result shows that majority of the respondents use public transport as their main mode of travel. If the users believe the journey as convenient and easy they may choose mass transit rather than using private vehicles for trips although it may need an extra period. Number of mode changes within the travel course will reduce the comfort level. Conversely, 'Simple home to work and work to home type trip chain' is a usual type of trip chain since it takes smaller travel time. From this study, it was revealed that the choice of different modes of transport for work trips depends on various socioeconomic and transport service-related factors. It was also revealed that 'time to reach destination' and 'comfort level' of the mode are influential attributes to choose a mode.

Mode choice is influenced by 'waiting time for the mode' and 'number of changes of mode to get the destination'; which suggests respondents' negative impression to wait for the mode and to change modes to reach destination. Gleave (2006) explored that journey period is one of the most important factors considered by users during selecting a mode. Based on the socioeconomic condition of Bangladesh it is a common scenario that people with higher income prefer to use personal vehicle, while middle- to low-income people prefer public transport like bus, tempo, or rickshaws. Moreover, the inadequacy of satisfactory mass transit services together with the diversity of land usage patterns in Dhaka decreases their usage in upper earnings class people. The increase in availability of public transportation may augment users' reliance on it. Number of bus users may be increased if the travel time by it is reduced. Hence some improvements are necessary to improve the service and comfort level of public transport. Transportation organizations should investigate the causes for delays.

This research may help to maximize the utilization of inadequate resources, which would enhance the travel modes. It is imperative to highlight the attributes enacting a vital role in the overall mode choice assessment since evaluations of public transit ridership and the use of alternative modes of transportation are mostly depending on studies of mode choice behavior and modal share of users'. For these reasons, planners and administrators of public transport need to be more watchful about these attributes while planning measures for enhancing the use of public transport. Several statistical analyses can be developed for a proper understanding of mode choice behavior of work trips. Those analyses may help in different transportation planning in future.

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Exploration of Urban Regeneration and Design of Characteristic Streets: A Case Study of Chengxian Street

Bin Tang

Abstract

The paper selects Chengxian Street in Nanjing, the ancient capital of six dynasties as an example, which has experienced some regeneration and reconstruction in history. After a long period of development, it has developed into a characteristic street with a variety of functions. This paper is based on the perspective of urban regeneration and urban design with literature, field survey, and other research methods. The paper then mainly analyzes the concepts of regeneration and design, including the classical theories and successful cases. After that, this research divides the evolution of Chengxian Street into stages and analyzes the characteristics, respectively. It shows that Chengxian Street had undergone five stages since the Ming dynasty: First, the period of prosperity 1381–1853; second, the period of destructive destruction 1853–1864; third, the period of restoration and reconstruction 1864–1949; fourth, the period of local regeneration 1949–2010; and now in a period of comprehensive regeneration. The current practice is oriented toward the objectives of organic regeneration. In addition, it also focuses on the problems existing in the recent regeneration and reconstruction of Chengxian Street after two comprehensive regeneration, including lack of traffic calming, several pedestrian spaces are not accessible, lack of public communication, poor street landscape, lack of local characteristic, and some street scale are unreasonable, etc. Finally, the paper gives further thoughts on the regeneration and design of Chengxian Street about traffic optimization, public communication, street landscape, street characteristics, and so on in order to promote the development of characteristic streets.

Keywords

Nanjing • Chengxian street • Urban regeneration • Urban design

1 Introduction

In the 14th year of Hongwu (1381), Zhu Yuanzhang, the first emperor of the Ming dynasty, who believed in the primary importance of education for the government, ordered that imperial college be built to the south of Jilong Hill (today's Jiming Hill). It was the dynasty's highest institution of learning and one of the world's largest institutions of higher learning at that time. The street by the imperial college, which was frequented by the students, was called Chengxian (becoming sages) Street because it was believed that the college could turn scholars into sage qualified for civil service.

Chengxian Street is a famous cultural street in Nanjing, the ancient capital of six dynasties in China. It is located in the central city of Nanjing, not far from the Nanjing government, the former capital Presidential Palace, 1912 Bar Street, Xinjiekou CBD, as well as Jiming Temple, Ming Great Wall, Xuanwu Lake, and other famous historical attractions. Chengxian Street is a branch road of the city, runs from the north to the south, from Zhujiang Road in the south to Beijing East Road in the north. It is 857 m long and 11.5 m wide, with a one-way lane. Historical sites on the street include the site of National Central University (the present Southeast University, including nine historic buildings in Nanjing), the Ministry of Education (Nanjing cultural relics protection units) of the National Government, the National Central Library (cultural relics protection units in Jiangsu Province) in the former capital period, and the former residence of Yang Tingbao, a great modern architect (Nanjing cultural relics protection units), etc. (Fig. 1). Meanwhile, the place name Chengxian Street is also a

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non-material cultural heritage of Nanjing. Although Chengxian Street has many historical buildings, it still fails to meet the requirements of historical blocks because the historical buildings on the street are too scattered to meet the evaluation standard of no less than one hectare of core protected area stipulated by China. Therefore, this paper classifies it into characteristic streets and studies them.

Over the past 600 years, Chengxian Street has been destroyed, but the area has been famous for its indoctrination. In addition to the historical buildings mentioned above, there are also a large number of modern shops on both sides of Chengxian Street, and modern buildings with different functions such as courts, banks, offices, hospitals, student dormitories, and communities.

In 2010 and 2018, two relatively comprehensive regeneration of Chengxian Street were launched by the Nanjing government, and the appearance of the street has been improved to varying degrees. However, there are still many problems in it, such as weak culture of physical environment, poor design or lack of design, unreasonable street traffic, including illegal mixture of transportation and disorderly parking, especially motorcycles. There have been relevant researches on Chengxian Street in recent years. For example, Gao and Han (2013) studied the history of Chengxian Street, while Huang (2017) studied the street space and creation of the vitality in three streets including Chengxian Street based on the concept of sharing. However, there are some problems in the existing research, for example, introduction over research or pay more attention to analysis but ignore the conclusions and the characteristic of Chengxian Street, etc. In view of this, this paper based on the recent renovation of Chengxian Street, combined with classical street design theory and traditional street regeneration and design methods, puts forward suggestions for regeneration and design of Chengxian Street in the future, in order to promote the space quality and vitality of Chengxian Street better.

2 Review of Related Literature

2.1 Self-organization Theory

Hillier (2007) held that the process of self-organization of space not only existed in traditional society but also existed in modern society. The self-organization of space in today's society should attach equal importance to man-made design. Yoshinobu (1984) believed that cities in Japan seemed chaotic and lacked order, but they didn't have adverse consequences. Instead, they were full of vitality and prosperity, which were mainly attributed to the hidden order in Japanese architecture and cities. Duan (2006) pointed out that the phenomenon of self-organization existed in the development of things widely, and extended it to urban

Fig. 1 Location of Chengxian Street (Made by author)

space, pointed out that the urban system was a typical self-organization system.

2.2 Street Regeneration

In the regeneration of characteristic streets, Chen (2009) believed that the main function of urban streets was mainly to provide public life, while new buildings in non-historical blocks should not only focus on the coordination of historical features but also reflect the atmosphere of the times. Yu and Lu (2008) emphasized that the characteristic street space should embody the characteristics of the city and pay attention to the protection and development of the street quality through systematic investigation and research on the streets of Beijing Old Town. Tang and Yang (2011) put forward the renovation goal and implementation principle of traditional street vitality creation based on the case studied of Jingdezhen Porcelain Street. Li (2017) also put forward the technical countermeasures of street landscape construction from the perspective of cultural inheritance. In addition, some studies of Wei and Zhang (2009) started with the relationship between traditional elements and cities and summarized the design principles of street furniture and traditional elements.

2.3 Street Design

In order to alleviate the contradiction between people and vehicles, improve the walking environment of streets, meet the needs of different street users, and reproduce street public activities and street vitality, many classical theories have been formed internationally. For example, Jacobs (1961) believed that safety and communication were the characteristics of a city. To create a rich variety of streets in a city, four conditions must be met simultaneously: complex functions, short streets, various buildings, and density of people. Jan (2011) studied the public activities of human beings and the public material environment needed for these activities. Yoshinobu (1989) clarified the classification, constituent elements, proportion, and scale of streets, and discussed the relationship between streets and cities, the behavior activities carried by streets, and the related theories, techniques, and methods of streets. Allan (1995) made a comparative study of hundreds of streets around the world. He believed that great streets should be places for walking, with a comfortable physical environment, clear boundaries, pleasant scenery, transparent buildings, careful maintenance and management, and harmonious coexistence between buildings and streets. Stephen (2004) studied how to create better urban places without compromising basic functions such as traffic circulation and access. Moughtin (2003) discussed the function, structure, and symbolism of streets, squares, and buildings from the perspective of urban design, aiming at restoring the pleasant scale of medieval cities. Michael and Evan (2003) traced the history of street design and planning, criticized the current situation we are in today, and proposed a more flexible, accommodating, and practical alternative.

3 Methodology

3.1 Documentary Research

This paper summarized the classical theories, methods of regeneration, design of ordinary streets, traditional streets and analyzed the evolution process of Chengxian Street further by literature review in order to enhance the awareness of street vitality, traffic connotation, and grasp the development trend of Chengxian Street. In a word, the purpose of documentary research is to provide a basis for the improvement of street vitality and traffic optimization.

3.2 Case Study Method

This paper also studied similar streets at home and abroad in order to provide references for the regeneration and design of Chengxian Street.

3.3 Field Survey

This paper investigated Chengxian Street in detail from the aspects of traffic, landscape, characteristics, and public communication so as to find out the problems and put forward corresponding solutions combined with literature and case studies.

4 Chengxian Street Evolution Analysis

4.1 Flourishing Period (1381–1853)

Yongle, 19 years (1421), Emperor Zhu Di changed the name of Guozixue to Nanjing Guozijian after he moved the capital to Beijing. It was often called Nanjian and stood side by side with Beijian in Beijing. During the Yongle period (1403–1424), Nanjing Guozijian reached its peak, with more than 9,000 students at one time. In the seventh year of Shunzhi (1650), after the Qing army occupied Nanjing, Nanjing Guozijian was changed to Jiangning Fuxue.

4.2 Destructive Damage Period (1853–1864)

During the Taiping Heavenly Kingdom (1851–1864), Chengxian Street suffered devastating destruction. After the Taiping Army established its capital in Nanjing in 1853, Jiangning Fuxue was transformed into Zaifu Ya which is a government agency in charge of slaughter. The main buildings of Jiangning Fuxue were destroyed by the war (Wei 2013).

4.3 Restoration and Reconstruction Period (1864–1949)

With the failure of the Taiping Heavenly Kingdom, Chengxian Street was restored. Guangxu, 28 years (1902), Zhang Zhidong, governor of Liangjiang, founded Sanjiang Normal School on the west side of Chengxian Street, which pioneered modern higher education in China. In the 1920s, the Government of the Republic of China located the Ministry of Education (43 Chengxian Street) and the National Central Library (66 Chengxian Street) in Chengxian Street. In 1921, the government of the Republic of China approved the establishment of the National Southeast University on the site of the former Sanjiang Normal School which brought a new fashion of Western classical architecture to Chengxian Street. In 1928, the name of the university was changed to National Central University, which was the most comprehensive and largest university in China at that time. To the north of the Central University is Academia Sinica (now Jiangsu Science and Technology Office), which was also established by the Republic of China Government with a Chinese classical palace-style building, and it was built in 1934. The Examination Institute of the Government occupies the north of Chengxian Street to the root of the ancient city wall (now the government of Nanjing city), and it is also a Chinese classical architecture (Gao and Han 2013).

4.4 Partial Regeneration Period (1949–2010)

After the middle of the twentieth century, Chengxian Street maintained its intrinsic pattern, except the regeneration where occurred in some place. After 1949, the former Central University has undergone innovation. Its site is now inherited by Southeast University which is a famous university in China. The campus environment has been listed in the sixth batch of national cultural relics protection units because of its long history and unique features. In the late 1980s, a new Nanjing Science Hall was built at the east of the north end of Chengxian Street, designed by Academician Zhong Xunzheng. After the construction and development of the peace age, there are many shops in Chengxian Street, including print shops, stationery shops, clothing stores, hotels, barbershops, supermarkets, Starbucks, and KFC. At the beginning of the twenty-first century, Nanjing High-level Talents Exchange Center was set up in the middle of the street.

4.5 Comprehensive Regeneration Period (2010–2019)

In 2010, the government of Xuanwu District, where Chengxian Street is located, launched a new project to renovate 103 streets and alleys within its jurisdiction. Chengxian Street has been renovated with the addition of Chinese-style purple bamboo, doorway, black brick, and small tile, an introduction to the Guozijian has also been designed along the street. After that, the historical and cultural atmosphere of Chengxian Street has been strengthened and publicized. At the end of 2018, the road renovation project of Chengxian Street and Beiting Lane began and was completed in mid-February 2019, and the contents of renovation mainly include renovation of elevation along the street, new asphalt pavement, greening, and upgrading, etc. The landscape of Chengxian Street has taken on a new look after renovation (Fig. 2).

5 Chengxian Street Core Issues Analysis

5.1 Traffic Calming Design and Facilities

In fact, Chengxian Street has consciously carried out some traffic calming before. It is a one-way lane with narrow pavement, including roadside parking on one side and non-motorized lanes on both sides with sidewalks on the outermost side of the street. Public transport such as bus and taxi are mixed in the motor lane. In addition to the original landscape trees planted on the outermost side of the street and in the central reserve area, low shrubs were planted in the central reserve area after the renovation in 2019. It not only beautifies the street environment, makes the street environment-friendly but also further reduces the width of the street visually. The above measures have greatly reduced the speed of Chengxian Street and the transit traffic to a certain extent, thus ensuring the safety of the street and providing possibilities for public communication.

Traffic calming practice in some developed countries such as Britain, Germany, the Netherlands, Denmark, and Sweden show that road arch, pavement materials, deceleration signs, and raising sidewalks may also be used to implement traffic calming except the traditional methods. Unfortunately, no such facilities and designs have been found in Chengxian Street.

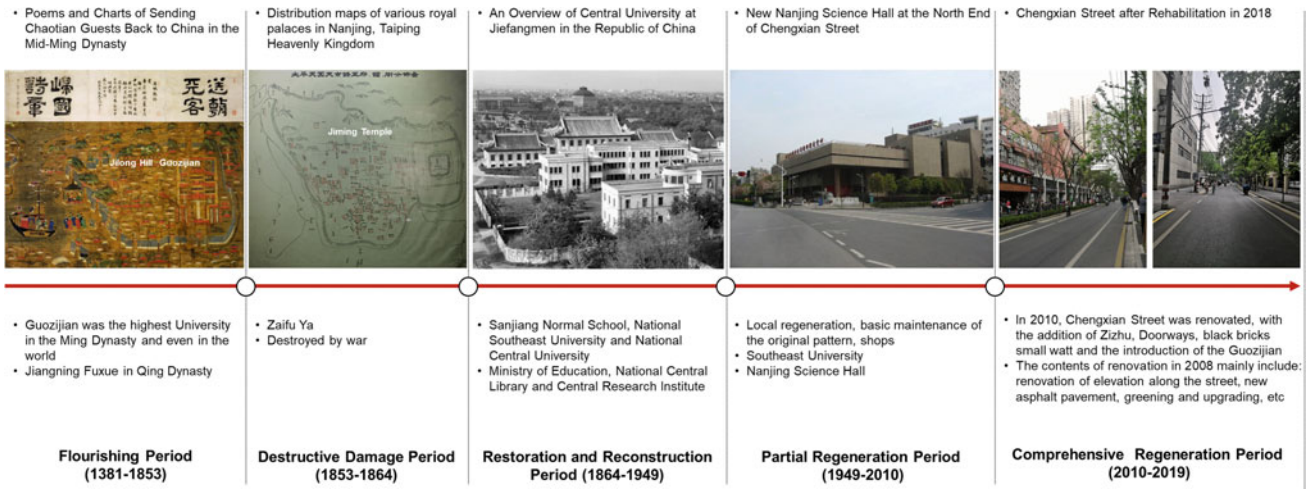

Fig. 2 Evolution of Chengxian Street regeneration and design (Made by author)

5.2 Street Landscape

In "Great Streets," Allan (1995) emphasized that streets become great because of "change." However, he also pointed out that vision must not be so rich that it became confused, disordered, and noisy. All the wires in Chengxian Street are laid overhead, showing a dense and chaotic picture over the street. Especially in winter, the trees have more branches and fewer leaves at that time. The sight goes through the complicated black wires and interweaves with many black branches, which aggravates the confusion of street space. Besides, all kinds of illegal mixing traffic and disorderly parking of vehicles (especially a large number of electric vehicles) are also the main reasons for the chaos of the street landscape (Fig. 3).

5.3 Cultural and Design Quality

The material and form of pavement are an important way to display the local culture and set off the historical atmosphere. The motor vehicle lane and non-motorized lanes of Chengxian Street were paved with asphalt, while the sidewalks were paved with gray brick blocks before the renovation in 2018. As the years went by, some pavements are warped and loosened, and water splashing will occur on rainy days because of disrepair, causing an unsmooth experience. In view of this, after the road renovation project in 2018, both the roadway and the walkway have been replaced with asphalt material in order to improve the street smoothness and avoid the phenomenon of water splash (Fig. 4).

To a certain extent, the black asphalt material combined with the gray strip decoration makes the street simple and lively, which seems to be in harmony with the traditional characteristic of Chengxian Street. However, an objective fact seems to be overlooked by people, that is, Chengxian Street has a history of more than 600 years. Although it is not a historical block, its cultural characteristics can not be ignored. In 2010, The government of Xuanwu District used traditional elements to announce the long history and cultural atmosphere of Chengxian Street consciously, but it is

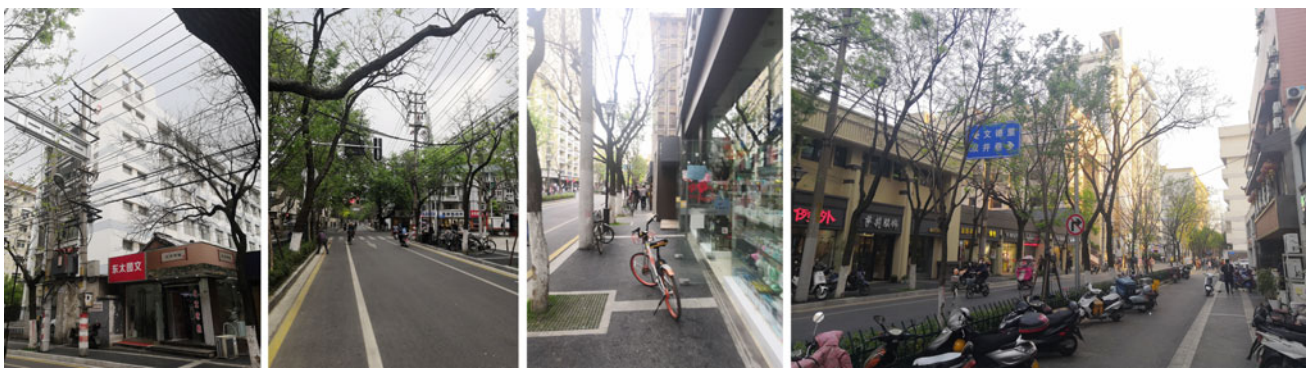

Fig. 3 Chaotic wires and non-motorized parking

Fig. 4 Renovation before and after 2018

still far from enough (Fig. 5). Recently, Chengxian Street has also worked with the wall along the street, adding a number of murals from the aspects of traditional culture and traffic, but the painting style and color are both worth discussing (Fig. 6).

5.4 Street Boundaries

The ratio of the width of Chengxian Street to the surrounding building height D/H is mainly between 0.7–1.2 and 0.8–1.4 according to the measurement. Chengxian Street is relatively close and symmetrical based on the D/H theory put forward by Yoshinobu Ashihara and the conclusion of 0.4–0.9 which exists in most great streets pointed by Allan B. Jacobs. However, a few high-rise buildings (three in total) make D/H at 0.2 or 0.3 cause the street space depressed slightly.

5.5 Walking Space and Walking Experience

There are two main reasons for the discontinuity of pedestrian space in Chengxian Street: one is illegal parking, the other is the discontinuity of the pavement itself. The west side of Chengxian Street has continuous pedestrian space, but there are a large number of illegal parking of electric vehicles, especially at the entrance of public buildings. It blocks the walking route, forcing pedestrians to continue to walk around the non-motorized lanes, causing safety problems for pedestrians and affecting the walking experience at the same time. On the east side of Chengxian Street, it is difficult for some sections of the road to build continuous walking space because some buildings along the street occupy the necessary walking space. In addition, some negative walking spaces are simply occupied by primitive key shops, abandoned telephone booths, exposed transformer boxes and other facilities cause the walking experience extremely poor (Fig. 7).

Until now, street furniture on Chengxian Street include street signs, stone carvings, street lamps, post boxes, road posts, telephone booths, power boxes, trash cans, newspaper booths, newspaper reading columns, painting columns, poetry columns, murals, flower beds, etc. But some furniture like seats, flower beds, sculptures, landscape walls, and other furniture are seriously lacking cause the quality of the street is not high. Meanwhile, some temporary garbage cans on the street are very casual in color, material, and the placement that also makes the street landscape poor (Fig. 8).

Fig. 5 Renovation after 2010

Fig. 6 Recent renovation

Fig. 7 High-rise buildings in Chengxian Street

5.6 Material Space and Communication Activities

At present, Chengxian Street hasn't been specially designed for people's social interaction. The main problems include poor quality, lack of public activities, interaction space is encroached on by parking, failure to combine ingenious design to form communication space (small parks, small squares, etc.), and failure to provide facilities for people to rest and sit idly (seats, steps, concaves of buildings, porches, etc.) (Fig. 9).

6 Suggestions

6.1 Urban Regeneration

In fact, only need to improve step by step, that can promote the quality and vitality of Chengxian Street because it has enough characteristics of being a great street. In order to achieve the purpose. The following set of measures should be taken:

Fig. 8 Street furniture on Chengxian Street

Fig. 9 Activities and possible communication spaces on Chengxian Street

- Follow the self-organization rules on the basis of maintaining the existing features of street.
- Use a small-scale, gradual organic regeneration model to improve the street as a whole.
- Protect and maintain existing historic buildings and promote their activation and utilization by giving them new functions.
- Give full play to the power of folk regeneration and combine with the effective guidance of the government to form a coordinated and innovative street landscape.

6.2 Overall Urban Design

The compilation of overall urban design is urgent, which may include the contents of function, traffic, parking, landscape, color, height, and furniture of street, etc.

6.3 Traffic Calming Facilities

The effective way to strengthen the traffic calming of Chengxian Street is to add traffic calming facilities (Fig. 10).

- Improve pedestrian areas, parking, speed limits, and other related traffic command boards to implement traffic calming further, while standardize various traffic behavior.
- Set block flat-top road arch (deceleration belt) on the motor lane according to the distance of 50–60 m or raise the intersection and pedestrian walkways (zebra crossing) by block so as to reduce the vehicle speed.

6.4 Traffic Calming Facilities Design

In addition to adding traffic calming facilities, the relevant design should be also carried out to form a good effect of traffic calming. The main method is to distinguish traffic calming facilities through the way of materials, colors in order to define the boundary of roadway and pavements (Fig. 11). Thus, narrow the motor lane visually and psychologically, making the streets safe, orderly, beautiful, and charming while reducing the speed of vehicles. For example:

- Build the road arches and walkways with the materials of Nanjing characteristics.

Fig. 10 Feasible traffic calming facilities

Fig.11 Suitable design of traffic calming facilities

- Unify the road arch and parking space into a beautiful light yellow.
- Set up colorful bicycle lanes on the basis of emphasizing routine maintenance by learning from the experience of Germany and Britain.
- Park the non-motor vehicles on the parking strip uniformly and consider to reduce the width of the west sidewalk if there is no sufficient parking space.
- Non-motor vehicle traffic except bicycle traffic can be restricted with the progress of city and improvement of policies in the future so as to solve the problem from the root.

6.5 Street Landscape

The poor street landscape is mainly caused by some chaotic wires and electric bicycles, so measures should be taken to make the street landscape more pleasant (Fig. 12), focusing on the renovation of chaotic wires and unreasonable electric bicycles. The specific measures are as follows:

- Standardize relevant behaviors through urban design so as to make the street more orderly.
- Cancel the non-motor vehicle parking on the sidewalks and return the space to citizens and their communication.
- Delineate the parking strip uniformly on the non-motorized lane near the west of central reserve area;

6.6 Culture and Design Quality

It is obvious that the characteristics of Chengxian Street are sectional, so it is necessary to carry out by sectional design. Through the way of traditional elements and deduction of traditional elements to reflect the culture and modern features. The plan requires the following measures:

- Use unique materials, cultural symbols, cultural themes, and appropriate cultural colors of Nanjing to decorate the pedestrian pavement in the section with more concentrated historical buildings based on the high-quality construction techniques.

Fig. 12 Potential street landscape

Fig. 13 Potential communication space

- Form a classic, natural, thick, and steady psychological feeling as a whole through the decoration of various street furniture in the section with more concentrated historical buildings to reflect the history and culture of Chengxian Street.
- Draw inspiration from the traditional materials, cultural symbols, colors and deduce modernization in pavement and furniture in the section of modern architecture, which mainly highlights the lively, simple, lively, and creative characteristics of modern cities.

6.7 Street Boundaries

Strict control should be exercised on the development of Chengxian Street, including the height and distance of existing and non-constructed buildings and measures should be taken such as the management of city to prohibit buildings from occupying the space of sidewalks.

6.8 Walking and Communication Space

Although the street space of Chengxian Street is crowded, but many cases are caused by the inefficient application of space. Street space can be created which is convenient and comfortable for communication through ingenious and reasonable urban design (Fig. 13). The specific measures can be summarized as follows:

- Use urban design to deal with discontinuous street space ingeniously in order to create a continuous street space.
- Make use of all available inefficient space, set up small parks, squares, seats, and other public spaces or facilities to create high-quality and communication space for people.

Make full use of facilities such as the concave of buildings, porches, and steps to provide people with a material environment for leisure, rest, watching, and communication.

7 Conclusion

As the regeneration of Chengxian Street was driven by the government, the efficiency of the regeneration project was generally kept at a high level, which rapidly improves the community life and business operation, and promotes the development of urban economy to some extent based on the promotion of land value. Meanwhile, the gradual regeneration model also better maintained the original living conditions of co-prosperity among business, community, and culture.

However, it should be noted that the limited participation of market and society also resulted in the absence of diversity, creativity, equity, and funds in the regeneration, thus the quality and vitality of the street couldn't be improved and maintained as they should be. In addition, the increasing number of traditional economic activities and a limited number of economic activities also led to the lack of commercial and cultural creative industries in Chengxian street. Most historical buildings were protected for the purpose of protection, which couldn't achieve effective historical inheritance and cultural innovation, so as to adapt to the development of a modern society or contribute to the modern economy. Beyond that, the street also failed to create enough cultural characteristic brand resulted in a weak functional status in the city.

Therefore, in order to improve the Chengxian Street further, in addition to the effective improvement from the aspects of organic regeneration, overall urban design, traffic calming, landscape, cultural integration, communication space, and other material means. The regeneration and design should also enhance the participation of market and

social engagement, and form a regeneration promotion and maintenance mechanism composed of the government, market, and society. At the same time, the proportion of traditional business and characteristic business should be adjusted, and the creative cultural industries should be effectively developed by using historical buildings, so as to achieve the comprehensive regeneration goals of social, economic, and environmental aspects.

Chengxian Street is a microcosm of the future development of characteristic streets in China. It is hoped that it can provide enlightenment for other streets through the analysis of Chengxian Street, but it should be pointed out that this paper has presented a case study in order to strengthen the attention to street development in China, and many of the suggestions in the paper are in a form of intention figures, and no specific design has been carried out, so further research in this field should be strengthened in the future.

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Integrating Pedestrian Circulation with Proposed Rapid Transit Route: Design Proposal of a Skywalk for Smart Dhaka

Khairul Enam and Sheikh Muhammad Rezwan

Abstract

The average traffic speed of Dhaka, one of the most densely populated megacities in the world, has fallen to 6 km per hour according to the World Bank, which is almost similar to the usual walking speed and this congestion eats up 3.2 million working hours per day. Till now, a lot of policy measures and plans have been taken and some of the developmental works, i.e. the construction of MRT (Mass Rapid Transit), BRT (Bus Rapid Transit), Elevated Expressway, numerous flyover, etc., are in progress, but the proposals barely accommodated the pedestrian mobility issue, that needs to be taken into consideration. Against this backdrop, this research conducts an extensive field survey in the New Market area, one of the busiest shopping areas, where there is a proposal for an elevated BRT line. The land use, traffic, pedestrian behavior, street vendor's information, etc., are surveyed. The impact of the proposed BRT line and the station is analyzed by reviewing the proposed design by the government and then connecting the literature survey with the field survey. Then an integrated elevated skywalk below the BRT line is proposed which has the possibility to minimize traffic congestion and ensure a safe pedestrian walking. The proposed skywalk accommodates energy-efficient and pollution reduction measures. The wide skywalk may promote art and culture through the design strategy. The proposed design of the skywalk dovetailed with urban life requirements will certainly contribute in achieving certain SDG goals which will lead towards a smart Dhaka.

Keywords

Skywalk • Smart dhaka • SDG goal

1 Introduction

Dhaka, one of the most densely populated megacities in the world, became the second least livable city by the Economic Intelligent Unit (EIU) of Economist's Global Livability Index 2018 and eventually, it surpassed the war-torn Damascus, Syria in the lower infrastructural score. Right now, the average traffic speed of Dhaka city has fallen to 6 km per hour according to the World Bank, which is almost similar to the usual walking speed and this congestion eats up 3.2 million working hours per day. According to the UK-based firm Zipjet, Dhaka is the second least livable city after Lagos, Nigeria, in terms of physical health conditions. Generally, cities are considered as the hubs for ideas, business, culture as well as a home of regulators which enable humanity to advance both socially and economically. For Dhaka, it has become burdensome that are hammering to all sorts of our activities including the country's productivity.

Till now, a lot of policy measures and plans have been taken and some of the developmental works, i.e. the construction of metro rail, BRT (Bus Rapid Transit), elevated expressway, numerous flyover, etc., are in progress. Definitely, after ending the ongoing city projects, people's mobility around the city would increase. Only metro line-6, itself, (Uttara to Motijheel) will carry 60,000 passengers per hour at both ends, according to Japan International Cooperation Agency (JICA). Moreover, after the inception of the Padma Bridge, mobility around the city would manifolds. One fact needs to be pointed out here that the ongoing project wouldn't meet the growing demand as the city population is expected to double by 2035. Expert always focuses on a major point that—'The roads of Dhaka City is made for Vehicles, not for People.' It is indeed a major topic

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to discuss. Designing for people has the potential to reduce traffic pressure on the road which is a passive but very efficient way. Other smart cities have acknowledged it well and practising this option. After all, it can be said that the above plans barely accommodated the pedestrian mobility issue that must need to be taken into consideration.

The objective of the research is the systematic management of pedestrian circulation due to the introduction of BRT, MRT and Elevated expressway in the city. The skywalk will encourage walking by providing supporting facilities and ease of access, thus reducing the pressure on the road. New innovative options of walking as an enjoyable journey, providing alternate options for hawkers, promoting art and culture through design strategy will also get priority. Options for Sustainable Development Goals/SDG achievement through the project will get priority in the proposal, as SDGs help for a smart future of a city. This study is an approach to propose the concept of the skywalk in the city by integrating it with the proposed infrastructure and thus solving the pedestrian mobility issue and SDG goal achievement.

2 Literature Review

2.1 Smart Solution for Pedestrian in a Smart City

An essential to the achievement of cities and the quality of life they offer is how people move around them. Every trip begins and ends with walking. Enrique Penalosa, Mayor of Bogota, in J.SPECK stated it rightly in his 'Walkable City' topic in 2012, 'As a fish needs to swim, a bird to fly, a deer to run, we need to walk, not in order to survive but to be happy'.

Walking, which is often taken for granted, needs to be considered as a primary focus among the smart city features to see transformative change in towns and cities, many of which undergo a legacy of being designed around cars. The quality of pedestrian environment is a key to encouraging people to choose walking instead of driving (Southworth, 2005). A recent research suggests that walking also promotes mental and physical health (Southworth, 2005). Besides having health benefits due to walking, there are many economic benefits for developers, employers and retailers. After all, walking has the lowest carbon emission, does not pollute the environment and is the cheapest and most reliable mode of transportation.

2.2 Skywalk

Skywalk is a crossing space and connective tissue that has a certain height above the ground and serves as networks of above-grade interconnecting pedestrian walkways consisting of sky bridges over streets, second-level corridors within buildings and various activity hubs, such as shops and offices (Ciu, 2015; Cui, Allan, & Lin, 2015).

In North America, skyways are usually owned by businesses and are therefore not public spaces. However, in Asia, such as Bangkok's and Hong Kong's skywalks, they are built and owned separately by the city government, connecting between privately run rail stations or other transport with their footbridges and run many kilometres.

2.3 Skywalk in Canada and Bangkok—Design and Policy

The world's largest continuous skyway +15 network with a total length of 18 km (11 mi) connects 80 blocks in downtown Minneapolis. The system is so named because the skywalks are approximately 15 ft. (approximately 4.5 m) above street level. Opening in 1970, the +15 network has expanded to include 59 enclosed bridges connecting dozens of downtown Calgary buildings. The central core of the system is a series of enclosed shopping centres and the city's flagship department stores.

New developments were required to connect to the walkway system; in exchange for this, they were offered more floor space (the "bonus density"). When not physically able to connect to nearby buildings, developers contribute to the 'Plus 15 Fund', managed by the city, used to finance other missing connections.

The City of Calgary conducted +15 pedestrian counts in July 2011 and again in January 2012 (Fig. 1). They found the use of the +15 drops about 70% in the summer. This proves that when the weather is nice, downtown workers love to walk outside, but when it isn't, they are happy to use the +15 as their indoor sidewalk.

Asian Example: The elevated walkway, Bangkok encompasses 3,000 m^2 and connects Siam Discovery, Siam Square, MBK, the Bangkok Art and Culture Centre and the National Stadium. The new skywalk, which the Bangkok Metropolitan Administration now owns, emerged from the concept of 'universal design', meaning it's handy and helpful for everyone, not just shoppers. The needs of the elderly and disabled are attended too with ramps and stair-

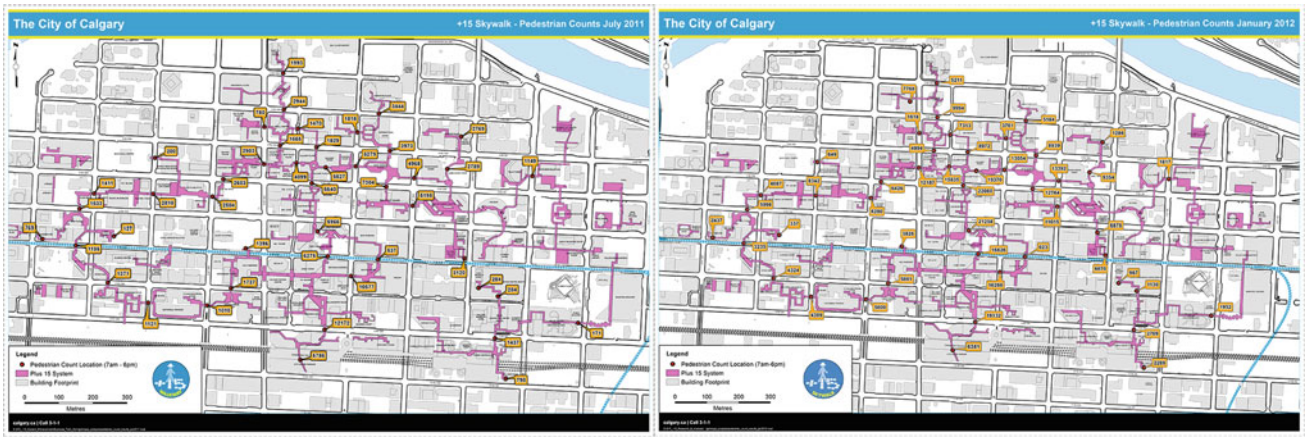

Fig. 1 Pedestrian counts July 2011 and pedestrian counts in January 2012 *Source* The city of calgary website

Fig. 2 Different view of the central elevated walkway, Bangkok pedestrian activity, street life and vertical access

lifts. The new skywalk not only improves safety and convenience for everyone but it's also intended as a large public area and an art space and was designed with aesthetics in mind (Fig. 2).

The multiple planning benefits of Bangkok skywalk include seamless integration with transport nodes, support for land use intensification, integration into the lifestyles of community users and offering a diversity of activity options (Woo & Choo, 2014).

These examples will help understanding skywalk from different perspectives, suggesting program formulation and providing public amenities. There is debate about the negative impact of skyways on urban areas. For example, the impact to street activities and reductions to the property value at ground level (Robertson, 1988). Skywalk systems could also be negatively associated with promoting consumerism (Woo & Choo, 2014). However, more researches are looking into the impact of skyways, particularly in developing countries (Ciu, 2015).

2.4 Skywalk as Public Place

There is a good number of debate of skywalk that it reduces the activities on the street and hence in urban design, it separates users from the street life. But at the same time, researchers are working on these issues to make skywalk a public space. How the characteristics of a public place and sense of public place can be ensured in the skywalk is the main research topic. A good number of research findings are compiled in the following diagram (Wiranata & Dwisusanto, 2018). There are some important conditions and characters of physical elements in skywalk as a public space that can affect the feelings of the skywalk users (Ujang, 2009; Najafi & Shariff, 2011). The form or the physical setting of the Skywalk associated with cognitive relationships, namely the perception of a person in understanding the geometry of the space and oriented within the skywalk (Steele, 1981), based on Skywalk Theory related to location, entrance, room layout, node, public furniture, landscaping and trees, facilities, shelter, materials, etc. (Carmona, 2003) (Fig. 3).

2.5 BRT, MRT Proposal in Strategic Transport Plan for Dhaka

Most of the MRT and BRT design shows that around 20,000–30,000 persons will be carried per hour (JICA study) at both ends. In its long route, around 5000–6000 persons will interchange a particular station per hour. The design

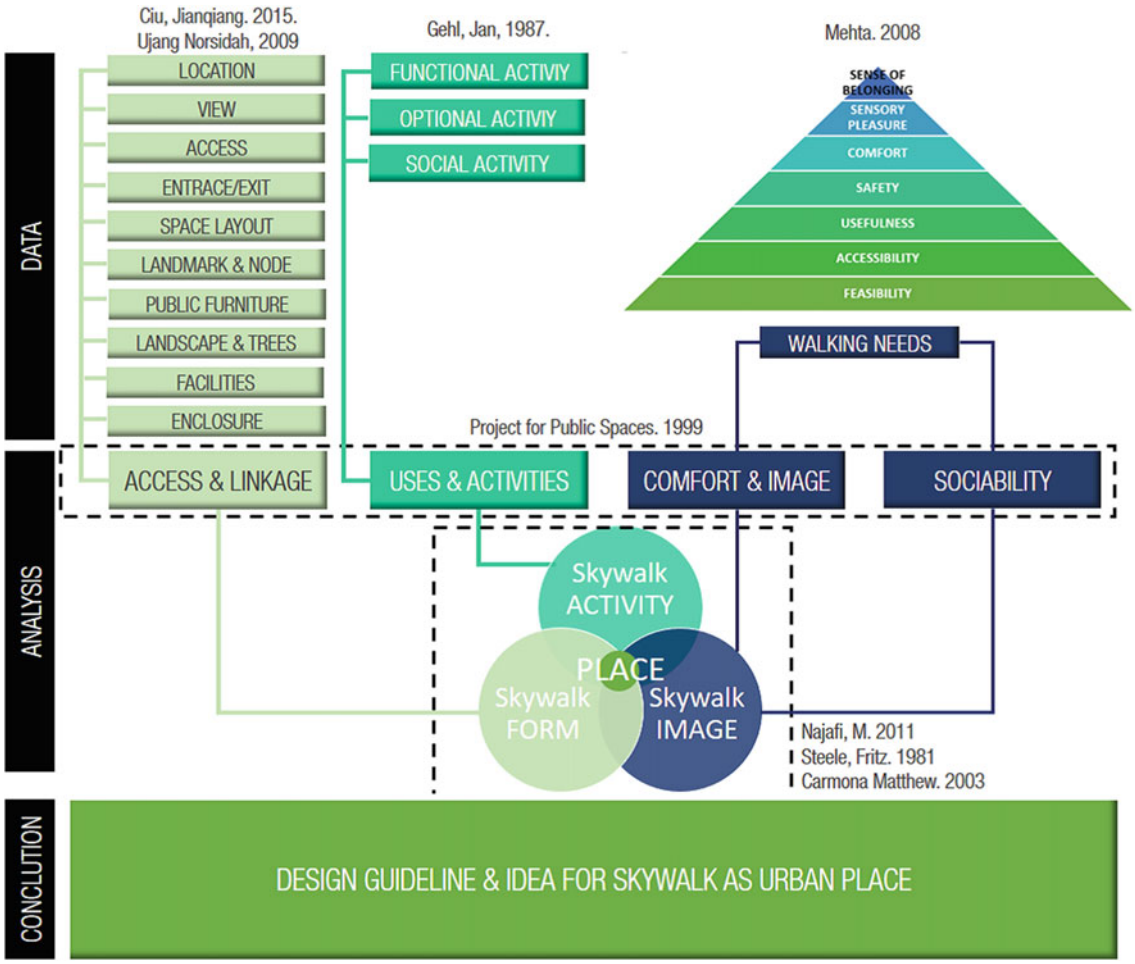

Fig. 3 Diagram of research analysis and theory

shows that all these passengers will come to the footpath which is accidental as our narrow footpaths are not prepared for this huge load. These footpaths are also encroached in many places by any means. Due to the narrow footpath, the MRT stations follow the same design of existing foot over bridge to disperse the passenger. A highly used footbridge in Dhaka carries 1000 persons/hour (DIU urban study—2018). So, it is obvious that these huge passengers need to be dispersed in different land uses and different destinations. Against this backdrop, skywalk may be a solution for the majority of pedestrian walking which might cover from very short distance to long distances (Table 1).

Table 1 Number of MRT/BRT passengers by line, 2025 and 2035 (proposed for Dhaka)

	2025		2035	
	Daily ridership (pax/day)	PPHPD	Daily ridership (pax/day)	PPHPD
MRT line 1	1,365,800	34,740	1,887,200	37,770
MRT line 2			10,846,000	23,020
BRT line 3	1,832,700	23,730	1,814,100	25,960
MRT line 4			332,000	17,930
MRT line 5			1,478,600	28,340
MRT line 6	483,200	16,440	1,816,700	45,860
BRT line 7			541,800	22,330
Total	3,681,700		8,955,000	

Source JICA study team

2.6 BRT, Expressway in the Study Area

The 10.5-km-long expressway will be constructed over the Mirpur Road corridor under a PPP initiative of the prime minister's office. Finance will be provided by Maisha Group Ltd. Feasibility study, officially known as the integrated elevated BRT, the expressway has been designed as a six-lane flyover with two dedicated bus lanes and four express toll lanes. It will have eight BRT stations and pedestrian crossovers at Gabtoli, Technical, Shyamoli, Manik Mia Avenue, Russell Square, Science Laboratory, New Market, Azimpur and Palashi areas. It will also have 15 exit ramps at different points.

The Prime Minister directed officials to conduct a feasibility study and shift the project to Satmasjid Road. He mentioned that "The flyover will be based on the existing median of Mirpur Road" and according to the Consultant of Maisha Group, "Although it is not listed in the Revised Strategic Transport Plan (RSTP), when it gets revised again, the plan for the expressway will be included".

The proposed rapid transit infrastructure has a major design limitation. It fails to address pedestrian disperse issue. All the proposed project drop off passengers at the footpath. The existing footpath has no space to hold this amount of passengers, which in return can be accidental. The right side image of Fig. 4 shows the imaginary situation of the scenario .

3 Existing Situation Analysis of the Study Area

The study area is famous for shopping, especially for ladies' garments, fabrics and knitting accessories. This area attracts people from all over Dhaka and even outside of Dhaka (Suburban, Gazipur, Narayanganj, etc.). It is one of the crowded places in the city. Also, there are many educational institutions (public universities, colleges, schools, training institutions, etc.) within 1 km radius. The city's largest retail book stores (Nilkhet Book Market) are also adjacent to the area. The area has been selected for its variety, complexity as well as its economic contribution to the city. The area demands a pedestrian-friendly solution for its future prospect. The BRT station is supposed to be in Nilkhet Node. So, the existing area needs to be analysed in terms of land use, traffic and pedestrian circulation. The field survey was carried for 1 week in the month of September 2018 by the students of Daffodil International University. Twelve students were involved in data collection. Photograph recording, video documentation, interviews, structured observation were conducted for the data collection.

3.1 Land Use of the Selected Area

The yellow-coloured shapes indicate the shopping centres (Fig. 5). The famous Nilkhet book market is at the south-east corner of the intersection. The dominant land use is residential (orange colour) which includes a government residential colony, hostels and apartment buildings. The violet colours are for educational institutions. From the land use analysis, it is clear that the passengers who will come at this point need to be dispersed in various directions to ease the movement. Shopping area entrance, entrance from the residential colony, entrance from educational institutions should be given the priority.

3.2 Traffic Movement and Vehicular Load

The traffic analysis shows that the primary road is over-pressurized due to traffic (Fig. 6). The overload is due to the huge number of cars. The new market has no car parking and car parks on the street side. Drop off–pick up is done on the main road. Also, public bus has no definite stoppage which creates a traffic jam. Comparatively in a science lab intersection, the ratio of Car: Bus is 49%:25% and in new market 83%:5%.

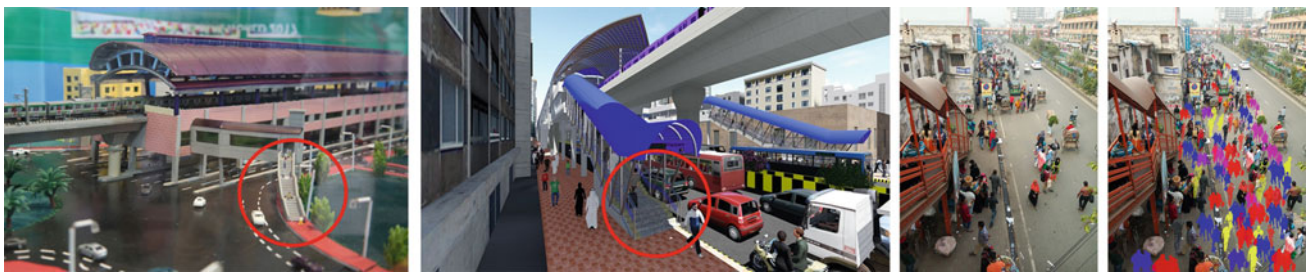

Fig. 4 Proposed pedestrian drop off and anticipated chaos at street level in the BRT, MRT project

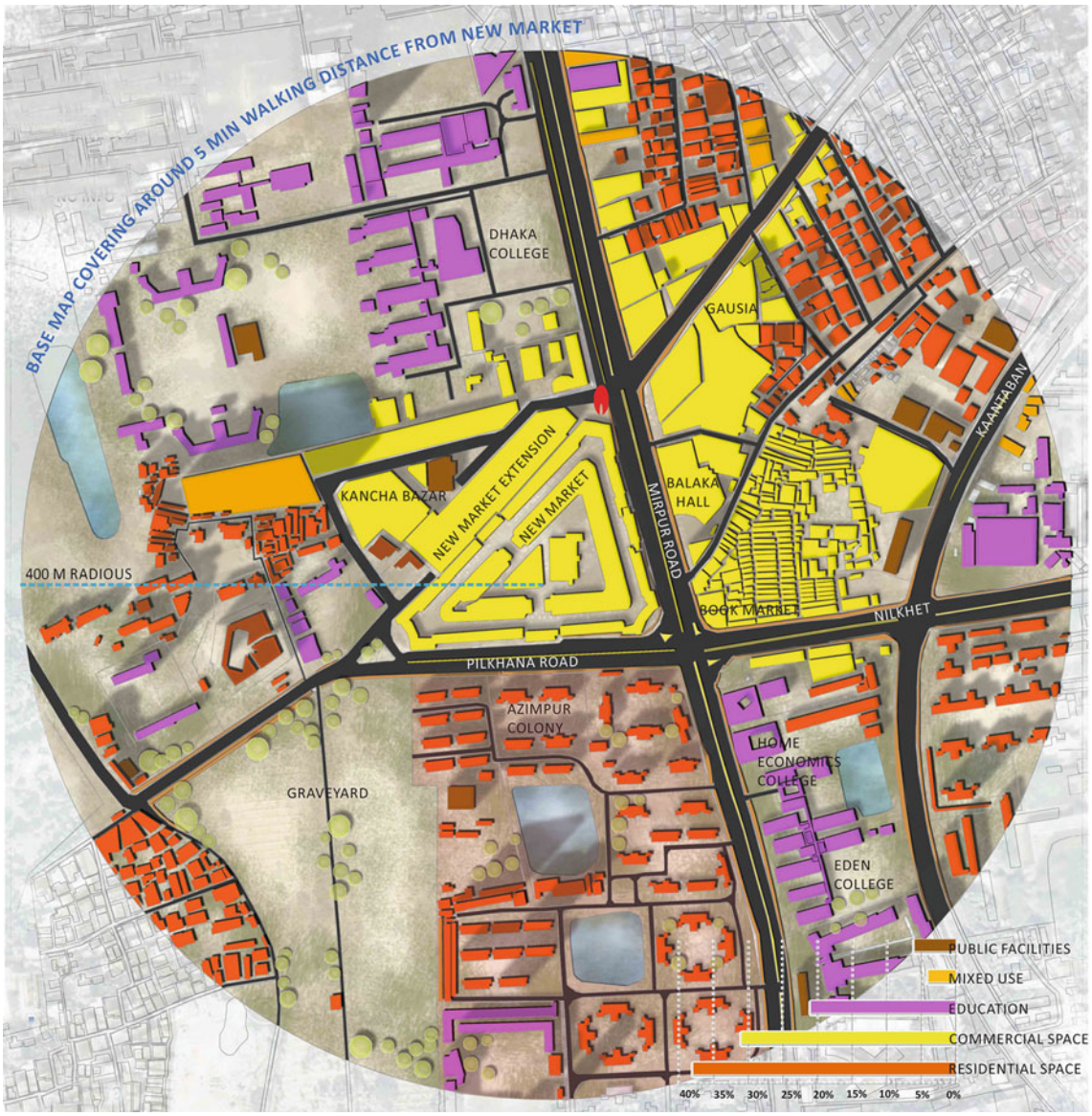

Fig. 5 Existing land use analysis (*source* BUET 4th year study)

3.3 Pedestrian Circulation and Hawker

The whole study area is crowded with street hawker/vendor (Fig. 7). The adjacent shop along the street side rents the front space to the hawkers. The hawkers also illegally pay daily fare illegally. The footpath becomes overcrowded from afternoon till 8 pm and it's very difficult to use the footpaths. Different sexual incidents happen with the girls. Govt. can't control the hawkers as they have an organization which protests against any decision. Holiday market/weekend market options were carried out, but eventually, they occupy the space. People have to use the main road, as they can't use the footpath comfortably. Hawker is a political/social issue, as many hawkers are the victim of climate change and they had to move to the city for a better living condition.

So, if the expressway station drops off the passengers on the footpath, the situation will get worse, passengers need to be dispersed in various markets ensuring security.

The present scenario shows that grade-level separation for the pedestrians can be one of the solutions.

4 Design Proposal

The proposal takes its inspiration from the Bangkok Skywalk Project and also from the research work in the literature review section. The position of the skywalk below the BRT

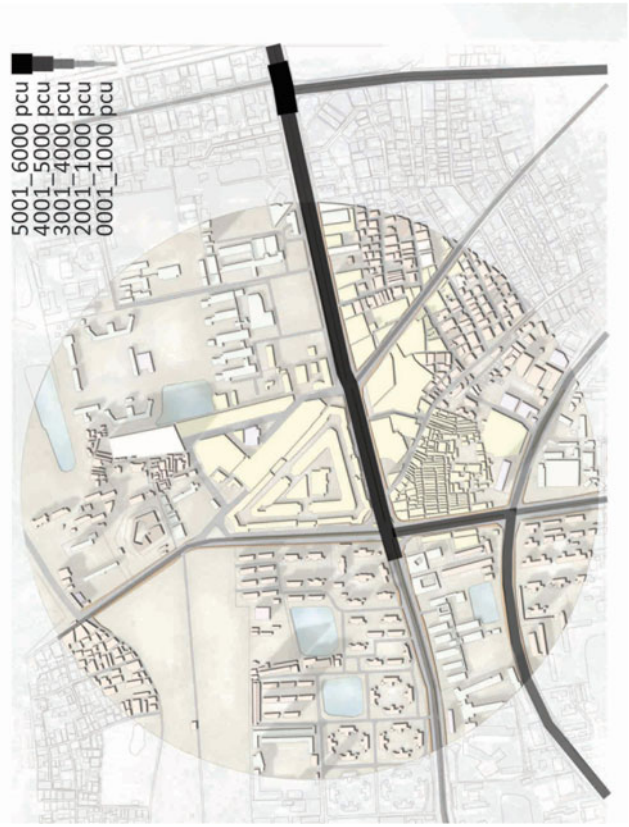

Fig. 6 Vehicular traffic study, PCU-passenger car unit (*source* DIU 4th year study)

line has been seen in the Bangkok Project. Also, the adjacent shopping/retail priority in Siam Business area and New Market area will be appropriate for consideration. To make it a public place, location, entrance, public furniture, landscaping and trees, facilities, shelter, materials, etc., have been considered carefully from the works of (Ujang, 2009). The design strategy promotes the achievement of certain SDGs which are also illustrated.

4.1 General Consideration

The skywalk system may work by connecting metro rail, BRT as well as other transport stations and buildings (civic buildings such as shopping malls, hospitals, etc.). It may be built solely by the government, private or Public–Private Partnership basis. If we look at the example of developed countries, especially Canada, Thailand and the USA, we can that they have already implemented this as the best solution for pedestrian walking.

4.2 Technical Data

The proposed skywalk system can be extended below the MRT station level keeping a minimum of 9 feet height (Figs. 8 and 10). The structural support of the MRT/BRT can support the skywalk without building new columns if it is decided in the design phase of MRT/BRT. A continuous walkway below the transport route, extending 8'–10' on both sides of the pier will be cost-effective also. This will need no shed. Electric fans can be used to make the skywalk comfortable as the heat in the urban areas is a major problem. Thinking about the elderly person, moving walkway (as used in the airport) can also be installed (Fig. 9). These features will also attract users of all ages to use the skywalk and increase mobility.

4.3 Reflection of Urban Life: Amenities and Celebration

The walkway can offer a vibrant lifestyle by offering different civic functions in its way, such as restaurants, parks, play zones, etc. The government can play a vital role in deciding the proposed functions in a different zone of the skywalk. Even the existing buildings' land use may be revised to make it more vibrant and economic. The best design of public spaces is the one that can trigger Optional Activities and Social Activities more frequently (Gehl, 2006), if we can ensure a safe pedestrian walkway, then definitely traffic congestion can be minimized by bringing to an end the pedestrian to the road. In this case, air pollution will be reduced by reducing the use of personal cars.

The integration of interaction between humans and the built environment to create a suitable sense of place becomes one of the benchmarks in creating public space as a place (Mehta, 2008). Not only this, taking inspiration from the Bangkok project, the wide skywalk may promote art and culture through design strategy, and the median and sidewalks may be used for tree plantation (Fig. 11). Small kiosks can be provided by the City Corporation to accommodate registered hawkers using both sides of the pier. This kiosk can have a uniform design which can be a sculptural design to promote art in the city. In this way, the skywalk can become an integrated system to urban life of Dhaka city.

4.4 Skywalk and SDG Goal Achievement

The horizontal surface of this infrastructure (platform, rooftop of the stations, etc.) will give the opportunities to

Fig. 7 Hawkers occupying the all market front. Different color for different market, the stretch of the colour line express presence of hawker

harvest rainwater as well. The rainwater can be used in public toilets, watering trees, water filters, etc. So, this project will also contribute to achieving SDG-7 Affordable and Clean Energy (Fig. 12).

The solar panel on the roof shed of the stations/on the light post can contribute to the energy demand of the skywalk. The skywalk project will enhance the health status by promoting walking and separating pollution level (noise and smoke) of the source and the user, that helps health-related SDG (SDG-3 Good health and Well-being) (Fig. 12). The social spaces in the skywalk have positive mental health benefits also. After doing all these measures, SDG-11 Sustainable cities and communities target will also be fulfilled, as it ensures public access, universal design, inclusion for all users, etc.

4.5 Recommendations

The design proposal presents recommendations to urban designers and architects. Providing skywalk below BRT line will require 2.8–3 m additional space, so new BRT lines/Expressway should accommodate this height in its design. The pedestrian issues need to be integrated with the big infrastructures project not as a separate project afterwards. The proposed solution takes the support from the

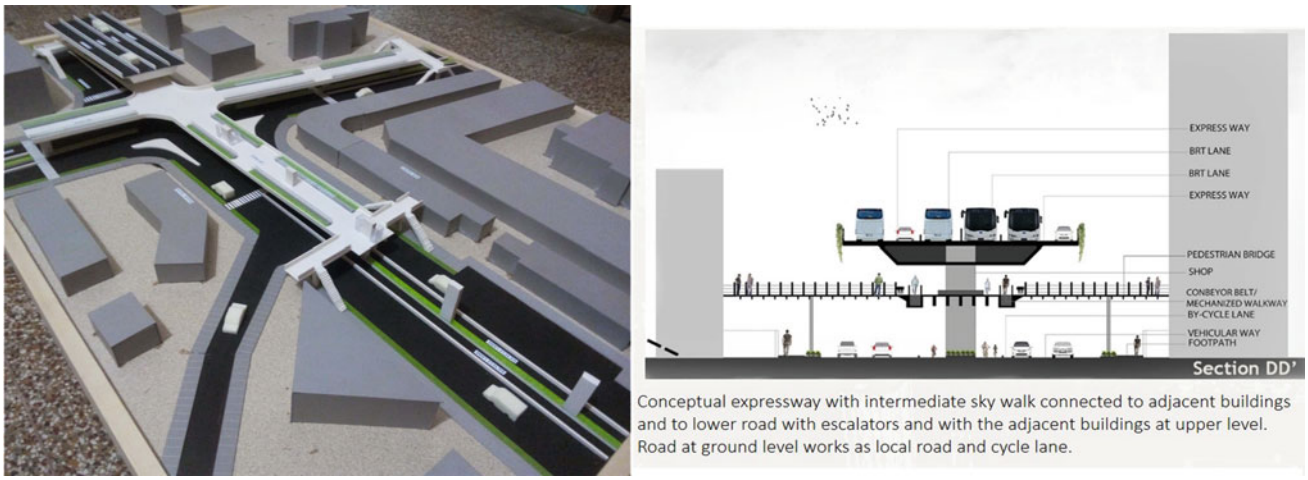

Fig. 8 The proposal showing skywalk below the expressway

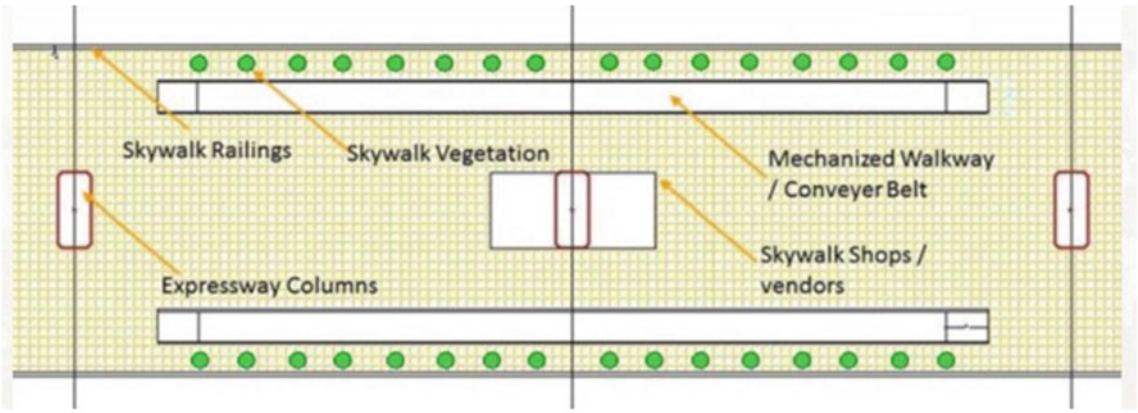

Fig. 9 Skywalk level walkway plan

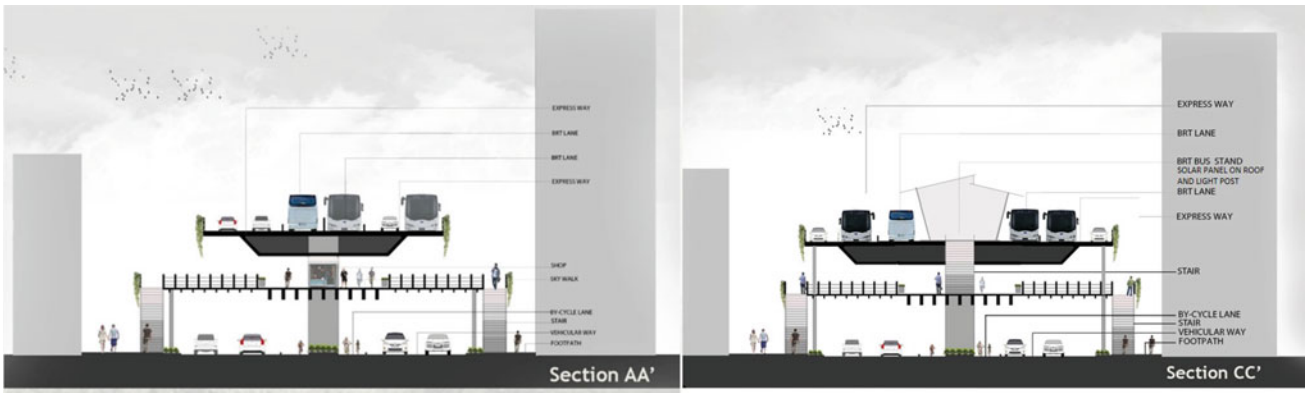

Fig. 10 Conceptual expressway with intermediate skywalk connected to the adjacent buildings. The existing road at ground level works a local road and cycle lane. Median and sidewalks are lined by plantation

Fig. 11 Proposed interior of the skywalk and scope of artwork

Fig. 12 Sustainability issues of skywalk

BRT columns; hence, the initial project cost will be increased, but this will ensure additional benefits which have been explained in the paper. Loss of money due to low level of walkability can be calculated and the money can be used in the project.

Pedestrian comfort should be strongly considered. Provision of ventilation, pollution reduction, ease of access, seating bench, water filter, snacks corner, etc., should be provided. The retail options need a sensitive approach so that the walkway doesn't advertise the business more than the walking. Solar panels and rainwater harvesting should be made mandatory for big infrastructure project.

Artists can be invited regularly to give the place a vibrant look. Surrounding institutions can be approached to display their work in the skywalk. In these ways, the skywalk will become a reflection of urban life.

5 Conclusion

Bangladesh confirmed an outstanding performance in the Millennium Development Goals (MDGs) and likewise unswerving to achieving most of the targets of Sustainable Development Goals (SDGs) by 2030 when Dhaka will be presumed to be the fourth largest Megacity in the world. Thus, sustainable cities and communities (SDGs-11) are also sustained by the government's development vision. The proposed skywalk can help in achieving that vision. Lots of infrastructural development is carried out in Dhaka in the transport sector and the pedestrian circulation incorporation should get the priority for a smart future of the city. Actually, the priority of the people should be at the centre for any transport-related development.

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The Importance of Green Commuting: A Campus Case Study in Schwäbisch Hall as Contribution to Responsible Urbanism

Wanja Wellbrock, Daniela Ludin, Benjamin Högele, and Erika Müller

Abstract

In its recent report, the Intergovernmental Panel on Climate Change of the United Nations (IPCC) has described the impacts and possible magnificent disturbances that arise from climate change. One of the fastest growing producers of CO_2 emissions is the transport sector. Cities need to take action to secure healthy living conditions in times of transition, e.g., by increasing green infrastructure and reducing emissions. Thereby, shifting mobility and transport to emission-free resources is one major factor to be considered in the context of responsible urbanism. Innovative mobility concepts are a necessary action and supplement. By executing an empirical case study, the authors try to investigate the potential for green mobility at universities in rural areas as a local contribution to smart and responsible urbanism. The campus Schwäbisch Hall, part of the University of Applied Sciences Heilbronn, serves as an exemplary setting for this field test. The aim of the project is to devise a mobility concept that creates incentives for all parties involved to dispense individual car traffic and switch to public transport or e-bikes instead. Incentives for other mobility opportunities and potential obstacles are investigated. By exchanging knowledge with local stakeholders and experts, measures and recommendations for sustainable mobility will be elaborated.

Keywords

Green commuting • Sustainable mobility • Rural area • Cycling • Public transportation • Modal split

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1 Introduction

"Eleven million Germans commute to work" (ZEIT Online 2018). This means that more than every fourth worker in Germany commutes (ZEIT Online 2018); related to the place of residence—urbanized or rural—the dependence on car commuting varies (Stahnke et al. 2016). The amount of daily traffic especially puts pressure on densely populated or urban areas, not only in terms of managing traffic flow and parking spaces but also noise and emissions. 18% of Germany's greenhouse gas emissions originate from the transport sector (Rudolph et al. 2017, p. 3). Negative effects are measurable both at local and global levels. In its recent report, the IPCC (2018) described the impacts and possible magnificent disturbances that arise from climate change, which is fuelled by transport emissions as well. The German Environment Agency (Umweltbundesamt—UBA) regularly measures concentrations of air pollutants in German cities (UBA 2019). Currently, the results of this year's assessment show that in 57 cities the measured nitrogen oxide (NOx) is above the limit values (Spiegel Online 2019).

On the local level, this means to invest into bottom-up approaches for sustainable urban development that consider the diverse characteristics of their local areas (Biesbroek et al. 2010; Carter 2011; Hulme 2008). Lehmann (2010) notes that transforming urban design into a green, more sustainable urbanism requires a multidisciplinary approach following the "triple zero framework of zero fossil-fuel energy use, zero waste and zero emissions (aiming for low-to-no-carbon emissions)" (p. 4). As urbanization is progressing and increasing worldwide, the role of cities becomes even more significant for sustainable development and hence securing healthy living conditions (Chourabi et al. 2012; Heidrich et al. 2016; Reckien et al. 2018; UN 2019). According to the BMZ (2010–2010) "80% of the world's population is expected to live in cities by 2050"; meanwhile, it is expected that population growth will decrease in rural areas. Shifting mobility and transport to emission-free

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resources is one major adjusting screw for cities to reach their climate protection goals and support the 1.5-degree-target (Rudolph et al. 2017). However, at the same time, innovative mobility concepts have to integrate more complex and sometimes conflicting aspects, besides renewable energy use. They need to offer good access to transport services, both for commuters and residents of an area that help to "reduce automobile dependency, but also the need to travel" (Lehmann 2010, p. 6). They should stimulate behavioural change, be affordable, avoid additional land consumption and use smart technological solutions in a constantly changing surrounding.

These developments also affect German communities and cities. The so-called "traffic turn" as part of climate protection measures is widely discussed among policy makers, researchers, companies and other stakeholders and favours, among other things, the substitution of fossil-fuel-based mobility technologies (BMBF 2019; Kasten et al. 2016; Ministerium für Verkehr Baden-Württemberg 2019; Rammler 2018; Rudolph et al. 2017; UBA 2014; VCD e.V. 2019).

Even though urbanization takes place in Germany, currently about 42% of the German population lives in villages or small towns (Bangel et al. 2017). Cars create 40% of the traffic volume in Germany in urban areas. In rural and provincial areas car usage accounts to 60–70%; public transport covers only 10% of the traffic volume (Ministerium für Verkehr Baden-Württemberg 2019; Nobis and Kuhnimhof 2018). Multimodal offers are increasingly present in urban areas. Mobility alternatives such as e-scooters, bike or car sharing offers might substitute the individual car usage (Nobis and Kuhnimhof 2018). However, these offers do not cover the mobility needs from rural areas into the next town or city and it is difficult to run them efficiently (Kugoth 2019; Nobis and Kuhnimhof 2018). Some studies even suppose that the number of cars per 1000 inhabitants will heavily increase in the coming years (Kugoth 2019; Nobis and Kuhnimhof 2018; Staatsministerium Baden-Württemberg 2019). A major challenge might be to find solutions that does not increase the differences between urban and rural areas, but help to sustain attractiveness, economic competitive advantages and accessibility of rural areas with sustainable means of transport.

Within the discussion of sustainable development, which is closely interlinked with climate protection, universities and higher education institutions play a significant role in terms of knowledge transfer and education for a more sustainable future (Ramos et al. 2015; U-Mob 2018). At the same time, the campus operations have an impact on the environment (U-Mob 2018). In many cities, universities are adding to the local traffic through daily commuting by students and staff to university facilities (U-Mob 2018). Therefore, considering a more sustainable way of university commuting as part of sustainable transport planning of cities can contribute positively to the overall urban performance and a smart city development (U-Mob 2018). Against this background, the authors recognize mobility as part of smart city development that contributes to sustainable development, climate protection and healthier living conditions (Rudolph et al. 2017).

Exemplarily, the implementation potential for green commuting is discussed in this paper. In a small-scale case study at the university campus of Schwäbisch Hall, the mobility behaviour of students and staff is examined. A field test of green commuting alternatives was executed. The aim of the project is to devise a valuable solution that creates incentives for all parties involved to dispense individual car traffic and find alternatives to fossil fuel-based traffic modes. The modal split as well as identified obstacles and barriers for developing a green commuting concept will be presented in this paper. The findings might add general input for other researchers and practitioners in the field of sustainable, smart urban development, while at the same time trying to address the peculiarities of rural areas.

2 Problem Description

Schwäbisch Hall is a medium-sized town with about 40,000 inhabitants, located in a provincial and rural area. The campus Schwäbisch Hall, part of the University of Applied Sciences Heilbronn, is the setting for a field test for green commuting alternatives. With 8500 students, the Heilbronn University of Applied Sciences is one of the largest universities of applied sciences in Baden-Württemberg, Germany. The campus Schwäbisch Hall is one of four locations belonging to the university. The number of students has increased from 150 in 2009 to 1067 in the winter semester 2018/2019. The number of professors, lecturers and staff in Schwäbisch Hall amounts to 89 people. Through the extension of further degree courses, these numbers might increase significantly in the next coming years. The university buildings in Schwäbisch Hall are split on two locations, with a distance of 700 m and a significant difference in altitude.

The campus is a typical commuting facility, students and staff are arriving and departing on a daily basis, as, for example, there are no living facilities on the campus and a significant number of students does not live in Schwäbisch Hall either. Additionally, students (and partly staff) have to change daily between both campus locations due to different lecture locations. The available parking ground at the campus comprises only about 142 spaces for students and staff, which is less than sufficient and leads to "wild" parking in the neighbourhoods.

Although being a comparatively small campus, students and staff add a significant amount of traffic and related

emissions to the overall daily traffic situation inside and around the city. Public and free parking space in Schwäbisch Hall is rare and other companies and institutions compete with the university campus. The offer of an alternative parking place in 1200 meters walking distance does not seem to be accepted sufficiently. The situation might deteriorate in the future, when more students are commuting to the campus.

Specific peculiarities of the mobility behaviour at the campus and the whole university were examined in the past years (Bernecker 2015; Klinkmann and Hotzy 2016). Studies show that just over half of the students are travelling by car. About 26% are travelling by bus and/or train and 23% are walking to the campus. 48% of the students are using the car to commute between the university buildings, 45% are walking this route, and only 6% are using the bus (Klinkmann and Hotzy 2016). Commuting by bicycle plays almost no role at all as a predominantly used means of transport (Bernecker 2015).

The mobility behaviour in Schwäbisch Hall results from the following aspects:

- 30% of the students describe access to public transport as inadequate (Klinkmann and Hotzky 2016). Main reasons are frequencies and costs (Bernecker 2015; Klinkmann and Hotzky 2016). There is a wish for a direct campus line that offers a quicker connection between the campus and the train stations (Klinkmann and Hotzy 2016).
- Due to great differences in altitude, the proportion of cycling in the city is quite low. This situation is reflected in the small number of bicycle parking facilities at the campus, there is space for 24 bikes, no shower and locker rooms are available so far.
- Besides lack of existing public transport infrastructure, the favoured means of transport is based on "individual user preferences, the personal mobility behaviour and the desired route chains and travel purposes" (Bernecker 2015).
- There is a strong wish for more free parking spaces (Bernecker 2015).

The findings of this study reflect the specific situation of rural and provincial areas, where the dependence on individual car traffic is higher than in more urbanized or metropolitan regions (Camarero et al. 2016; Kugoth 2019; Nobis and Kuhnimhof 2018).

The public transport system in Schwäbisch Hall itself is well developed, but it is not possible to cover all surrounding remote areas with adequate connections. Developing mobility alternatives for reaching the campus in Schwäbisch Hall needs to consider both city-internal traffic as well as overland traffic, meaning commuting from the surrounding or smaller villages into the city. Mobility needs and behaviour might be addressed differently for the various target groups (students vs. staff).

3 Bottom-up Approach for Sustainable Mobility: Case Study and Field Test at the Campus Schwäbisch Hall

Based on the key findings of the existing surveys, a 12-month project was started in November 2018. The focus of the project "Sustainable mobility at campus Schwäbisch Hall" is on the development of a concept for sustainable mobility and greener commuting by offering alternatives to individual car traffic. The Ministry of Science, Research and the Arts Baden-Württemberg provides financial support. The main project milestones are the execution of a test phase for an e-bus and e-bikes and the generation of quantitative and qualitative data through an online survey. Local stakeholders such as the public transport provider, the city of Schwäbisch Hall, student representatives, the Bausparkasse Schwäbisch Hall (owner of parking areas), bike shops and others are integrated. Furthermore, the potential for integrating start-ups is assessed.

Roupé (2015) defines three different types of sustainable commuting:

- Commute types that have no emissions: walking and bicycling.
- Commute types that transport more than one passenger: public transportation and carpooling.
- Commute types that replace fossil fuel with renewable energy: electrically powered forms of mobility with green electricity (p. 4).

All three types of green commuting are part of the concept development and were included in the test phase.

Commute types that transport more than one passenger and partly replace renewable energy

During the period of 20 May 2019 to 24 May 2019, students and staff had the opportunity to use an e-bus for their way to the campus, which has used a separately established campus route for the test phase. Here it was important that the bus stops connect all important junctions, like the two campus buildings, the alternative parking space in walking distance and the train station. With further stops between these junctions, a good accessibility could be ensured. The electricity for the bus and the bikes was purchased by the municipal utility of Schwäbisch Hall. It generates already 64% of its energy from renewable sources (Stadtwerke Schwäbisch Hall GmbH 2017, p. 7). As a small addition, the idea of ride sharing was promoted to reduce the number of cars, a mobility consulting was offered as well as the participation in a bicycle campaign for climate protection.

Commute type with no emissions

At the same time, students and staff had the option to rent e-bikes for their way from and to the campus and between the campus buildings. With two rental systems, people could rent an e-bike either for the entire week or for short periods to get to the other campus building. The last-mentioned app-based rental system was available for six weeks.

It should also be mentioned that the test phase tried to integrate two framework conditions: The parking space for students was closed for 2.5 days. Students were motivated to use the alternative parking space with a distance of approximately 1200 m and the offered mobility alternatives. The parking space was available as normal on the other days of the week. Alternative parking space and mobility offers were still promoted to reduce the pressure on the parking space at the campus. The idea was to simulate on the one hand the mobility behaviour under normal conditions and under extreme conditions regarding the parking space availability and examine possible impacts.

All mobility services were offered free of charge in order not to let any potential fees be a hindrance to the target groups. Throughout the concept development, the feasibility of such services is examined as well. The findings of the project shall contribute to reducing the traffic volume in the city and reducing CO_2 emissions and support more efficient mobility and traffic planning.

4 Status Quo for Green Commuting at Campus Schwäbisch Hall: Results of the Test Phase

In the current project, two surveys were conducted after the test phase to examine the status quo of on the campus in a more differentiated way and the potential for sustainable mobility offers. The survey results form the basis for developing concrete implementation measures and recommendations. For the evaluation of the test phase, two surveys were designed for all university members of the campus Schwäbisch Hall. The evaluation of the first survey will initially show the current situation at the campus Schwäbisch Hall. Against this background, the results from the first week of testing, in which the focus was on the use of the e-bus and e-bikes, can be analysed. The second survey will show the results of the six-week test phase, which refers exclusively to the use of e-bikes with the lending system via app (bike sharing stations).

4.1 Verification of Modal Split

To analyse the possibilities of green commuting, the statistical results of the project's survey are described below. This includes the distance of residence to the campus, the preferred choice of transportation and the qualitative analysis of the mobility behaviour (modal split).

The first online survey focused on collecting mobility data (modal split), current mobility behaviour, evaluation of existing infrastructure at the campus and the acceptance of green mobility offers.

The total sample unit comprised 1156 people, all students and staff members at the campus have been invited to participate. The response rate was 9.17% in total. As only 5.62% of the contacted staff members participated in the survey, the received answers are not representative. For that reason, the analysis of data is focused only on student's responses.

In this survey, 106 students were questioned on how far they live from the campus. Only 30% of the students are living near up to a distance of 5 km. 21% have a one-way commuting distance of 20–40 km and 25% of at least 40 km. In context of Fig. 1, the existing need to travel and corresponding travel volume becomes obvious, as the campus has big catchment area.

In addition, the modal split for students' mobility was surveyed by asking about the preferred choice of transportation to the campus. The frequently large distances from residence to campus in combination with a rural catchment area explains an above-average use of car. The modal split in Figure 2 verifies that the preferred regular mean of transportation to the campus is the car with almost 50%. The use of bicycles is almost non-existent. Approximately 70% of all students never go by foot or use public transport. The survey showed that for 28% of the students it would take much more time to get to the campus, if they use public transport instead of commuting by car. 26% said that the schedule for public transport is too irregular to fit their lectures times. Similar to the use of public transport, the expenditure of time with bicycles would be much higher for 23% of the participants. Furthermore, the topography was an exclusion criterion for using the bicycle by almost 20%. The lack of safe and consistent bicycle infrastructure was also a reason for not going by bike. Not only physical conditions but also social characteristics can explain the preferred choice of transportation. Here, the survey has shown that for 89% independence and for 86% of the participants' time saving are among the most important reasons for choosing a particular means of transport. The factor cost saving is only important for 45% of all students and climate protection for 13%.

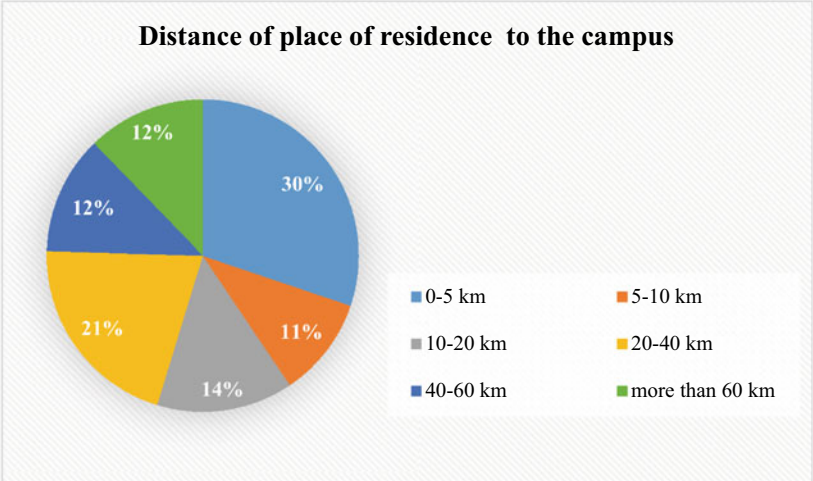

Fig. 1 Distance of place of residence of interviewees to the campus (n= 106). *Source* Own research

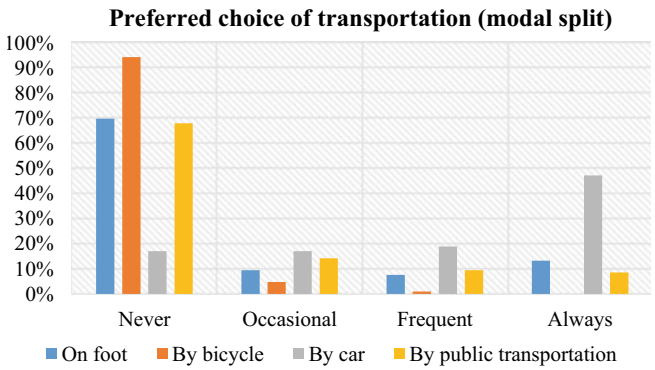

Fig. 2 Preferred choice of transportation to the campus (n=106). *Source* Own research

4.2 General Acceptance of E-bus and E-bike

The number of passengers using the e-bus during the test phase was tracked. Generally, the response rate for this mobility service was quite low, showing a decrease over the week. Higher passenger numbers might be associated with closed students' parking spaces as well as with bad conditions in the first days. Further reasons for the low acceptance derive in part from the survey results. One reason was that the bus only went in a circular route and not in two directions on the same route, which led to longer waiting or driving times. In addition, the schedule did not always fit the departure times of trains and could not cover the whole day of lectures. Besides that, the testing phase of one week most probably was too short. Feedback from the survey suggests that people might need some time to get used to new offers respectively until they actually recognize them. The aspect of negative emotions among students because of the closed parking space might have led to a rejection of the offered services.

The focus of the second survey was the evaluation of the six-week test phase with e-bikes. The app-based loan was designed primarily for the path between the two university buildings. With a rental period of 10 min to 72 h, users could choose the period themselves. The survey focused on three factors: acceptance, usability and type of use.

Table 1 shows the results from the interpretation of the rental statistics of the fleet software. With a number of 44 active users, 324 rents were started in the six-week test phase, and the average rental period was just under three hours. With a total distance of 2478 km, it can be assumed that the e-bikes were also used for purposes other than overcoming the distance between the two university buildings. Bikes were often rented over the weekend and during good weather periods. The rental statistics also show an increase in user numbers over time, which might reflect the fact that testing or establishing of new mobility services needs time until the target group uses it.

Figure 3 shows the type of rides the e-bike was predominantly used for. Only 11% have used the e-bike for the originally planned purpose of use between the campus buildings. A technical aspect regarding the loan process of e-bikes could be a reason for the low use for this route and should be mentioned here: The bikes were station-based; this means that the rent could only be ended at the same station it was started at. Both, trips to free time activities as well as trips from residence to the campus were reported by about one-third of the users. With 21%, the use of e-bikes for rides to shopping is also higher than the use of e-bikes for commuting between the university buildings.

Therefore, it can be assumed that a rental system with the possibility of renting e-bikes for a longer period would be more appropriate for the users at the campus. Nevertheless, when asked which rental system would be preferred on

Table 1 Excerpt from the rental statistics of the fleet software

Active users	44
Rents (total)	324
Average rental time	2 h, 51 min
Driven kilometres	2478

Source Own research

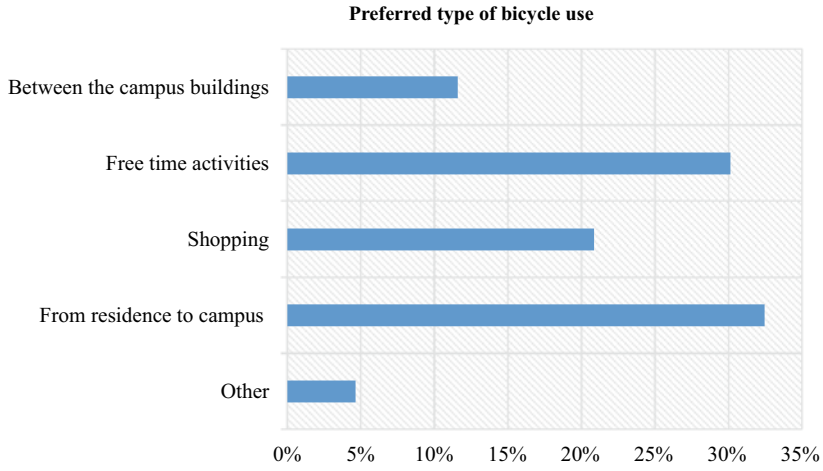

Fig. 3 Preferred type of rides with e-bikes during the test period (n=44). *Source* Own research

campus for a permanent establishment, the answers show a relatively balanced result as shown in Table 2.

When asked if a rental system would be a permanent solution for the campus, 96% affirmed it.

The answers about the preferred rental system show that a loan for the whole semester is slightly favoured by 49% (Table 2). Furthermore, 38% prefer a rental system, where e-bikes are bookable for single rides. 14% suggested a rental system where the e-bike can be rented over a specified period. The timeframe was up to one week. Based on Table 2, it can be assumed that a reasonable solution for the campus could be the establishment of both rental systems.

4.3 Results of the Six-Week Test Phase for Station-Based E-bikes

When looking at the distance from place of residence to campus, Fig. 4 clearly shows that the majority of e-bike users stems from a radius of 3 km. About 13% have a distance of 4–20 km, only 4% have a distance of over 21 km.

Figure 5 shows the frequency of car usage by students who live within 5 km distance of the university. Despite the relatively short distance, only 42% never use a car. Nearly 30% of the respondents are using the car permanently or frequently. These rather unambiguous values could be another reason to assume that e-bike utilization has relatively little relevance for journeys between university buildings alone. Especially for people living in close vicinity to the campus or inside the city (up to 5 km distance from the campus) the e-bike might be an attractive means of transport for commuting between the place of residence and the university. Here the authors see a big potential to establish alternative mobility solutions and motivate the target group to substitute commuting by car with commuting with an e-bike. The number of driven kilometres within six weeks is quite surprising. By assuming an average CO_2 emission of 140 g per car kilometre driven, about 347 kg CO_2 were avoided in the six weeks through the 2478 km of cycling.

Table 2 Preferred rental system for e-bikes

Per semester	18
Bookable for single rides	14
Other system	5

Source Own research

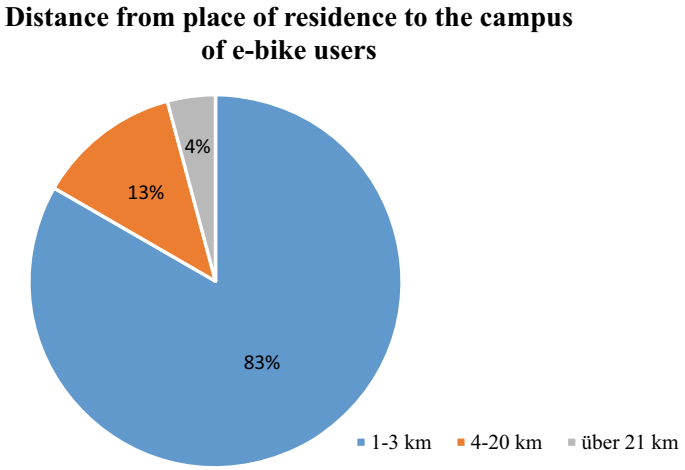

Fig. 4 Distance from place of residence to the campus of e-bike users (n=44). *Source* Own research

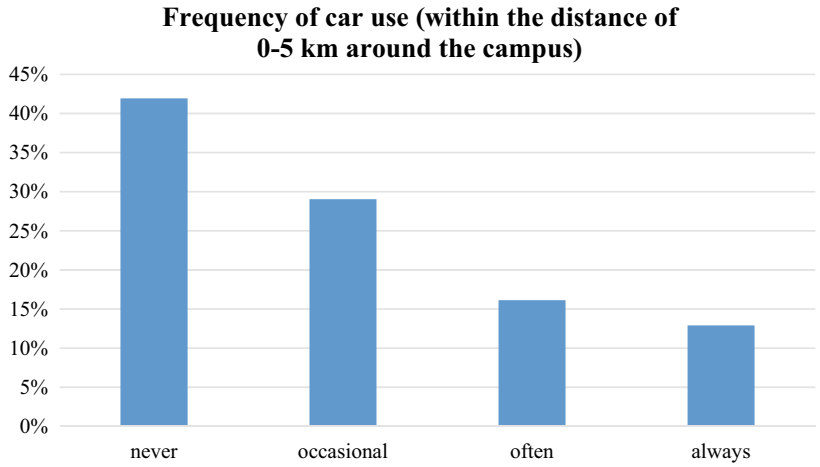

Fig. 5 Frequency of car uses by people that live within a distance of 0–5 km from the campus (n=31). *Source* Own research

4.4 Obstacles

The survey has also shown the main obstacles for greener commuting in Schwäbisch Hall, as summarized in Fig. 6. Partly, they are interlinked with each other. A few of these interlinkages are described below:

Habits and Parking facility management

Even though the number of survey responses allows a statistical evaluation, the majority of students and employees were not reached by the survey. Reasons for that might be manifold, ranging from lack of interest to lack of information etc. Closing the student's parking space has caused resistance and criticism. Future considerations to shifting mobility behaviour might also provoke resistance, anger or other negative feedback. For example, the introduction of a fee-based parking facility management that does not offer free availability for all students might be "unpopular" and perceived as detrimental by the target group. The test phase proved that it is not only important to offer equally attractive alternatives, but also that an appropriate mixture of communication, incentives and policies is crucial. Another important factor might be that people need time to get used to changed circumstances. Considering the good and warm weather during the e-bike test phase of six weeks might have had a positive influence as well and made it more attractive to use a bike and to change one's normal travel habits. Alternating seasons and weather conditions in the summer and winter semester will most probably influence the user frequency and amount of necessary e-bikes. In order to balance this alternating utilization rate and to develop attractive alternatives for e-bike users during times of uncomfortable weather conditions, adaptable and various mobility alternatives might be needed.

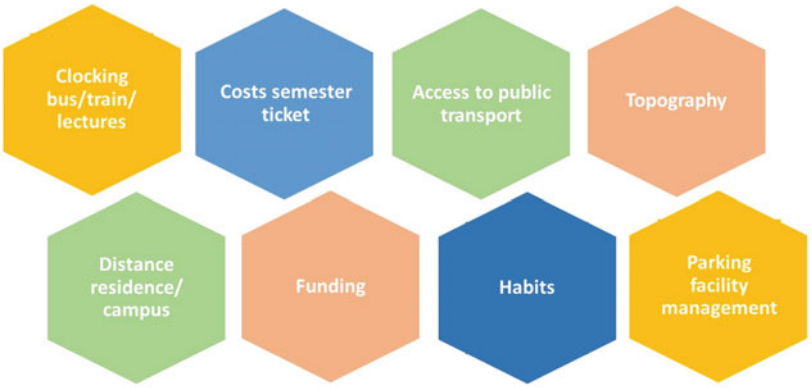

Fig. 6 Main obstacles for greener commuting to the campus Schwäbisch Hall. *Source* Own research

Distance/residence campus and access to public transport

Due to the relatively large distance of the residence of some students to the campus, this group of people should be considered separately because one of the goals of the concept is to create incentives to give up the car. However, it has to be taken into account that not only a small number of students are dependent on the car, in particular because of the partly limited public transport connection so that a different solution has to be worked out for this purpose.

The survey results also stress the need for differentiating the target group of students living in Schwäbisch Hall itself or in the closer vicinity from those commuting from a greater distance. The tested city-internal solutions for green commuting like the e-bus and e-bikes are not solving the general lack of sufficient public transport connections from Schwäbisch Hall to more remote areas. The development of viable solutions requires further involvement of stakeholders and lobbying for the integration of sustainable mobility solutions in the cities and district master plans. Nevertheless, this system will only be successful, if the public transport is attractive enough in terms of time spent, flexibility and costs. Only then, this might be an incentive for students to use more environmental-friendly traffic modes. The authors of the project cannot directly influence the establishment of further bus connections. The fact that the dependence on cars in rural areas might prevail longer than in urbanized areas needs to be accepted for the moment, as it needs large-scale infrastructural approaches to change this situation.

Costs semester ticket and clocking bus/train/lectures

The limited range of the existing semester ticket and its high price in combination with the non-exhaustive public transport into the city diminishes its attractiveness. As long as it is cheaper and more flexible to go by car, the incentive for switching to public transport is quite low.

Survey results and discussions with students have shown that train arrival times at the station do not match the lectures, so in many cases students would have to travel one hour earlier to get to the lecture on time. This interlinkage is not easy to solve, as, for example, the pricing of tickets is also depending on the amount of possible users. With its 1000 students the demand weight of the university is limited compared to other user groups such as school students that generate a bigger demand. Discussions and lobbying for more solutions that are attractive need time and are influenced by manifold aspects.

Funding

The e-bus and e-bikes were free of charge during the test phase, which most probably had an impact on the utilization rate and the positive feedback. During regular operation, this mobility service is most likely not free of charge. Students were asked about their willingness to pay for such services in the survey. The results can be seen as a reference value for elaborating a bike rental system. The prices mentioned would not cover the costs for running such a system. To find the right balance between attractive pricing models and feasibility might also be a challenge. Of course, it is not possible to predict how the target group will accept a fee-based offer.

Topography

The topography partly aggravates the shift to more non-fossil-fuel-based mobility services. Bicycles without electric support are not attractive due to the hilly topography, but are costlier than non-motorized bicycles. It might even

be too steep to use other micro-mobility services such as (e-) scooters.

4.5 Solution Approach

Considering the survey results, a solution approach shall address obstacles and introduce measures that are feasible under the existing conditions. Although there are other reasons for the rather low number of users of the e-bus during the test week, which are not directly related to the actual use, a recommendation for the introduction of a campus line as part of the mobility concept seems not justifiable and will not be pursued.

In contrast, the use of e-bikes showed a greater potential based on the results of the survey. The survey showed clearly that the students gave a positive feedback for the possible permanent installation of a bike sharing system, both for booking per route and a so-called "semester bicycle". Especially for students directly living in Schwäbisch Hall, the use of e-bikes has been attractive.

For this purpose, three superior subject areas include measures that can be subdivided into subordinate topics: bicycle traffic, parking space management and public transport. Measures will concentrate mainly on city-internal traffic or people commuting within a radius of 5 km. The authors assume that such measures are more likely to be implemented on short term, while finding solutions for the traffic over longer distances would involve further stakeholders, are dependent on more variables and most probably need more time and progress in technology etc.

The proposed measures mainly address students, but shall be easily adapted for staff members as well.

Bicycle traffic

To create alternatives for the city-internal traffic the promotion of bicycle traffic seems to be an adequate and promising measure for people living in Schwäbisch Hall or within a radius of 3 km. E-bikes that are rented out for a longer period, e.g. for one semester, might motivate those students to switch from car use to cycling more regularly. The authors propose to establish an e-bike rental system that covers this target group. Based on a survey at the end/beginning of each semester the number of e-bikes needed can be detected and the amount of e-bikes easily be adapted respectively scaled up or down. Besides that, bicycle traffic can be part of multimodal transport solutions for the last mile, e.g. by offering e-bike sharing stations at the train stations or at park and ride facilities. Financial feasibility, the number of required e-bikes and the establishment of additional infrastructure as well as further stakeholder participation need to be examined and integrated into the mobility concept of this project.

Parking space management

For a possible solution of the parking space problem, one aspect of the urgent need of a parking lot has to be considered besides substituting the use of cars with other means of transport. For example, university members with a greater distance from the place of residence to the campus are more dependent on their car than persons who come directly or from the immediate vicinity of Schwäbisch Hall. As Kugoth (2019) explains, in rural areas it is not always possible to create incentives that make car abandonment attractive to all. Too often, the distance and/or topography for using a bicycle is too big or the connection of public transport is insufficient or is associated with a much higher expenditure of time.

Therefore, a possible parking management system may be an approach that measures a parking permit according to certain scoring criteria such as the location of the place of residence. For the introduction of a scoring system, which ensures that especially people with an increased need receive a parking permit, the proportion of car-driving people from Schwäbisch Hall should first be filtered out. For this group of people, alternative mobility solutions have a particularly high potential due to the short distance to the campus.

Public transport

Discussions about new pricing models for a semester ticket with the relevant decision makers and stakeholders will be started. Probably trans-regional solutions might be required as well as field tests. To improve the clocking of arrival times of public transport and lectures, a key aspect might be to change the starting time.

Ride sharing

The aspect of individual travel time of students depending on their lecture plan is an obstacle for using most of the available ride sharing apps. Other universities have therefore developed a specialized app, which allows finding ride sharing not only based on the day and place of departure, but also based on lecture plans. This option would make it easier to match supply and demand in university context. To develop an app is costly, but it might be interesting either to adapt existing apps to the local requirements or to work on app development in the form of a student's project or start-up.

5 Conclusion

The campus Schwäbisch Hall serves as a role model for greener commuting solutions at universities, but also in a more generalized way for sustainable and fossil fuel free transport modes in rural areas. The test phase and surveys were focused on the particular local framework conditions at the campus, so the results are limited and need to be adapted to contribute not only to the overall climate protection activities of the city, but also to create synergies with the total university's sustainability performance. Nevertheless, the authors are of the opinion that the main obstacles that can be derived are "typical" obstacles for universities respectively cities in rural surroundings and also reflect the general challenges in the transition phase of society, politics, public institutions and technology in the field of sustainable, fossil fuel-free urban development and transport solutions. The authors hope that the findings might add general input for other researchers and practitioners working on similar topics. It becomes clear that the reasons for transport means preferences are manifold.

The authors will continue working on developing detailed measures that can be implemented in a stepwise approach. Thereby, a key factor is the further implementation of stakeholders. Implementing measures that mainly address the city-internal mobility are likely to be focused on in a first step. As here, the potential for a cost and time-effective implementation seems to be highest. In return, the potential for saving CO_2 emissions is most promising as well. It could also be derived that planning accompanying communication measures, creating incentives and giving people sufficient time to try out new offers and change their behaviour are essential. In the future, connecting with other projects conducted at the Heilbronn University of Applied Sciences will be a goal to create synergies and a bigger impact and contribution to local and global climate change activities and smart city development.

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Smart and Digital Applications

As cities become more livable and open, it is essential to highlight the imperative role of technology and its effect on the urban environment. As it is now injected into the lives of residents through smartphones, laptops and tablets, instant information about traffic, announcements, health, transit and more are now more accessible. The digitalization of physical space and materials, the management of assets, users and businesses and the transmission of information and communication has enabled infrastructure to become smarter. However, current digital and management systems are not where it ends. The next industrial revolution, for one, will be founded on artificial intelligence where the Internet of Things (IoT), Big Data, Virtual Reality and a combination of digital and real infrastructure of a city will replace humans. That said, this section focuses on digitalization applied to the built environment and infrastructure that eventually will be the foundation of a Smart and Resilient City where systems are interconnected, provide abstraction in services, higher efficiency and a reduction in cost. In the chapter titled "Citizen potholes e-Report System As A Step to Use Big Data in Planning Smart cities in Malang City, Indonesia", the authors respond to the existing challenges of smart city implementation by creating a dialogue between the citizens and the government through Data Analysis, Text Mining and Geovisualization in Malang city, Indonesia. Through an exchange of information in spatial planning, social agreement between different parties such as city councils, local governments, urban planners and the community is established in an effort to provide direction and recommendations that formulate urban policies.Moreover, the application of smart technology and innovation in design and construction has also gained momentum in the construction industry as a way of reducing re-work, enhancing economic sustainability in project delivery as well as meeting smart construction requirements. In the chapter "Essential Features of Design Process for Professionals Participating in IBS Projects in Malaysia", the authors illustrate a new aspect of the design process of IBS projects that is the participation of the professionals that conduct them. After a desktop survey of the existing literature, the authors highlight critical cases of the design process for professional designers on IBS projects, potential means to close the design coordination gaps between various design professionals and recommendations for improving professional-to-professional communications.Alongside using data and technologies to create economic development, a smart city utilizes technologies that make it more efficient in terms of energy use. Today, major cities are experiencing the challenge of managing power usage efficiently. Accordingly, a current interest in smart cities has triggered a number of technology-led discussions and scalable solutions. In the chapter titled "SOLARQUIM: Dual Electric Power Generation system for Housing", the authors explore the potential of using solar and chemical energies and applying new technologies to obtain sustainable energy in cities. The author designs and develops a prototype that uses these energies to develop and generate electricity while reducing the emission of CO_2 at a low cost. The chapter introduces a dual electric power generation system designed and built by the author for a housing (SOLARQUIM), using solutions of crystalline solids and photoelectric cells, for a home housing four people in Texcoco, Mexico. The chapter provides insight into the importance of integrating clean energy technologies in cities and buildings and deems it necessary to take advantage of existing spaces and using alternative energy to reduce greenhouse gases (GHG) resulting from the combustion of fossil fuels. The increasing number of different energy options to generate electricity in Mexico will provide a cleaner environment that will gradually mitigate climate change, guaranteeing sustainable development for the next generations.Chapters in this part go as far as bring about benefits to multifarious areas such as sociology analysis, big data demonstration and hierarchy representation. Touching upon information visualization as a strategic source in the analyses of urban phenomena and data and as a result of rapid technical

advancement in connectivity, computer processing capacity and information and communication technologies (ICTs). In their research on "RumorClock: Visual Representation of Online Rumor Spreading", the authors propose a new information visualization model that can handle and compare rumors holistically with one another across time. Another chapter, titled "Towards the Building of a Visualization Method to Highlight Top Users' Trends in Social Networks", puts forward and analyzes an information visualization model, namely, the Social Network Public Emotion Information Visualization (SNPEIVM), that can show the public opinions in social networks and allow users an in-depth understanding of popular trends comprehensively.

RumorClock: Visual Representation of Online Rumor Spreading

Wu Dayong, Wang Jingyi, and Raja Majid Mehmood

Abstract

Information visualization has brought huge boons to multifarious areas such as sociology analysis, large hierarchies' representation, and big data demonstration. Specifically, online rumors spreading has become rampant due to the advanced development of social media. Effective governance of online rumors serves as a pivotal requirement for tycoons in social media areas like Facebook, Twitter, and Instagram. However, due to the tremendous volume of everyday rumors and their dynamic essence, pure texts or simple graphs can hardly demonstrate them accurately and comprehensively. Thus, in this study, we proposed a new intuitive visualization model called RumorClock, which can handle large scale of rumors as well as compare holistically between different rumors across time.

Keywords

Information visualization • Online rumor spreading • RumorClock

1 Introduction

Information visualization (Keim, 2010) is a visual representation of information to help users understand specific knowledge or phenomena. It assists researchers because under some circumstances, visualization may reveal valuable findings behind the data. A great deal of information can be shown in a clear and organized way as well, making it easier to perceive complex issues.

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Social media has promoted the dissemination of information and becomes an ideal platform for rumors diffusing (Luo et al., 2010). The governance of network rumors is important to social stability, economic development, and national security (Zhao et al., 2014). However, the information spreading in social media is usually large scale and social media is dynamic and complicated (Dang et al., 2016). Related works are concentrating on analyzing who spread rumors online, why, and how. Various novel models are proposed to study the spreading mechanism of network rumors or concrete propagation relationships.

In this study, we propose RumorClock, a new intuitive visualization model, which can handle a large scale of rumors as well as compare holistically between different rumors across time.

2 Problem Statements

We have surveyed the previous studies and selected one model that is recognized as public benchmarks in visualizing rumors spreading.

2.1 Reviewed Visualization Model

In "Toward Understanding How Users Respond to Rumors in Social Media" (Fig. 1), researchers used Reddit API (Weninger, Zhu, & Han, 2013) and jReddit (Dehghani, Johnson, & Garten, 2017) to extract 11,125 users' comments on 195 submissions about rumors "Obama is a Muslim" (Barreto, Redlawsk, & Tolbert, 2009) from Reddit since 2007 till 2015. They adopted D3 and jQUERY (Nixon, 2014) to display three types of data using multiple types of visualization methods, which were time-series graph of users' submission, user's interaction network graph about the selected rumors, and "who replies to whom" ground-truth

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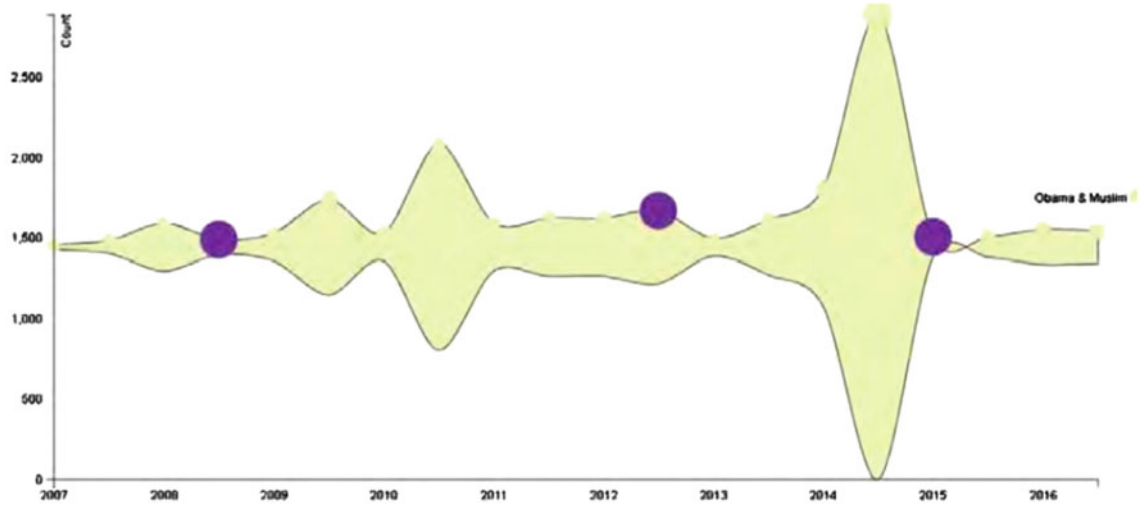

Fig. 1 Visualization from "Toward understanding how users respond to rumors in social media"

Table 1 Evaluation on the reviewed visualization method

Parameter	Evaluation
Position	Time is represented horizontally, starting from 2007 until 2015. Each node represents a submission, and the nodes are positioned according to posted time. The y-axis represents the number of comments of each submission. The purple nodes represent the submissions of one user's comment
Size	Lines indicate the general trend of the number of comments based on the rumors "Obama is a Muslim". Normal nodes show the number of comments in each year while nodes in purple represent the submissions of one user
Shape	–
Stipple/texture	–
Curvature	–
Motion	–
Title/orientation	–
Color	Besides the basic color of the chart, only purple was specially introduced to indicate the comments of a user

user network graph. Table 1 shows the evaluation on mark and channels.

This paper implements a general approach using Reddit data, and demonstrate its use by determining which users engage with a recurring rumor. It also analyzes their comments using qualitative methods. The paper seeks to reliably classify users into one of three categories: (1) "Generally support a false rumor", (2) "Generally refute a false rumor", or (3) "Generally joke about a false rumor". It aims to identify and classify those rumors-spreading user categories automatically and provide a more holistic view of rumors spread in online social networks (Table 2).

Apparently, the selected paper, namely "Toward Understanding How Users Respond to Rumors in Social Media", has broad vacancy for us to improve its ideas and means of visualizing data, social phenomena and research findings. Hence, we further analyzed its limitations.

- Not accurate enough: Readers can procure a merely abstruse understanding of changing trend of the popularity of a certain rumors.
- Commonplace in discriminability: The chart has very limited visualization elements to present data.
- Nondescript in salience: It bears little clear purpose of what to present or who to present.
- It has potential risk in grouping: There may appear overlapping if more than one user comment in the same year.
- Intuition is diaphanous: It does not meet the commonsensical ways of data presentation. Users need to do a lot of calculation.

Table 2 Evaluation on characteristics of the reviewed visualization method

Characteristics	Evaluation
Accuracy	Due to the utilization of areas as the mark and lack of variety of visualization methods, the figure is extremely vulnerable on accuracy in demonstrating detailed and quantitative information. Readers can procure a merely abstruse understanding of changing trend of the popularity of a certain rumors. Accurate value of the number of comments in a certain year is hard to perceive
Discriminability	The visualization in this paper seems mundane and moderate. It performs ordinarily in displaying discriminability to the users since it possesses very limited visualization elements. Only one color is particularly exploited, and all nodes are in the same size and shape
Salience (Pop-out)	The figure is nondescript in terms of salience. It bears little clear purpose of what to present or who to present. Using purple nodes for the user "kickstand" is meaningless and elusive. Moreover, the data density is superficial, leaving the chart with huge space unexploited
Separability	Separable representation is applied
Grouping	Nodes in the same color are used to display the comments of the same user. However, there may appear overlapping if more than one user comment in the same year
Intuition	The figure is vague when it comes to intuition. The reason is it does not meet the commonsensical ways of data presentation. Users must calculate the difference between the values of the two waveforms (upper one and beneath one) to acquire the result of the number of comments in that year, which is absolutely a waste of time
Interactivity	The interaction level is shoal. First, apart from the purple nodes added by the author just in order to highlight a user, there is no second color in the chart except the base color. Given that deficiency, the way users can access and interact with information are minimized. Users waste tons of time just in calculating and counting, there is no conspicuous or salient visualization to make the perception easier
Scalability	This visualization method is poor in scalability at root. As it is mentioned above, when more users are highlighted, overlapping is ineluctable if more than one of them comment in the same year. Let alone its inborn flaw that when the user volume becomes extensive, the visualization becomes chaotic

- Interactivity is shoal: Apart from the purple nodes added by the author just in order to highlight a user, there is no second color in the chart except the base color.
- Poor in scalability: Overlapping is a problem, while it also has its inborn flaw. When the user volume becomes extensive, the visualization becomes chaotic.

In order to improve the channel effectiveness and try to solve the current problems, we propose a new visualization method in the next chapter.

3 Research Methodology

3.1 Design Ideas

Based on the deficiencies of Fig. 1, our initial improvement was built upon the theories and concepts of radial chart, circular heatmap. The crux of our design was to improve the channel effectiveness (Fig. 2).

First and foremost, we used 10 datasets, and each contained one rumors with their respective number of

Fig. 2 Design draft of our proposed method RumorClock

comments. The source of the data stemmed from the same origin as our selected paper, namely Reddit. After getting the data, we pre-processed it, extracting the largest number of comments among all the 10 rumors and eliminating those rumors that had less than 100 comments. This was to exorcise anomalous data.

The design was based on a circular heatmap which was partitioned into 12 sectors, representing the 12 months of a year. Each sector was segmented again into four small sectors, indicating the four weeks of a month. Afterwards, we made each sector into 10 grids in equal length. Each grid meant one rumor. The width of a single grid indicated the largest number of comments among all the 10 rumors.

Supposing the number is 3000, subsequently, we put a scale ruler and each frame counted 500. Therefore, we could easily fill up each grid which indicated each rumor. In the end, users could easily perceive a circular line on each rumor which was fluctuating according to the change of its number of comments.

What's more, since the 10 rumors might not necessarily start at the same time, we made a color bar to as a color collection and used different colors to represent different years from 2010 to 2018. Then we filled up each grid by referring to the color bar and choosing proper color. Gradient colors were used to indicate the increment of years, which was a metaphor indicating the change of years is linear.

After filling up all the grids for all 10 rumors from their respective starting point to ending point, the initial improvement design was completed. It was highly scalable which could hold more rumors just simply by adding more girds in each sector, and the unit in the scale ruler could be adjusted according to the dataset. It was also of high interactivity since there were various kinds of colors to enable users to perceive. Users were also able to zoom in to see a more detailed scale ruler and the rumors title with the number of comments at one time by hovering the cursor on that point. The overall picture of the design vividly demonstrated the developing trend of each rumors. Taking a closer view user could also find tons of details revealing the attributes and changes of each rumors. Hence, the new improvement was upgraded in many aspects compared to the visualization in our selected paper, including accuracy, scalability, interactivity, etc.

3.2 Development Process

Our model was based on D3 (Zhu, 2013), which is a well-known visualization tool and library. We used JavaScript and CSS files to define elements and attributes of our model while HTML files were created to visually demonstrate our model in the browser. CSV and JSON files were used to store our dataset.

We initially made a heatmap diagram (Pryke, Mostaghim, & Nazemi, 2007) using JavaScript, in which a new object named circosHeatmap (Zhang, Meltzer, & Davis, 2013) from the class Circos was defined. In the corresponding function of circosHeatmap, 10 rumors (rumor1, rumor2 until rumor10) were created together with their respective attributes (block_id, start, end and value).

Subsequently, after finishing creating all the variables, we began to construct the layout. We drew the outermost circle representing the 12 months first. To realize the circle of months, we first needed to write code to illustrate its attributes (radius, colors, size and so on). Afterwards, we connected it to our dataset, which was a JSON file named "months". The color of each month was derived from a JavaScript file named "colors".

After drawing the circle of months, we started to delineate the real heatmap. As it is mentioned before, in this model, we deployed 10 rumors to test our design. Therefore, we needed to portray 10 heatmap diagrams. Since we had already created 10 rumors, which meant now we can use their respective id, start time, end time, and value. We made 10 heatmaps with their corresponding colors, indicating the year of each heatmap.

After all the work had been finished, we simply wrote a ". render ()" to give an order to the computer and portray our tracks (Fig. 3).

When the heatmaps representing the years of those 10 rumors were drawn, we began to show the number of comments of each rumor on its heatmap. The way we showed each one's number of comments was by filling up the grids and in the end a circular line that was fluctuating would be created. The wavering trend of the line revealed the change of the number of comments of each rumors as time goes by (Fig. 4).

To draw lines, we referred to our rumor's dataset. We used the same source of data in our selected paper, namely Reddit. We collected and pre-processed the dataset,

Fig. 3 Visualization of the rumors

Fig. 4 Visualization of the lines

eliminating those anomalous data. Then we used a CSV file to store the data. Our dataset had three attributes, namely, comment id, time, and value. We used JavaScript to render and demonstrate the lines according to the dataset. Finally, we utilized d3. queue () to load the path of our dataset (Fig. 5).

In the end, we rendered the heatmap diagrams and the lines together. Then we used index.html to arrange and project our final design to the browser.

3.3 Validation Test

- Accuracy. RumorClock is of high accuracy. Since we have introduced a scale ruler, and our arrangement of the heatmap is precisely according to the time duration of each rumor, one can easily read the exact number of comments of each rumor at a certain point of time. Additionally, users can see the rumors title and accurate number of comments at one time by hovering the cursor on that point.
- Discriminability. First, the overall layout, which indicates the 12 months can be perceived. After that, number of circular heatmap diagrams representing the number of rumors can be witnessed. The color of each heatmap showing the year of the rumor can be observed. The length of each heatmap which speaks of the duration of a rumors can be detected. What's more, the fluctuating line on each rumor which illustrates the change of the number of comments of a certain rumors can be noticed by the user. The scale ruler justifying the unit measurement of the number of comments can also be calculated.
- Separability. The interaction is high. We have different rumors nested inside the big circle one by one which vigorously compare their duration, changing situation of number of comments, and reveal the results to the user. Multifarious colors are also deployed to vividly show different attributes to the user. Specifically, we user gradient colors to represent the years of different rumors, which in fact is a metaphor of the linear characteristic of time passing.
- Pop out. In RumorClock, the peak in each rumors curve shows the abnormal data. Besides, if a user wishes to investigate a particular year, the unique color of the year is very conspicuous which renders it extremely recognizable.
- Grouping. All rumors are represented by circular heatmap diagrams, so if one wants to look for rumors, heatmap is

Fig. 5 Final performance of the proposed model (left) and zoom in view (right)

the kind of visualization that he or she needs. All lines are used to show the number of comments of rumors and they are all arranged above the heatmaps. Therefore, it is very clear if one wants to perceive the specific value of number of comments of a rumors. This model can show the frequency of occurrence of rumors to a certain degree because users can clearly see the distribution from the visualization display.

4 Results and Discussion

Based on the evaluation test results, we proposed a new visualization design in order to improve the channel efficiency. As shown in Fig. 6, there were mainly four changes, while the rest remained the same. First, the original white curves were removed while each rectangular background was shaped according to the number of online rumors, which was supposed to be a better encoding with higher discriminability than the previous combination of lines and rectangles. Third, when the number of online rumors was larger than two-thirds of the track height, this area was highlighted to indicate the abnormal situation. This was to achieve a higher salience, making it easier for audience to find the abnormal data. Finally, the color of the scale ruler was changed to black to make it more visible.

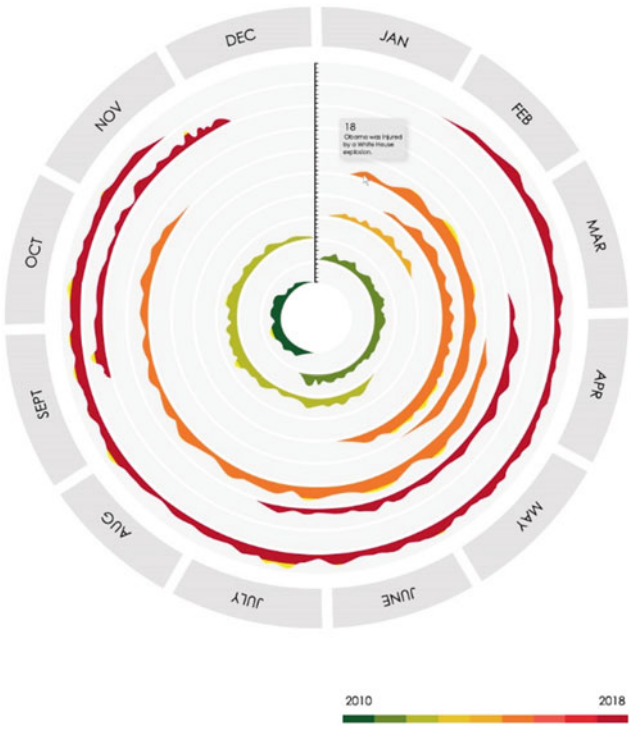

Fig. 6 The newly proposed visualization method

A questionnaire survey was conducted to allow the public to evaluate our two visualization models. Participants were lecturers and undergraduate students of Xiamen University, Malaysia. There were three sections in the questionnaire [8]: collecting participant's basic information, feedbacks on the original model, and the newly proposed model. Evaluation questions included first impression, time consumed to understand the graph, and Likert scale questions to measure participants' opinion toward accuracy, discriminability, salience, separability, grouping, intuition, interactivity, as well as scalability.

According to the feedbacks from all the participants, although the survey was conducted separately and individually, the results were nevertheless highly consistent. Participants averagely took 1–3 min to understand our original model and less than 1 min to comprehend the newly proposed model, which indicated that both models possessed high perception. The survey results also showed that when participants tested the validation of the original model for the first time, they tended to give marks between 6 and 8 (the range is 0–10). But when they saw our newly proposed model, the lowest mark of all the results was 8. This phenomenon showed that our first model was impressive by itself with being outperformed by our newly proposed one (Fig. 7).

Therefore, considering the results of validation test and questionnaire survey, we decided that the newly proposed model should be our final design. Compared with the visualization method in our selected paper, we have done significant improvements on every dimension in terms of the validation test. For instance, the new model leveraged fluctuating background instead of the combination of lines and rectangles to represent the number of online rumors, which gave users higher discriminability.

5 Conclusion

To recapitulate, our research was to select published papers related to information visualization field and detect as well as ameliorate their visualization flaws. Our thesis mainly focused on online rumors spreading, and we had selected one paper among three as our base model to further design our own visualization representation methods. Our final model RumorClock successfully outperformed all the baselines of the selected paper when we conducted validation test both by ourselves and by participants.

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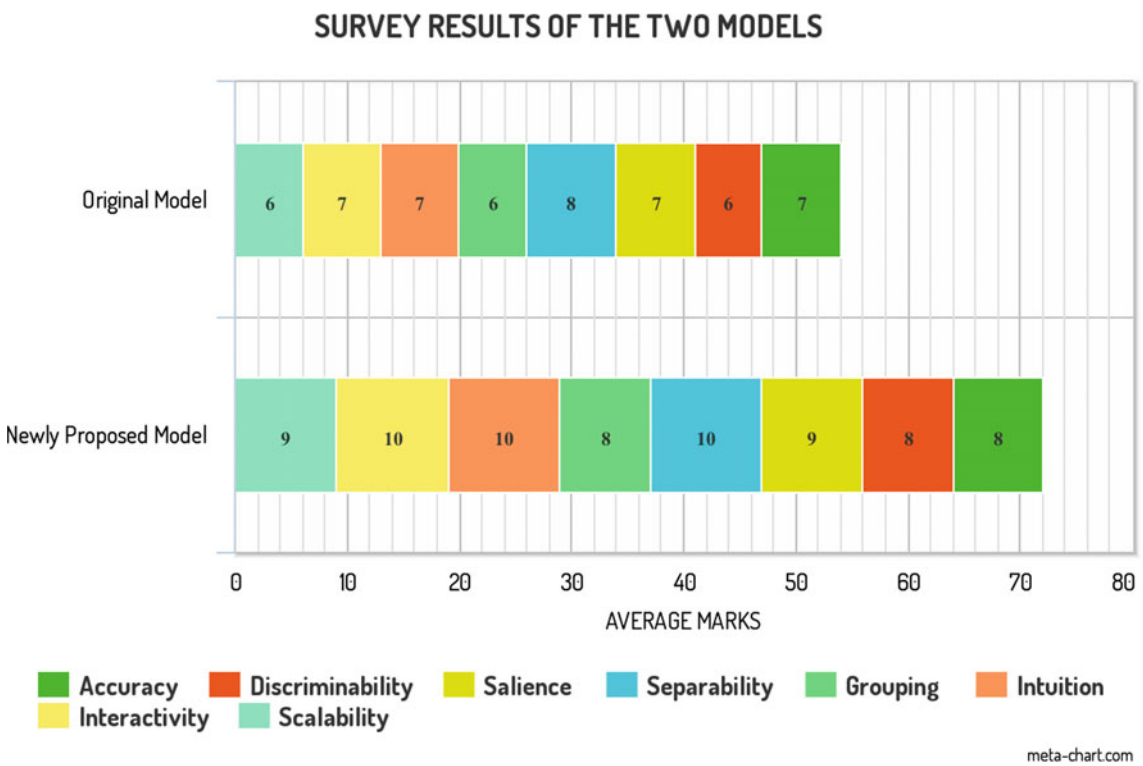

Fig. 7 Survey results of the two models

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Toward Building of Visualization Method to Highlight Top Users' Trends in Social Networks

Liu Quanwen, Zhang Yan, and Raja Majid Mehmood

Abstract

Social media plays an essential role in people's daily life. It is prevalent among the young generation. Social media applications, such as Microblog Sina Weibo, Twitter, Facebook, Instagram, are occupying significant positions in social connection and human being communication. Social media applications, like Weibo, provide the function of publishing, viewing, commenting, and sharing information. They also provide a platform for people to freely express their true feelings and opinions about the events through comment, retweets, and thumbs up. Information transmission on Weibo is real time, timely, and continuous, which helps track public interest and attitudes on a particular topic. Based on the information transmission on these similar social media networks, the sense of time, space, and strangeness between publishers and audiences is eliminated. Using information visualization can make the public opinions in social networks clearly show. The layered display composed of flower graph, radar graph, and pie chart allows users to have an in-depth understanding of popular trends from comprehensive to detailed. We choose Sina Weibo and 5G themes as visualization examples to demonstrate visualization methods applicable to all social media networks. We used a questionnaire survey to evaluate our visualization model. The analysis result shows that the model is creative, accurate, and easy to understand. In the end, the Social Network Public Emotion Information Visualization Model (SNPEIVM) is put forward.

Keywords

Information visualization • Social network • 5G topic

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1 Introduction

In this paper, the users' attention information of 5G is extracted and visualized by using the data from social media Weibo (Chinese famous social media application). Chinese users prefer to share their news or opinions about exciting or attractive things on Weibo. This application is the place where the news broadcasts most quickly and widely. Topics related to 5G are scorching, and its topics are transferred in Weibo. There are many posts and discussions related to it in Weibo every day. The user's attention keeps changing with the development of its development progress. There exists a relationship between different hot topics and the time they happened. It is similar to a flower, which has relationships between different leaves and the main trunk.

It is exciting and useful if the changes of user attention can be extracted and visualized to make people understand the general public attitude and trend changing of this topic. At the same time, the relationship among related topics is helpful to make people understand the whole topic rather than just a subtopic. There are some differences among different subtopics, and they can be analyzed by comparing different heat values of thumb, comment, and transferring. This heat value is beneficial to make people understand the differences among different subtopics. No information visualization tool or model can get all the value in a quick time.

Using information visualization can make the public opinions in social networks clearly show. We collect relevant information, analyze it from different dimensions, and then visualize the inappropriate information ways. There are around 100 questionnaires collected based on a literature review paper's information visualization methods and own methods. The layered visualization composed of flower graph, radar graph, and pie chart allows users to have an in-depth understanding of popular trends from comprehensive to detailed.

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https://doi.org/10.1007/978-3-030-63567-1_10

We choose Sina Weibo and 5G themes as visualization examples to demonstrate visualization methods applicable to all social media networks. We used a questionnaire survey to evaluate our visualization model. The analysis result shows the model is creative, accurate, and easy to understand. In the end, the Social Network Public Emotion Information Visualization Model (SNPEIVM) is put forward.

2 Literature Review

In 2017, Funayama, Yamamoto, and Uchida found that Twitter can be the application used for the government to transmit and collect data when the disaster happens. They focused on the Twitter SNS. They collected data by using the Twitter REST API and keywords. By using the meaning of the word of interest, they can predict the affected individuals' status. The Text Manning Studio of NTT DATA Mathematical Systems Inc. morphologically analyzes the collected data (Figs. 1 and 2).

Furthermore, information is added to the co-occurrence relationships of the words. After filtering Twitter data and generating interactive visualizations using the Network-vis package in R, they were able to extract specific information. Using this method, they developed a web application using the Shiny package in RStudio. Additionally, the number of words to be displayed, and the occurrence number can be arbitrarily set (Fig. 3).

In 2014, Lu, Yu, and Wan described the data mining scheme in the microblog network and the propagation path of the tweet. The article uses nodes and edges to represent relationships between users and tweeters and followers. Tweet data are collected through the open API. By using the Gephi platform, they visualize the tweet diffusion and find two typical propagation path modes, which are dandelion mode and the double-star mode. Two notable examples of microblogging are used to explain the characteristics of these two patterns (Fig. 4).

In 2015, Calderon, Chang, and Argueta, etc. provided a transparent, user-friendly summarization of the public's feelings expressed in Twitter regarding an event or subject. Additionally, the researchers integrate tools to the visualization, which altogether can lead to significant conclusion as to how events or individuals involved in these events impact society's perception or the public's feelings toward them. The graphical features presented in the work Emo-Trend is used to integrate a pattern-based emotion classifier. First, they selected all the posts containing the related tags.

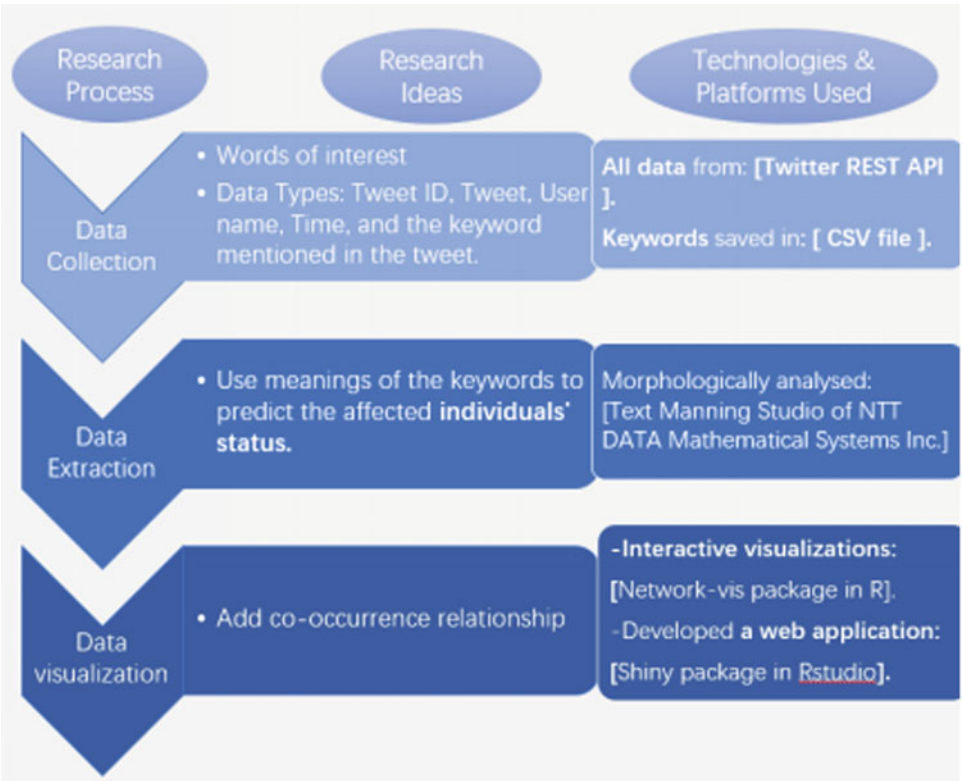

Fig. 1 Reference research process

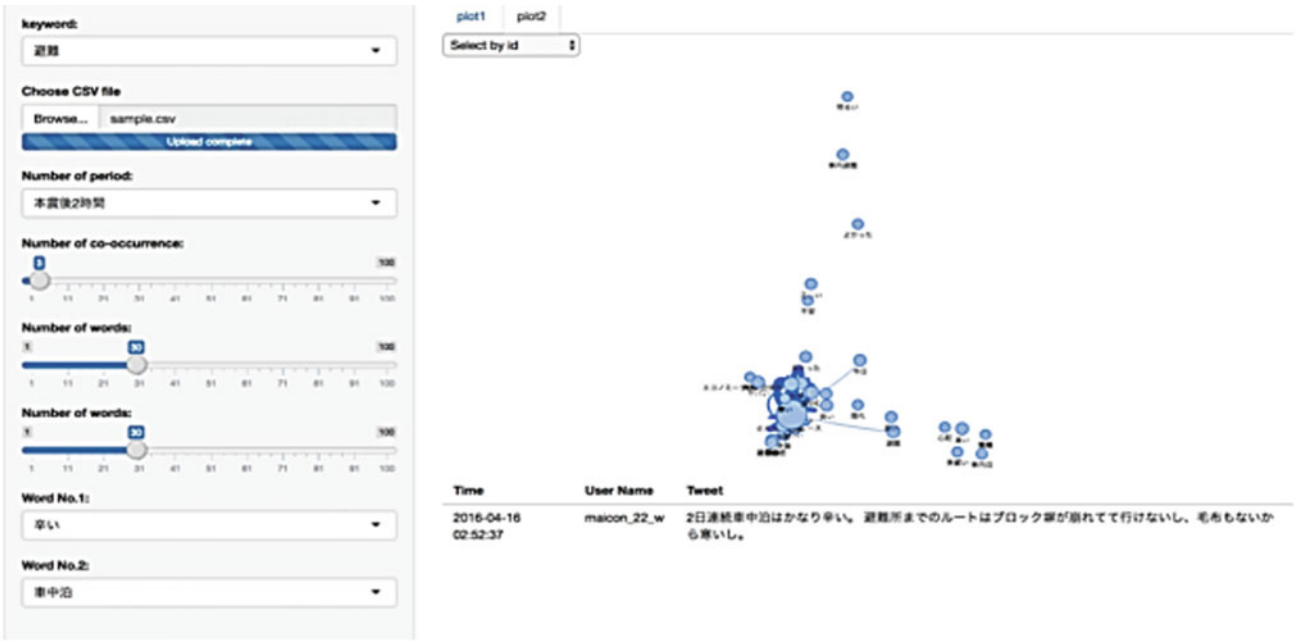

Fig. 2 Visualization application for the extraction of information from tweet data

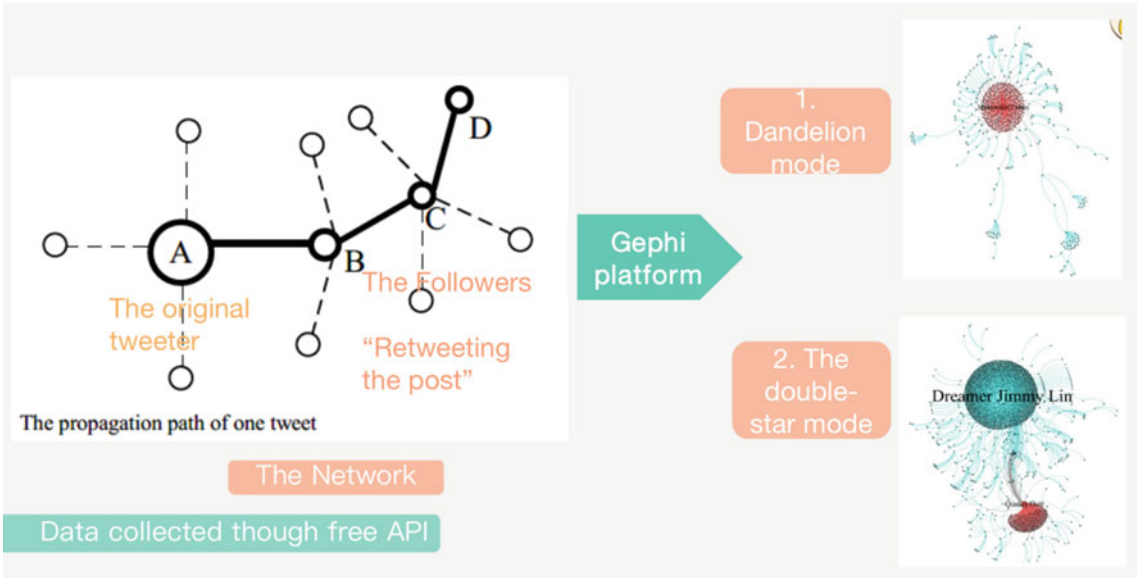

Fig. 3 Two kinds of explosive propagation pattern

After collecting the data, they use an emotion classifier to label all tweets according to the eight emotions is Plutchik's wheel. Next, the system visualizes those labeled data according to user-detailed queries regarding keywords and time to a time-based distribution. Besides, at the critical time point before and after each new episode update, the proportion of various emotional labels of users can be displayed by a bar chart or a pie chart.

3 Proposed Method

3.1 Our New Visualization Models

Our model provides not only the overall trends of social media users but also detailed information about topics and users by designing interaction in it. In this way, our

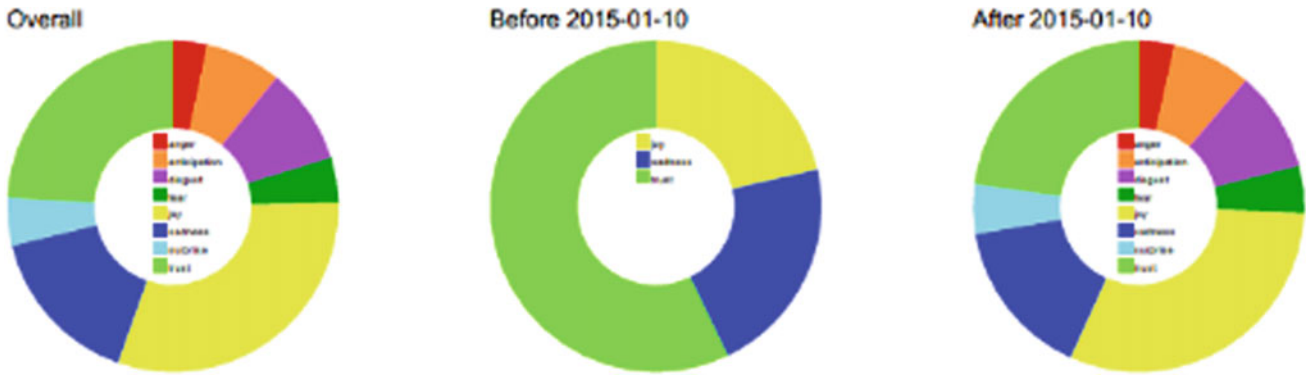

Fig. 4 Emotion distributions for the analyzed subject and partition date

visualization model is a combination of a tree chart of general topic trends, a heat map that contains all the subtopics related to a particular topic, pie chart of different emotional distribution states for a subtopic, and keywords with emotion clouds.

The following flowchart shows all the levels that users can reach by interacting with the model and the corresponding visualization results with the example of the 5G topic. Each process represents a hierarchy. The visualization results in the model were integrated by Micro index, draw.io, Excel, Weibo Application, and Worditout tools (Fig. 5).

In the tree chart, the whole tree shows the overall user trends in one social media, while a bunch of branches and leaves of a particular color shows users' trends of all the subtopics related to one specific topic. One leaf stands for one subtopic, and the size of a leaf shows how popular this subtopic is. As can be seen in the graph, many thin branches are extending from a thick branch, representing many related subtopics under this topic. In one branch, several shades of leaf color represent different kinds of subtopics; in this case, subtopics related to people, subtopics related to events, and subtopics related to countries (Fig. 6 and Table 1).

Use the 5G topic as an example. Since 5G is one of the hottest topics on Weibo, topics related to 5G are all integrated into one cluster. In this cluster, three sub-branches, each with the same color scheme, spread out from the thickest branch, representing three subtopics related to 5G. And each subtopic is represented by a leaf on each of these three branches, by category (Fig. 7).

The types of the three heat indexes are used to express the ranking of different subtopics in the three heat indexes by visualizing. When a user clicks on a leaf that represents a subtopic of interest to him, he can go to the third layer of the model and get the subtopic heat information displayed by a heat map. The vertical axis of the heat map represents the different subtopics related to the 5G topic. The horizontal coordinate is the three index types corresponding to each topic that are used to judge the popularity of the topic, namely comments, retweets, and thumb up numbers. Also, we used two colors to represent the extreme value after ranking the data of each heat category, blue for the maximum value and red for the minimum value. The shade of the color indicates how close the data is to each end. We chose white for the middle data to highlight the message. For example, if users want to find the subtopics with the most significant and smallest forwarding volume under the forwarding heat index, they only need to find the subtopics corresponding to the deepest blue and deepest red (Figs. 8, 9 and Table 2).

The specific data about each heat distribution can be obtained through the user's interaction with the model to the next level. Data labels occur when a user clicks on the corresponding box to get specific data, such as the amount of "Mr. He" subtopic forwarded. If users want to learn more about a specific microblog content, for example, if they want to know what is the microblog with the highest forwarding volume of the subtopic "Mr. He," they only need to double-click the grid, and then the profile picture of the microblog with the highest forwarding volume appears. By clicking the profile picture, they can know the information of the blogger and the microblog content with the highest forwarding volume (Fig. 10).

The distribution of the number of users with different attitudes in each subtopic is shown in a word cloud. The keywords corresponding to each kind of attitude in each subtopic are converted into a word cloud by the WordItOut platform to realize word frequency visualization. We set the frequency of each text and its corresponding frequency through the word frequency data collected by statistics, to clearly distinguish the frequency and importance of labels or words and make the visualization results more intuitive and more transparent. Additionally, one specific color is chosen for the keyword cloud for each attitude, such as the word cloud with red and orange fonts to indicate support for this attitude (Fig. 11).

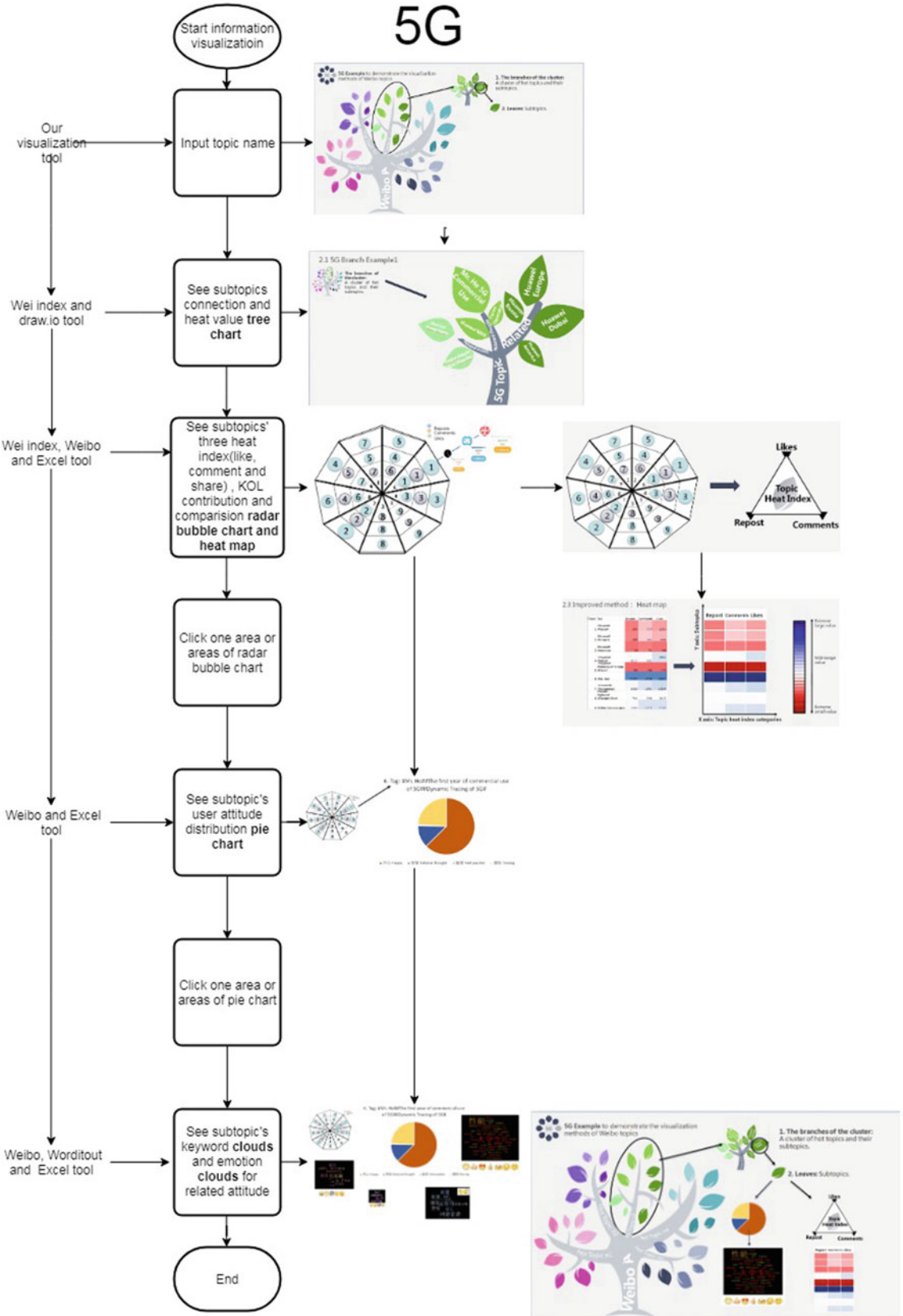

Fig. 5 Overall of new model

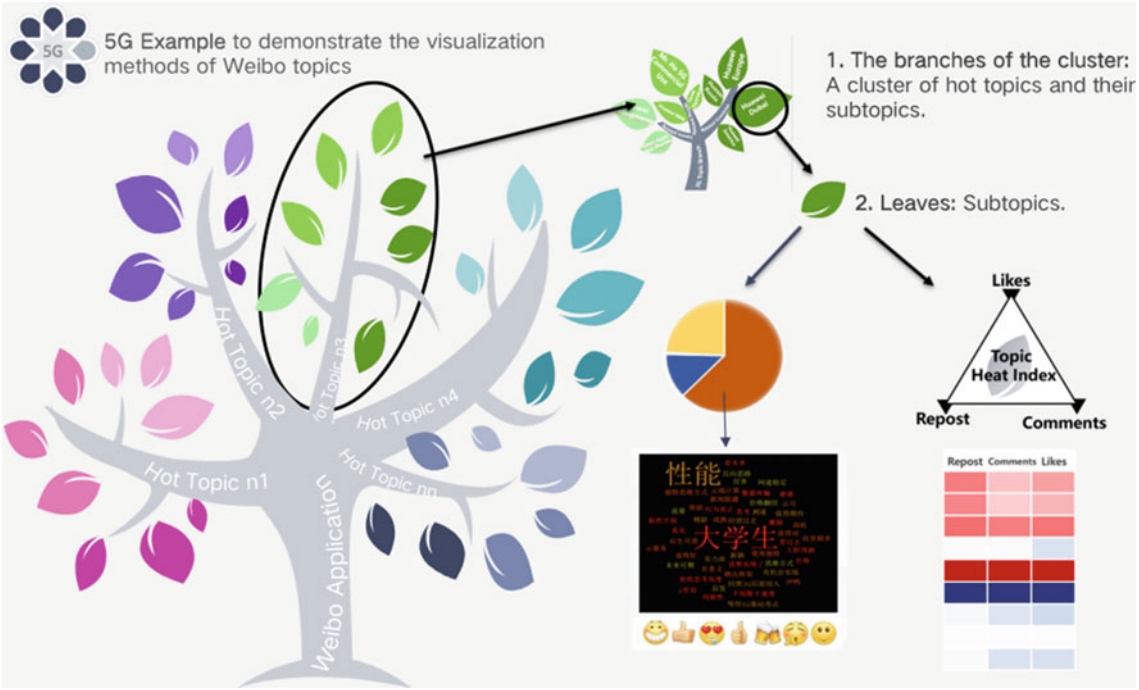

Fig. 6 Overall hierarchy of our visualization method

Table 1 Tree chart explanation

	Meaning	Degree	Color
Whole tree	Topics on Weibo application	Tree trunk	
A bunch of branches and leaves	A related topic integration	The thicker the branches, the hotter the topic	Different colors distinguish different integration topic areas
A sub-branch under a branch that represents a hot topic	Different categories of subtopics under this hot topic	The thicker the branch, the more subtopics the analogy has	Use the same color system to represent different subtopic categories

3.2 Collection of Weibo Data

We used the data provided by microblog platform, including thumbs up of a single microblog, the number of comments and reposts, the number of thumb up of each comment under a single microblog, and the heat value of the topic.

Information resources (Get high praise comments) are:

- Keywords. Keywords related to emotional expression and perspective on significant issues.
- Image(emojis). Emojis are the second way that users can assist in expressing emotions and attitudes. Emojis often use visual effects to directly express or reinforce the user's attitude in the text. Hence, facial expressions are also essential information.

3.3 Information Extraction Method

To analyze the event more comprehensively from different perspectives, we extend from the core event to find out the roles involved in the event or observe a single microblog with great attention during the development stage of the event (e.g., this microblog was on the hot search list because of its high popularity). In this way, we can collect users' views and attitudes toward different roles in this event. These related subtopics are often registered as hashtags by users so that they can focus and exchange views in the "topic square." After listing the hash-related tags, we searched these tags one by one, ranking the Weibo with relevant hashtags by heat, and finding the three most popular Weibo

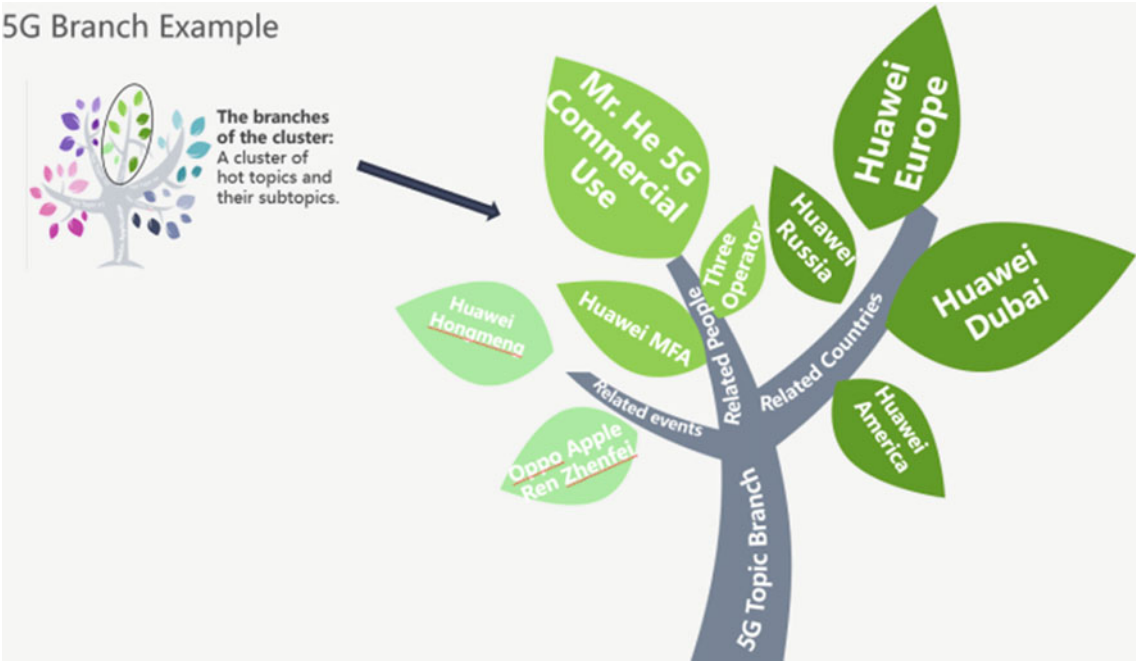

Fig. 7 Take 5G and its subtopics as examples to show the visualization effect of each subtopic

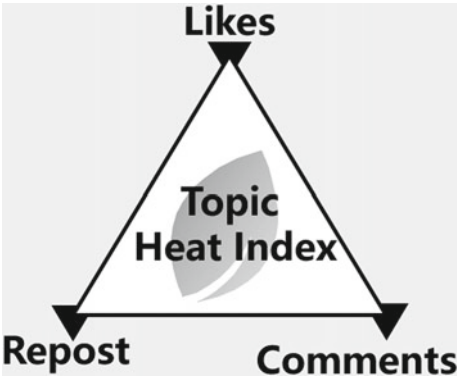

Fig. 8 Topic heat index

based on the number of comments forwarded by thumbs up (Fig. 12).

After identifying the three most representative popular microblogs, we recorded the publishers of popular microblogs. These publishers tend to be verified as official Weibo users, or bloggers with in-depth research on such topics. We recorded the content of Weibo as well as the number of followers and the certification profile of the corresponding publisher, as the reference data for later analysis (Fig. 13).

Next, we sorted the comments on Weibo by the number of thumbs up. The higher the number of thumbs up, the more users agree with this comment. Therefore, this comment is representative. It also avoids the tedious task of sifting through the data one by one for all comments. Thus, the number of thumbs up for comments would be recorded as data for word frequency analysis (Fig. 14).

Start with the most thumbs up comments and extract the keywords contained in the comments. The content of the comment is then classified by analyzing the meaning of the keyword in the context. Keywords and emojis are also recorded in the comments. We repeat the steps of extracting data from comments with thumbs up numbers at the bottom until enough data is collected, and the number of comments thumbs up to be collected in the queue is negligible. After data extraction, we visualize the information in different techniques and ways (Fig. 15).

First of all, for each subtopic, we generate a pie chart of each attitude and the corresponding number of thumbs up using the analytical visualization tool of excel so that the distribution of the number of users with different attitudes in each subtopic is transparent. Next, the keywords corresponding to each kind of attitude in each subtopic are converted into the word cloud by WordItOut platform to realize word frequency visualization. WordItOut is a kind of visual pattern that presents labels or words in different fonts or colors. We set the frequency of each text and its corresponding frequency through the word frequency data collected by statistics, to clearly distinguish the frequency and importance of labels or words and make the visualization results more intuitive and more precise (Fig. 16).

Additionally, we chose a specific color for the keyword cloud for each attitude, such as the word cloud with red and orange fonts to indicate support for this attitude, which makes

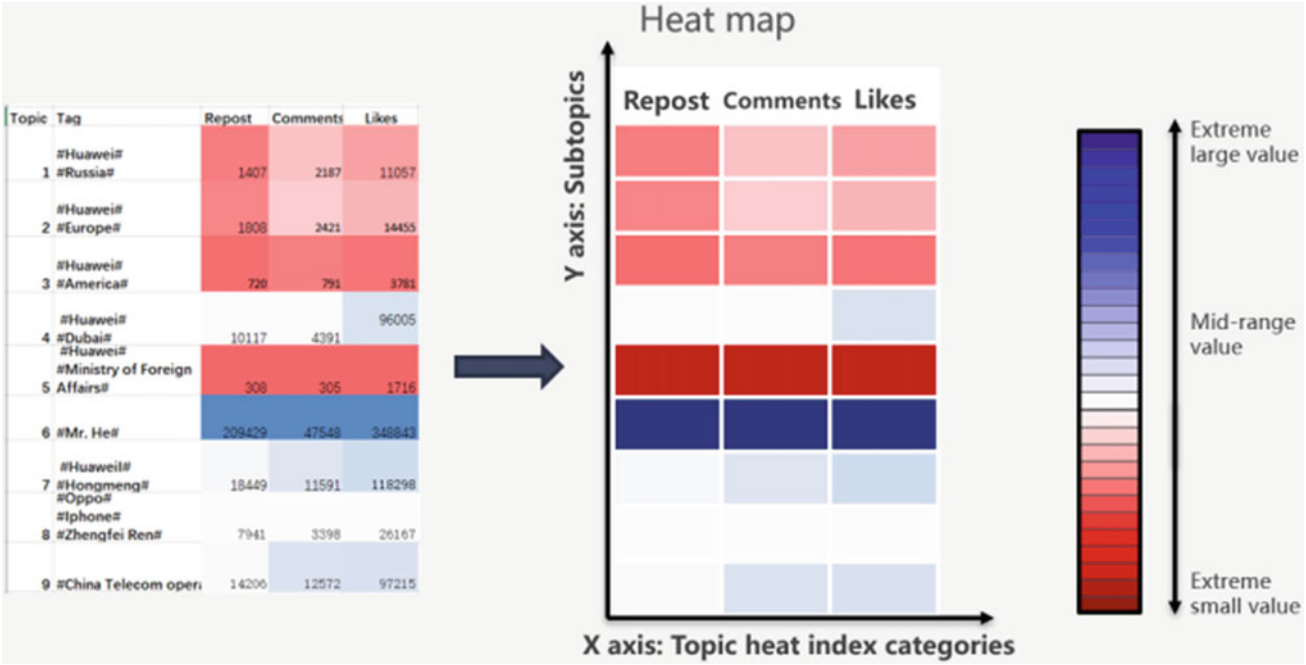

Fig. 9 Heat map for subtopics

Table 2 Description of heat map

Vertical axis	Horizontal Axis	Gradient of color	Color		
Different subtopics	Heat index category	How close the data is to the extreme	Blue	Red	White
			Extreme large value	Extreme small value	Mid-range data

it easier for users to judge the attitude represented by the cloud visualization results. It is also helpful to obtain information through horizontal comparison of keywords contained in different subtopics of the same attitude (Fig. 17).

After analyzing the heat curve of each seed topic, we recorded the turning point of heat trend of each topic, and then integrated the heat trend of nine seed topics into a broken line graph by Excel (Fig. 18).

This makes it easy to compare the heat trends of the nine sub-topics over time. Finally, we counted the total retweets, comments and thumb up quantity collected by each sub-topic in excel, and then visualized the popularity of the nine sub-topics in one chart by bar chart (Figs. 19 and 20).

4 Results and Discussions

By using our visualization model, we find that 5G is a scorching topic, and there are so many people concerned about the subtopics. There are some subtopics more exciting and attractive compared with other subtopics. For example, the subtopic tagged with "Huawei," "5G commercial usage," and "He university student" is more welcomed than "Huawei Russia." The hottest topic "He university student" is published by a KOL He university student who experienced the 5G in his university. Besides, "Huawei Russia" is an international and political topic. The different subtopics under 5G have different heat values, but there are similarities and connections among them. At the same time, different KOL take different effects on the transportation of this 5G topic. Our visualization model makes it very clear to see the subtopics heat value, change, relationships, and public emotion distribution and comments. Using the analysis of "5G" topics in the social software Weibo to obtain an information visualization model helps to analyze other social media networks and other topics in different fields.

By analyzing the evaluation result, we find our model marks are easy to identify. And different marks (color and size) are helpful for users to extract information from

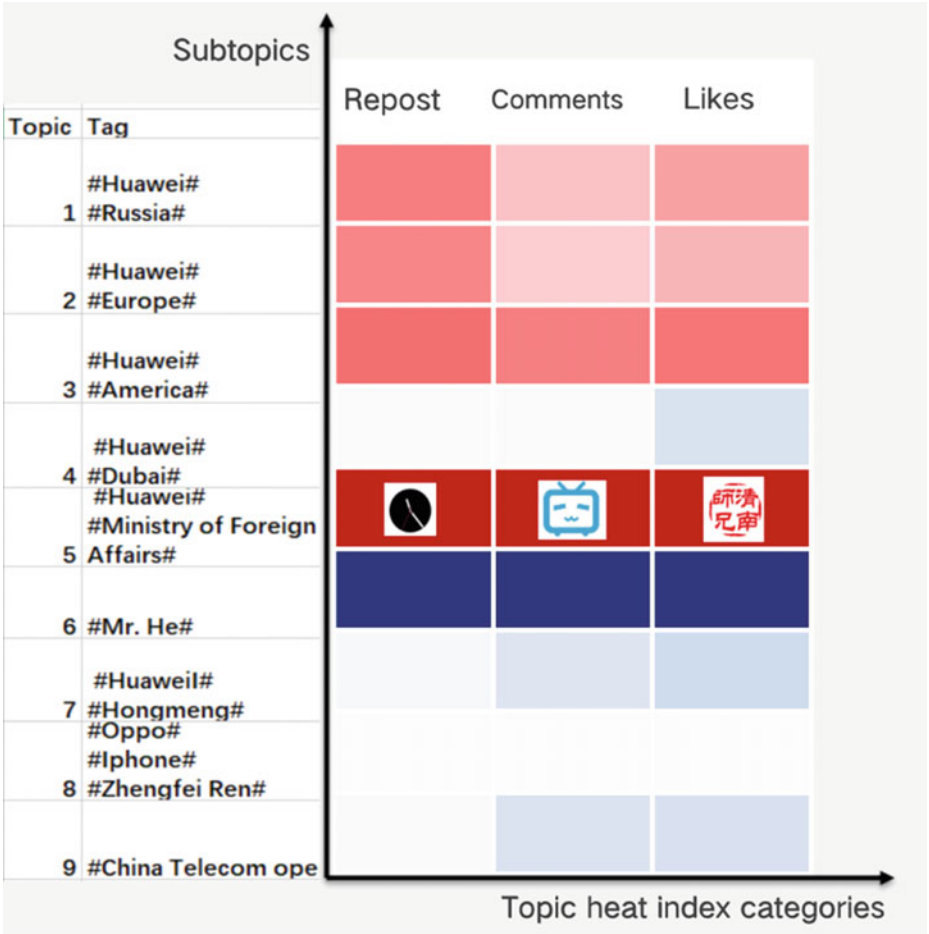

Fig. 10 The heat map grid displays the specific Weibo and blogger information interactively

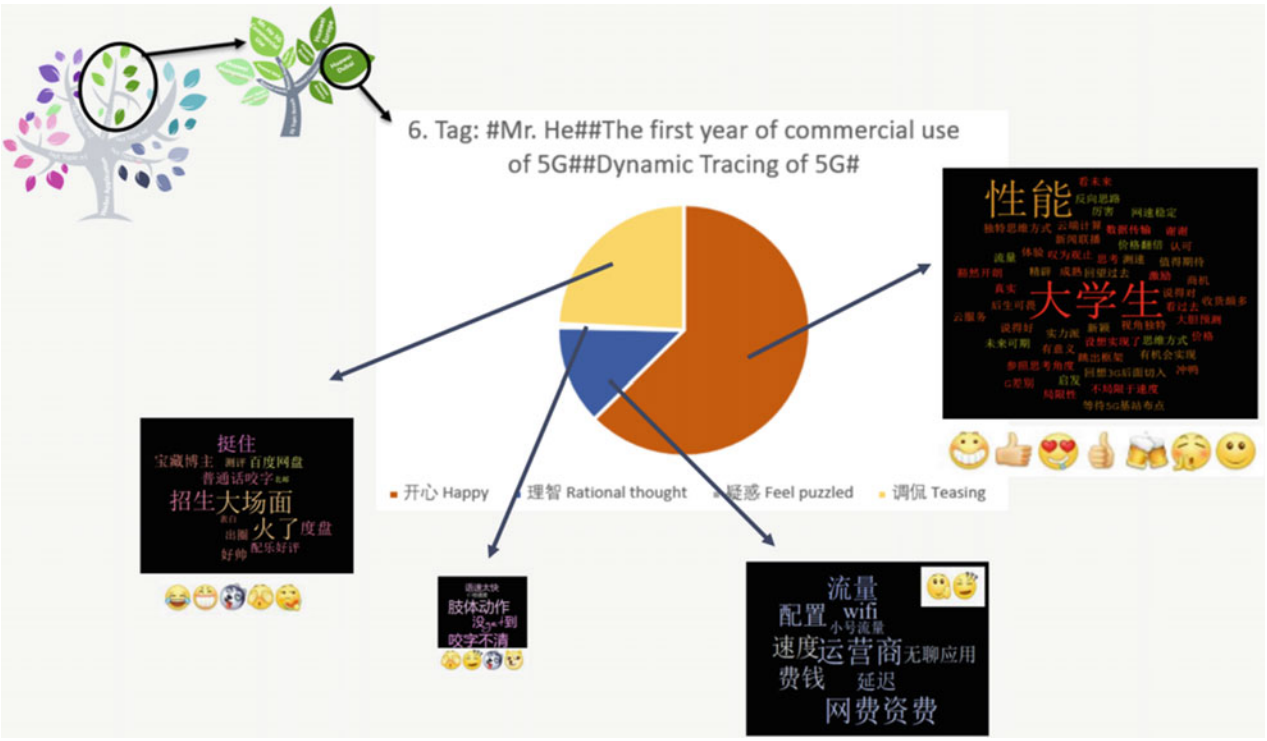

Fig. 11 The proposed visualization method displays the specific Weibo and blogger information interactively

Fig. 12 Data for one Weibo

Fig. 13 Data for ONE Weibo Publisher

diagrams more quickly. It is designed right enough for perception because, without description, they can get the meaning of different marks quickly. For the real meaning connection, most people think the connection is good and clear enough. They think this information visualization method is both creative and interesting.

At the same time, from our evaluation result, we find our information visualization model is better than other existing models, which are mentioned in our literature review parts. Our evaluators cannot have a clear enough understanding of the marks and channels. They are challenging to understand and connect these marks and channels with real meaning. It is hard to eliminate the descriptions which are put forward by us to make them have a good understanding and do a proper evaluation scorching.

5 Conclusion

Mentioned in the above phases, our information visualization model makes 5G as our tested topic. Under 5G topic, our information visualization model can give users chance to understand the relationships and heat value of different subtopics, public's most popular action (likes, comment or share) toward those subtopics, most significant KOL in the information transferring, public's emotion and most discussed keywords distribution and clouds. By using our information visualization model, the users can get the whole generating trend of their interested topics together with related topics or subtopics. Compared with other media or information visualization tools, they can not only get knowledge of these topics but understand the public's attitude toward these topics.

In the stages of data collection, data extraction, and data visualization, we use different technologies and platforms to process data and make models. Weibo public data is used to grab relevant data to get the public's attitude and discussion keywords; the Wei Index platform is used to get the heat value, such as thumbs up or the number of comments; WordItOur word cloud tool and Excel are used to visualize data. By analyzing our test and evaluation results, we found that our information visualization model was enough to attract users to use our model.

In this paper, we just put forward our information visualization model. In the future, we will develop more tools to make our model more efficient in dealing with users' actions. At the same time, the interaction part of our information visualization tool will be improved. We will make our

Fig. 14 Comments for one Weibo

用户情绪

开心（获赞 6063=3288+1000+461+847+176+142+62+48+25+14）（美假 5G 美被中国虐 美 价格翻倍 实力派 表情--加油）

理智（获赞 2331=1942+349+30+1+9）（美坑民众 怪特朗普 差距 表情--拜拜）

疑惑（获赞 280=216+64）（对讲机 怀疑 表情--费解）

吃瓜（获赞 163=56+30+19+19+18+2+7+4+4+1+1+1+1）（妹子 对讲机 表情--笑哭 咧嘴笑 狗头 阴险 吃瓜）

Fig. 15 Users' emotion calculation

Fig. 16 Keyword cloud generation by WordItOut

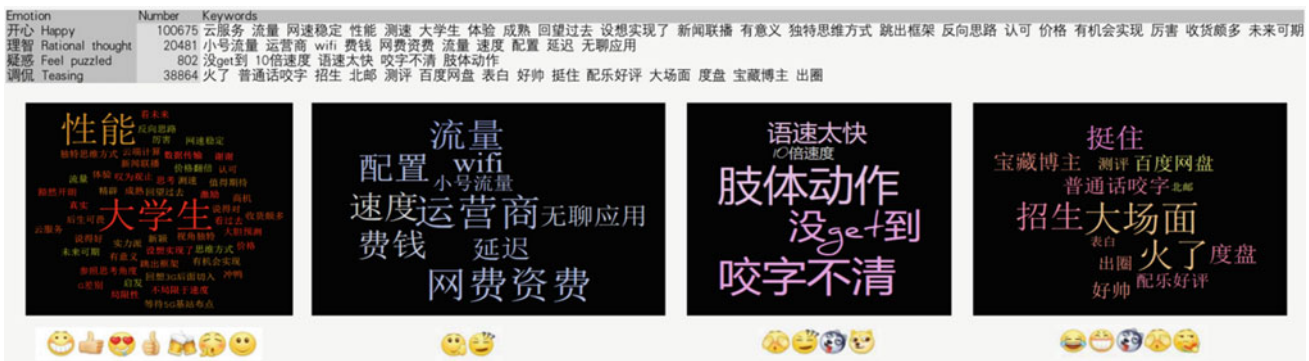

Fig. 17 Keyword cloud for different subtopics

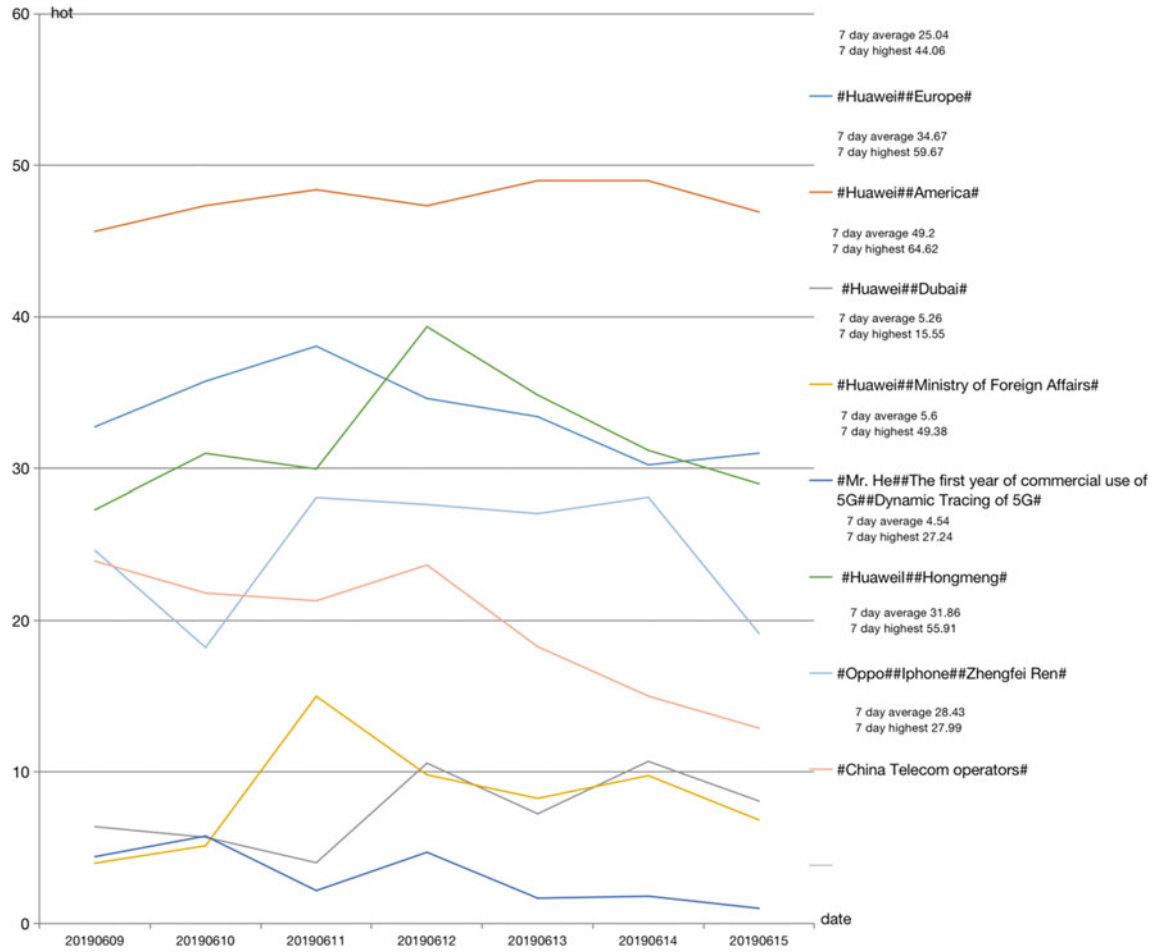

Fig. 18 Sub-topics heat trend line chart

Topic	1	2	3	4	5	6	7	8	9
Tag	#Huawei# #Russia#	#Huawei# #Europe#	#Huawei# #America #	#Huawei# #Dubai#	#Huawei# #Ministry of Foreign Affairs#	#Mr. He# #The first year of commercial use of 5G# #Dynamic	#HuaweiI# #Hongmeng#	#Oppo# #Iphone# #Zhengfei Ren#	#China Telecom operators#
Repost	1407	1808	720	10117	308	209429	18449	9774	7799
Comments	2187	2421	791	4391	305	47548	11591	1515	1164
Likes	11057	14455	3781	96005	1716	348843	118298	13620	37697

Fig. 19 Subtopics Weibo repost, comment and likes dataset

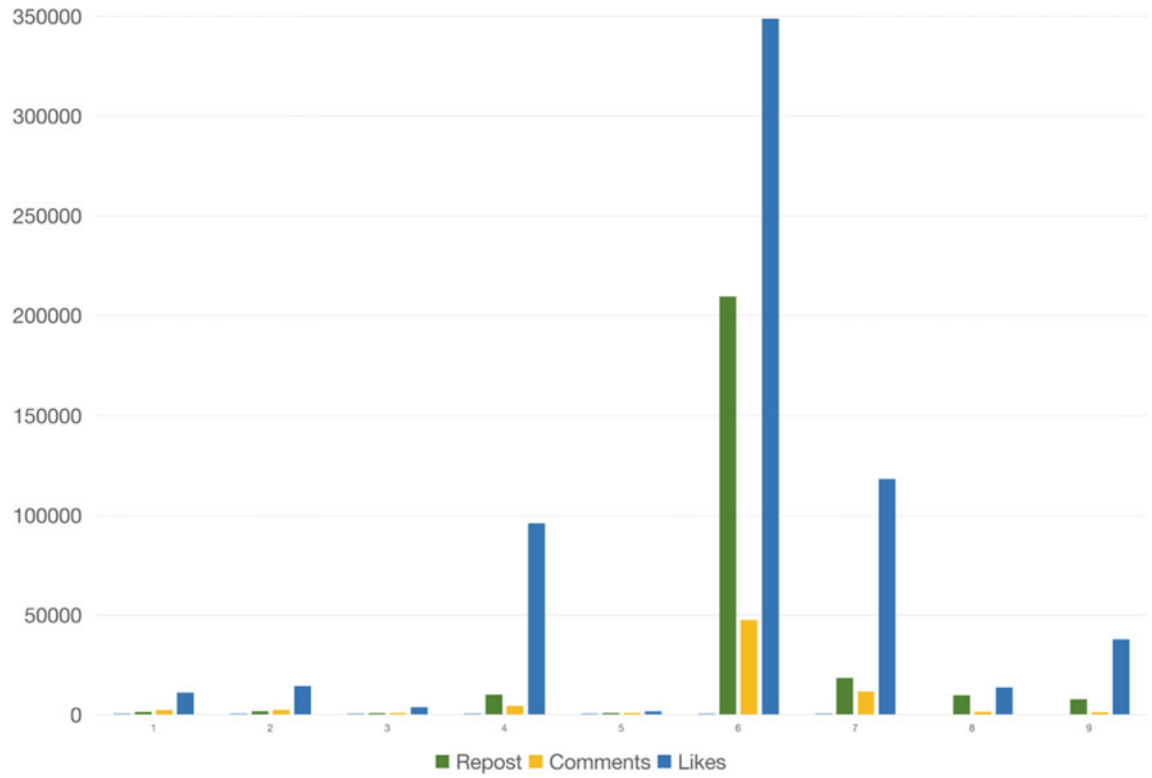

Fig. 20 Sub-topics Weibo repost, comment and likes bar chart

information visualization tool good enough to deal with the whole social media network topics and subtopics.

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Essential Features of Design Process for Professionals Participating in IBS Projects in Malaysia

Mohsen Delfani and Rahinah Ibrahim

Abstract

The present study attempts to improve on previous works regarding critical factors during the design process of Industrialised Building System (IBS) projects among professional designers by proposing a conceptual model. Although the literature points to the numerous contributions of IBS in the construction industry, in reality, the usage rate is rather slow in picking up. In this regard, the literature highlights one of the essential issues that much information must be coordinated among different disciplines, teams, and sub-teams for successful project delivery, which renders the design stage in IBS projects as a critical stage. This paper is an empirical effort to understand the sources of highly intensive coordination works and to report the discovery process of potential tasks and means to ease or reduce such coordination work during the design process. The focus is on the involvement of various disciplines and identifying functions or actions for IBS projects during the design process, which could cause bottlenecks that might be the cause of delays faced by the usage of IBS. The result reveals the participation of multiple disciplines during the design stage of an industrialised building, thus highlighting critical cases of the design process for professional designers of IBS projects. It is hoped to also highlight potential means to close the design coordination gaps between various design professionals and to provide recommendations for improving professional-to-professional communication. The study aims to contribute to promoting the usage of IBS among professional designers in the construction industry and to reduce potential re-work during the construction phase by using smart technology and innovation to deliver the design and accordingly meet smart construction requirements, which can enhance the economic sustainability of project delivery in Malaysia.

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Keywords

Industrialised building system (IBS) • Design process • IBS design • Professional designers • Smart building

1 Introduction

Nowadays, the construction industry is recognised as a sector that influences the economy of nations through a crucial role in societies to motivate domestic economic activities and development. However, the sector is unable to respond to the demands due to facing hindrances such as delays in the schedule, poor quality, cost overruns, health and safety, low productivity, high material wastage, low speed of production (Vrijhoef and Koskela 2000; Jabar et al. 2013), and various conflicts during implementation off and on construction sites. Therefore, these create a negative image of the construction industry as a low-paced sector for society.

Additionally, concerning the progress of different technologies in various fields, particularly over the past few decades, the construction industry is ranked to lag behind other sectors (Martinez et al. 2008) in getting benefits from, and taking advantage of, smart technologies and innovative performs (Eichert and Kazi 2007). So, the construction sector has been criticised for having poor performance due to its fragmented nature (Eichert and Kazi 2007).

Likewise, it is stated that the sector has not benefited from smart technology in construction methods and design, which leads to various emerging gaps. The hindrances have motivated the conscious mind of the stakeholders to move towards the concept of smart buildings. Many attempts have taken place to create new techniques and update old methods to boost the sector (Gibb and Isack 2003; Pan et al. 2008). Therefore, the industry welcomes a renewed interest in industrialisation to address the abovementioned problems (Jonsson and Rudberg 2014) as a solution.

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In fact, industrialisation contains a higher step of standardisation of both products and processes, a higher level of prefabrication and offsite production, platform-based approaches, and moving the value-adding activities upstream in the supply chain (Barlow et al. 2003). Additionally, industrialisation brings numerous advantages to attention, such as achieving agreed costs and time frames, high quality, minimising on-site duration, and covering skill shortages (Pan et al. 2007).

To implement industrialisation in the sector, under the umbrella of Modern Methods of Construction with some of the same targets, many concepts with different interchangeable names have emerged in various contexts. Following that, the concept of the Industrialised Building System (IBS) was coined as one of the essential terms, which is used for private and government sectors of the construction industry for Malaysia as a fast-developing country (CIDB 2003; Jaganathan et al. 2013).

However, apart from the vast majority of benefits of IBS projects, in reality, most stakeholders and professionals are as yet reluctant to welcome IBS. This declaration is supported by several studies that have advocated that offsite construction only contributes a low percentage in the market of developed and developing countries (Goulding et al. 2015). For instance, exercising office construction is not yet recognised in the private sector projects in Hong Kong, but the market portion in the U.K. is run only by around 6% of small companies, nearly 7% in the USA and around 20% in Japan (Jaillon and Poon 2009; Taylor 2009). In an IBS midterm review in Malaysia, it was seen that IBS was involved in only 10% of completed projects in 2006, while the estimation by the IBS road map (Hamid et al. 2008) was much higher at 50% in 2006 and 70% in 2008.

Although there are numerous passive and active contributions of IBS for the construction industry, the usage rate of IBS in the sector is considerably low in reality. From this point on, this study puts its efforts into discovering the most significant step towards creating a stepping stone for further studies, which would be able to overcome the problems of IBS projects that would increase the usage rate of IBS.

So, as the benefits of applying an IBS have been well recognised globally in the construction industry, the application of IBS is particularly limited in developed countries. As a consequence, the low quality of IBS is considered one of the key issues affecting its application (Gan et al. 2017), which is mostly related to the design part, where it is considered as one of the essential phases of IBS projects. Some efforts have been applied to identify the critical factors in framework IBS in Malaysia (e.g., Nawi et al. 2014). The present study attempts to improve on previous works regarding the critical factors during the design process of IBS projects among professional designers using a conceptual model.

2 Theoretical Background

2.1 IBS Projects

These days, IBS is acknowledged as an answer to solve the enormous cumbersome problems of the construction industry in terms of social, technical, organisational, economic, political issues, etc. This term is to represent industrialisation in construction and is majorly used for widespread understanding by practitioners and academicians in Malaysia (Kamar et al. 2009).

In 1971, Dietz defined IBS as the integration of all systems and subsystems from the entire process, fully applying industrialised production, transport, and assembly. Following that, Warszawski (1999) pinpointed IBS as a set of interrelated elements working together to enable the achievement of the designated performance of buildings. Briefly, based on the several definitions of industrialisation (Warszawski 1999; Gibb 1999; Gann 1996), it can be represented by the following working definition in the construction sector: Industrialisation is a business strategy that alters the traditional construction process into a manufacturing and assembly process to reduce cost, time, and improve the quality of the product/service. This achievement is actioned through engaging people, embracing new technologies of process/products, and translating the needs of clients into building requirements through new contractual working relationships across the whole supply chain.

Also, it is generally believed that the design process plays a significant role in all construction projects in terms of cost-effectiveness, timeliness, and quality of the entire construction projects (Chua et al. 2003). Furthermore, Moum (2006) mentioned that the fundamental pillar of a successful construction project is the design process. To explain the crucial role of the design process in IBS projects, Delfani argued that the effectiveness of the design process to succeed would be considered as one of the main factors in the projects (Delfani et al. 2016). However, Sadafi stated that the problem is related to the design process of IBS, which is categorised as the most crucial issue (Sadafi et al. 2012). So, it is essential to take urgent actions to solve the design phase problem in IBS projects, which motivates this study to investigate the existing design process of IBS projects.

2.2 IBS Design Features

According to the literature, IBS causes a transformation, which modifies or alters traditional methods of thinking, encourages and motivates capital development, enhances cooperation, boosts trust between parties, and raises transparency and integrity (Shaari and Ismail 2003). Alongside

the above, based on the leading role of design for a project to succeed, this transformation starts from the design process of IBS projects, so that there are undoubtedly vital aspects that need to be investigated, namely, two items including the concept of Modular Coordination design method and participation of professionals in the design process of IBS projects.

2.2.1 Modular Coordination (MC) Design Method

IBS encourages the change from craft and resource-based construction towards production, manufacturing, and industrialisation (Leabue and Viñals 2003; Warszawski 1999). Neelamkavil addressed that IBS tries to adopt the principles of mass production and mass customisation taken from manufacturing to respond to the demands (Neelamkavil 2009), which motivate IBS to move towards a new concept to obtain benefits from the Modular Coordination (MC) concept in the design process (Delfani et al. 2016).

MC is defined as a system devised to coordinate the sizes of factory-made building parts with the designs of buildings (Piroozfar and Farr 2013). To highlight the applicability of MC in IBS, several authors declared that MC and standardisation are essential requirements underlining the productive employment of IBS, Thanoon et al. (2003), Onyeizu et al. (2011), and later Delfani et al. (2016). Therefore, this injected concept brings along new challenges for IBS, particularly in its design stage.

2.2.2 Professional Participation in the Design Process of IBS

From another point of view, Friedman stated that design is an activity that designers utilise to solve problems, to create something new or to transform fewer desirable situations to preferred ones (Friedman 2005). In addition to that, as IBS constitutes various systems, subsystems, factory-based products, and manufactured components (Rahman 2013), the number of design specialists will be increased according to the increase of the production in building and technical complexity (Otter and Prins 2002).

However, regarding the current complexity of construction projects, various numbers of designers, constructors, and directors are needed to deliver a project environment due to the participation of numerous organisations and specialists who work apart (Atsrim et al. 2015). In fact, IBS is not an exception among these disciplines as well, and that it could be specifically related to IBS projects in which the components must be manufactured in different locations, which will be a new challenge.

Ultimately, as IBS is considered a complex project (Blismas et al. 2006), it requires collaboration among project designers, engineers, and advisers (Prins and Owen 2010), which might create new challenges for the design process of IBS projects related to the specific design method employed.

2.2.3 Challenges of the IBS Design Process

This study will address the abovementioned challenges briefly, as explained in the following. First, IBS is supposed to simplify construction work (Kamar et al. 2009) by abstracting the projects into different and unlimited combinations of building components (Nadim and Goulding 2011; Blismas et al. 2006). Thus, there is a necessity to involve coordination amongst a considerable amount of parts from other disciplines that can be known for calling integration components, subsystems, and systems into implementation processes (Dietz 1971). This integration is to reach the aim of the MC design method to maximise the usage of standard manufactured components (Kamar et al. 2011). Therefore, it works like a system that all parts match together without cutting or extending, even while different suppliers (Abdullah and Egbu 1999) produce subsystems, systems, and fittings.

Since IBS is considered a complex project (Blismas et al. 2006), IBS design problems are becoming more and more complicated, so that there is a need to have the contributions of several specialists rather than one single designer (Ensici et al. 2013). In fact, the number of participants in different stages of projects is increasing due to shifting from the conventional construction method into industrialisation (Gibb 1999). This is due to the adoption of IBS that has brought about new necessities to the construction sector from design, transportation, and supply chains to installation processes (Blismas and Pendlebury 2005). Following that, increasing the number of participants during the design process of IBS projects becomes another big challenge in the design of such projects.

Additionally, IBS revolutionises the way individuals in the construction sector work, not only the products but also the process itself (Lou and Kamar 2012). This alteration is done in a way that the whole or a part of the building construction moves from the construction site into a controlled environment or factories (Arif and Egbu 2010; CIDB 2003). Two publications Tam et al. (2007) and Rahman (2013) revealed that freezing designs, layouts, and details to send to the factories to prepare related components in different sites at the initial stages of the design process is preferable for the adoption of prefabrication. This significant factor also emphasises the concept of early frozen designs that could be known as the critical challenge of IBS apart from the participation of professionals and coordination between components during the design process.

3 Research Methodology

This study involves a literature survey of selected topics under critical factors during the design process of IBS projects among professional designers in Malaysia. These

keywords were identified using Ibrahim's (2008, 2011) research question construct categorisation technique to identify three Research Question Constructs (RQS); "WHO," "WHAT," and "HOW." Ibrahim defines the "WHO" construct as the element used or impacted by the research, the "WHAT" construct as the information required in order solving a research problem, and the "HOW" construct as the action or impact on the element or information of the research. This study covers IBS projects, IBS design features, and challenges of the IBS design process under "what are the critical factors during the design process among professional designers of IBS projects?"

This exercise outcome is aimed to produce a synthesised summary for each topic. This paper considers the cross-analysis, integrated possibilities, and prioritises the synthesised information gearing towards highly probable solutions in a collaborative process to enhance the quality of the design process of IBS projects and usage of IBS presented in a flowchart (see Fig. 1) (Ibrahim and Mustafa Kamal 2018). This paper concludes with a discussion of potential integrated solutions for the future development of a proposition to support highlighting the critical factors during the design process of IBS projects, which are dominated by the participation of various professionals and the concept of early frozen designs.

4 Results

4.1 Collaboration in the Design Process of IBS Projects

It is generally believed that as the design process of current projects is becoming more and more complex, no individual has all the knowledge needed to realise a design task, so collaboration becomes a necessity (Kleinsmann et al. 2012) both for designers and other professionals involved in the design process of projects. Additionally, more specialists as a team are required to attempt to work together with considerable enthusiasm and commitment to work collaboratively to achieve the project goals (Sebastian and Prins 2009). Likewise, Peng (2006) mentioned that engaging collaboration in large-scale design projects like IBS is essential amongst a considerable number of team members from different disciplines. However, again, in the case of IBS, it is a more likely possibility that the process of collaboration would be a source of failure between designers since the professionals are mostly distributed in different sites to produce the IBS components. Ultimately, this can be known as a challenging phase in the design process of IBS projects, which needs to have a specific consideration to be tackled. Any actions of participants who are involved in the collaboration during the design process of IBS projects could render a critical place where new hindrances emerge, such as decision-making.

4.2 Decision-Making During the Design Process of IBS Projects

Marples (1961) defined design as a sequence of decisions. Also, Chiu (2002) said that design is considered a particular phase of construction projects where many of the most critical decisions are made. Furthermore, decisions during the design process involve plenty of funds and other resources necessary for the successful completion of the building project (Sanvido and Norton 1994). Therefore, the process of decision-making would be one of the impacting factors during the design process of construction projects with regards to the specific design method of IBS.

Indeed, decisions have been defined as critical situations in the product development process because they have a decisive impact on the quality of the design solution and, consequently, on the success of the product in the market (Badke-Schaub 1999). This statement, also supported by Goldschmidt (1991), mentioned that reaching a final decision usually requires many preceding decisions, and most decisions are linked with other decisions in many different ways.

However, decision-making at the development of the concept stage majorly governs the quality, cost, and success of the end product, while any failure in decisions could affect surcharges on the projects through high cost for redesigning and time overruns of later phases (Self 2019). This statement is also supported by the fact that mistakes, drawbacks, or failures resulting from design decisions have far-reaching consequences (Ensici et al. 2013).

Finally, as the IBS is conducted by various sub-teams, teams, and individuals, having communication as the driving force of development teams (Tavčar 2005) would be a great advantage. A cumulative conclusion of these agendas results in emphasising the critical role of decision-making during the design process of IBS projects, which is dominated by the concept of MC, including the participation of design professionals under the umbrella of the early frozen concept.

4.3 Lack of Accessibility to Information of Design Professionals

One of the vital features of the IBS concept is that all layouts and details are abstracted to components, subsystems, and systems to send to manufacturing. This process makes IBS such a complex construction project involving many parties from different disciplines. Therefore, sharing and exchanging information among various parties about IBS projects are

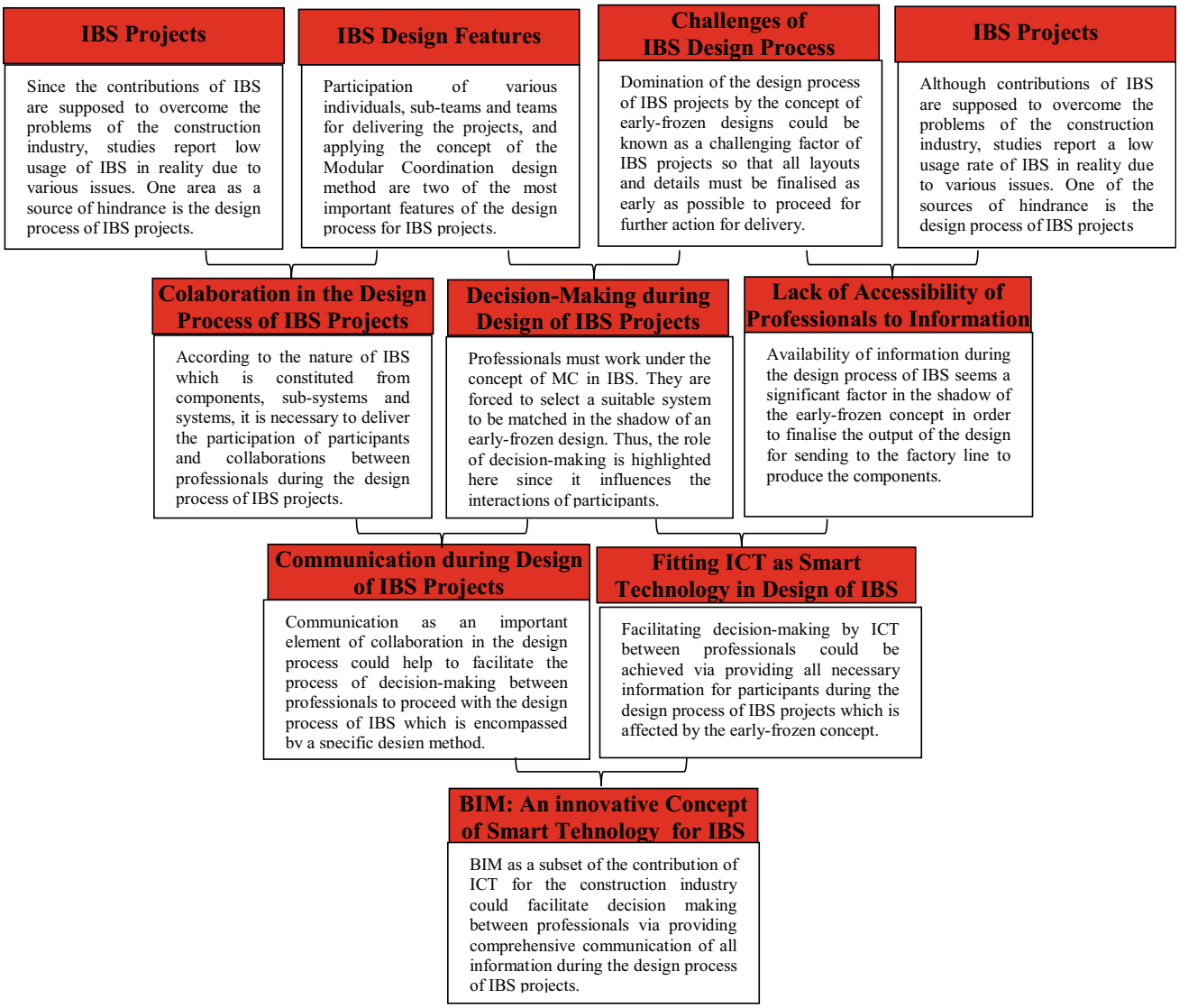

Fig. 1 Point of departure tree diagram (Adopted from Ibrahim and Mustafa Kamal 2018)

hugely involved. These activities can create several errors due to a large number of layouts, details, and specifications as they are mostly in a paper-based format that is not adequately managed, which can lead to miscommunication (Wikforss and Löfgren 2007).

On the other hand, Zakaria et al. (2013) argued that adequately managing information to ensure all parties in the construction projects receive the right information and utilisation is counted as the fundamental aspect of accepting new concepts during the design process. Singh et al. (2011) also mentioned collaboration is a must in the context of complex projects, facilitating the activities of teamwork by promoting communication, consolidating project information, and making it accessible (Cheng 2003). Therefore, communication, sharing, and exchanging of information, which are core elements in creating a collaboration (Gautier et al. 2009), could be considered as the most critical factor in the design process of IBS projects.

Moreover, according to the revolutionary achievements of Information and Communication Technology (ICT) in the construction industry, obtaining benefits from ICT seems essential to manage communication and, accordingly, facilitating decision-making in IBS projects. This reason is supported by many works in the literature emphasising the need to make effective decisions at several levels in the architectural design process (Kalay 2004; Moum 2006). As ICT is offered as a tool for communication to facilitate decision-making between professionals, the study motivates the usage of ICT during the design process of IBS projects.

5 Discussion

5.1 Communication During the Design Process of IBS Projects

The usefulness of communication during the design process of construction projects like IBS is highly emphasised to share design information and further coordinate the design tasks. Foley and Macmillan (2005) underscored that only gathering together does not guarantee that team members would function well as a team, while it might even be that the team is undermined by disorganisation or weak collaboration. In fact, regarding the critical role of collaboration between professionals during the design process of IBS and the vital role of the coordination between the components in the early stages of IBS projects, it necessitates communication as the critical aspect of collaboration and highlights the need to coordinate.

Furthermore, the early frozen concept in the design process also emphases on calling for intensive communication at the early stages of the design process of IBS projects because the effectiveness of design communication is one of the critical factors for designers in their decision-making (Chiu 2002).

Finally, it can be concluded that apart from all the necessary background for the essentiality of communication in IBS projects, a new challenge emerges during the design process of IBS, which is called decision-making between designers during the design process. Since the IBS design participants need to follow the early frozen concept during the design process, the process of decision-making between professionals from a range of components becomes a hindrance. In fact, any potential failure in this action can cause the design process of the IBS projects to become inflexible so that this problem is ranked highly in a survey in Malaysia as the main barrier to the design process of IBS (Sadafi et al. 2012).

5.2 Fitting ICT as a Tool of Smart Technology for Communication in the Design Process of IBS

Over the past few decades, ICT has become an essential factor in life so that without some facets of the technology, the routine tasks of life are rendered dysfunctional. ICT provides the ability to address to the highest quality, affordability, being on time, standardisation, and customisation, and adopting ICT is a beneficial way for the construction industry (Eastman et al. 2008). Likewise, Marshall-Ponting and Aouad (2005) mentioned that ICT plays a crucial role in fast-moving and leveraging different processes that can be obtained in the construction industry as well. Therefore, ICT can provide smart communication and innovation over the lifecycle of the construction projects to obtain benefit from using smart technology in the design and construction of the project.

ICT is a smart and innovative concept for the construction industry that can be used to enhance collaboration amongst design professionals from various disciplines. To support this statement, Senescu et al. (2013) revealed that ICT could facilitate communication for teams to deliver increasingly complex projects, such as IBS, where designers, engineers, and advisers often need to collaborate (Prins and Owen 2010). In another study, the authors argued that ICT had revolutionised the design and communication processes in past decades, and significant developments could also be seen in the area of smart and intelligent buildings (Goodier and Pan 2010). Some of the evidence of this statement has been mentioned in another study by Delavari et al. (2011), such as a computerised design collaboration process to work in a distributed design environment or a virtual design studio. Therefore, the implementation of ICT in IBS can be considered to backup integration of accurate data, to support users in choosing processes, to facilitate the supply chain, and to obtain cost-effectiveness (CIDB 2003; Lessing et al. 2005; Eichert and Kazi 2007).

Moreover, in different research, Eichert and Kazi (2007) mentioned that ICT applications in IBS projects could be an expanded way, such as communication with the customer, actors, quality control, performance measuring, and re-using experiences. ICT also seems to be essential for IBS projects to work in market analysis; intelligent component catalogues; planning of assembly procedures; and monitoring tools, design, and configuration tools, as observed by Manu-build (2008).

5.3 BIM: An Innovative Concept of Smart Technology to the IBS Projects

Apart from all the impressive contributions of ICT tools to the construction industry, Building Information Modelling (BIM) as a sample of ICT offers several potentials to achieve many desired objectives for the construction sector (Azhar et al. 2008). BIM is highlighted as one of the significant innovative smart technologies for IBS projects. It is an enabling way that brings integrity in design, virtual prototyping, simulations, non-collocated access, retrieval, and maintenance of the building data (Fischer and Kunz 2004). In addition, a variety of BIM-based technologies and their applications have been proposed (Cited in Oh et al. 2015). Regarding BIM contributions, Goulding et al. (2012) mentioned it would provide benefits such as speeding up the delivery, enhancing quality, higher tolerances, decreasing

cost, reducing labour, and re-working on sites. The study puts its efforts into expanding BIM as a solution to solve emerging issues from the design process and to enhance the quality of design, which would cause increasing usage of IBS.

It is articulated that the most significant development of productivity in the construction sector would come from automation and offsite activities that could be facilitated by BIM. Rashidi and Ibrahim (2017) argued that IBS implementation necessitates the mixing of ICT at the design stage and construction phase to leverage the level of productivity in the construction sector of Malaysia, calling for fast-tracking of the implementation of BIM to solve the challenges of the IBS sector.

Finally, this study supports the statements of Azhar (2011) who revealed that BIM could enhance collaboration and reduce fragmentation in the industry. This statement could be seen as a sign of implementing innovative smart technology in the design stage and construction of IBS projects to achieve higher benefits from a large number of contributions that a smart delivery method would bring to the sector.

6 Conclusion

To sum up, the researcher posits that decision-making during the design stage in IBS projects is drastically impacted by the direct and indirect influences of communication. Also, this condition is due to the communication and participation of design professionals needed to work under the shadow of MC and the early frozen concept. Therefore, there is a need to facilitate decision-making between the design professionals participating in the design process of IBS. This could decrease the inflexibility of IBS projects by using BIM as a means of facilitator communication tools. In the end, this facilitation could be achieved by implementing smart technologies as an innovative solution to solve the design process hindrances and moving towards smart technology in the lifecycle of buildings.

Ultimately, the present study attempts to improve previous works regarding the critical factors during the design process of IBS projects among professional designers. It involves a literature survey of selected topics under critical factors during the design process of IBS projects among professional designers in Malaysia, considering the research question construct categorisation technique. This paper concludes with a discussion of potential integrated solutions for the future development of a proposition for supporting and highlighting the critical factors during the design process of IBS projects, which are dominated by the participation of different professionals and the early frozen concept.

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SOLARQUIM: Dual Electric Power Generation System for a Housing

Javier Aguirre Contreras, Miguel Arzate Pérez, and Javier Aguirre Muñoz

Abstract

This article was designed and built as a dual electric power generation system for a housing (SOLARQUIM) using solutions of crystalline solids and photoelectric cells to have greater energy efficiency in housing for four people located in San Luis Huexotla, Texcoco, State of Mexico. The development and use of SOLARQUIM promote the use of chemical energy and solar energy, making it possible to generate electricity 24 h a day, 7 days a week (24/7). The cost of the material for the prototype is $29.00, the savings in electricity is $18.79 in a year and the prototype also avoids the emission of 5.11 kg of carbon dioxide (CO_2) per year. With the use of chemical and solar energy, the reduction of greenhouse gases (GHG) is promoted, because more than 70% of the generation of electricity in Mexico is obtained by the combustion of fossil fuels (gasoline, diesel, gas and coal). The integration of clean energy technologies in cities, buildings and homes should be a requirement and not an optional trend in Mexican Republic, for new buildings or for those that already exist; in both cases you should take advantage of and adapt the existing spaces to reduce a percentage in the emissions of GHG and this is a predominant factor in climate change (CC).

Keywords

Housing • Ammonium chloride • Renewable energy • Clean energy technologies • Greenhouse gases • Fossil fuels • Climate change

1 Introduction

The intervention by human on the environment on the planet is growing since the Industrial Revolution because of the economic development of society has increased, from 1950 to date, because of which the CC has worsened due to excessive consumption of fossil fuels (oil, gas and coal) (PNUMA 2010).

In Mexico, in 2015, the installed capacity for the generation of electric energy corresponds to 73.6% for technologies that use fossil fuels such as natural gas, fuel oil, coal and diesel, while the remaining 26.4% corresponds to clean energy. Electricity consumption in Mexico has increased 3.63% annually in the period from 2011 to 2015, increasing consumption from 223.4 to 231.50 gigawatts per hour (GWh), respectively (SENER 2016). In 2016, the installed capacity to generate clean energy in Mexico reached 28.81%, while 71.19% was from technologies that use fossil fuels, so there was a growth of 2.41% capacity installed clean energy with respect to 2015 (SENER 2016).

Therefore, the Energy Transition Law (ETL) was published in the Official Journal of the Federation (OJF) in December 2015, which states that the Mexican Republic will have to increase its clean energy supply from 2018 to 2024 from 25% to 60%, basing its change of energy matrix mainly in solar and wind energy, and likewise establishes that by 2030, it must reduce its CO_2 emissions from 3.9 to 2.9 gigatons (Gton) (DOF 2015).

Mexico is considered to be the country with the highest number of clear days in the year. The foregoing is essential to fulfill the main purpose of the Development Program of

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the National Electric System 2015–2019 to increase the supply of energy electricity by 25%, adding 1.82 GW in the same period (SENER 2016). Solar radiation takes advantage of two main forms; the first as solar thermal power, in which the radiant energy of the sun is used to heat fluids that would be used to drive turbines, while the second way is to use solar panels, where solar energy is directly used to generate electricity (CONNUE 2007). The use of renewable energies was born as an alternative to solve the problems of electrical interconnection that occurs in the world, especially in remote areas due to its difficult access; another important reason why this type of energy should be implemented is the progressive reduction as an energy source based mainly on fossil fuels (non-renewable), mainly oil, coal and natural gas, considered as the main contributors in the progressive increase of the temperature of the planet (INECC 2010).

Mexico has a great potential in solar energy since it has the highest number of clear days in the year compared with countries of similar latitude. According to the average daily solar radiation, the country is divided into three regions, which are (SENER 2016):

a. Region I: It is the one with the highest average daily solar radiation in the range >5.8 kilowatt hours per square meter (kWh/m^2) that includes the states of Sonora, Baja California, Baja California Sur, Nayarit, Michoacán, Guerrero, Chiapas and northern part of the Yucatan Peninsula.
b. Region II: This region comprises 70% of the country, with a range of 4.7–5.8 kWh/m^2, which are located in the states of Chihuahua, Nuevo Leon, Tamaulipas, Aguascalientes, Durango, Zacatecas, Guanajuato, Querétaro, Jalisco, Metropolitan Area of the Valley of Mexico and southern part of the Mexican Republic.
c. Region III: This has a range <4.7 kWh/m^2. It is located in the high mountain regions of the Sierra de Veracruz.

The Metropolitan Area of the Valley of Mexico that belongs to region II receives an average of 5 kWh/m^2 of daily global radiation, which implies that in 1 m^2 and considering that the solar equipment presents an efficiency of 50%, it receives daily an equivalence of contained energy in 1 cm^3 of liquefied petroleum gas (LPG); however, the provision of solar energy is neither constant nor fluid, given that in the months of May–October when the rainy season is normalized, the efficiency of solar system is significantly reduced, by up to 80% (CONNUE 2007). The photovoltaic energy grew in 2017, reaching a generation of 1,149.6 GWh, which is 934.81 GWh more than in 2016. The increase in the use of photovoltaic energy is that Mexico has set short and medium-term goals for electricity generation from renewable sources that are established in the ETL (SENER 2017).

Another way to generate electricity in a no renewable way is through chemical energy; for example, in 1880, the brothers Pierre and Paul Jacques Curie discovered that some crystals have the characteristic of electricity by pressure or piezoelectricity since when they are compressed or stretched in certain directions, their structure is distorted, accumulating charges on the surface where the force is applied. These crystals are used to obtain sparks in lighters and high-frequency oscillators (Ebbing and Gammon 2010).

In ionic crystalline networks, the electrostatic forces of attraction hold together large amounts of anions and cations. In the process of forming the crystalline network, the atoms that will be the anions obtain one or more of the electrons that belong to the atoms that generate the cations (ionic bond). The internal structure of the crystals is represented by the so-called unit cell that repeats itself over and over again in the three directions of space. The set of elements of symmetry of an object that passes through a point defines the total symmetry of the object (point group of symmetry). Combining the two translations and the angle between them, there are only five possible formations of flat networks: parallelogram, rectangle, square, hexagon and rhombus. If we form a spatial network by stacking these flat networks, only 14 possible formations representing the simplest forms in which crystalline matter can be decomposed without losing its original properties; these are the so-called Bravais networks (Ebbing and Gammon 2010).

Most of nature's solids are crystalline, which means that the atoms, molecules or ions that form them are arranged geometrically in space. This ordered structure is not seen in many cases at first glance because they are formed by a set of microcrystals oriented in different ways forming a polycrystalline structure, apparently amorphous. The ammonium chloride (NH_4Cl) has a crystalline structure whose ammonium cation is in the center of the molecule, surrounded by eight chloride anions (Fig. 1). The NH_4Cl is used in the manufacture of dry cells, adding the above to zinc plating and tin plating processes, as well as being used as a flux in

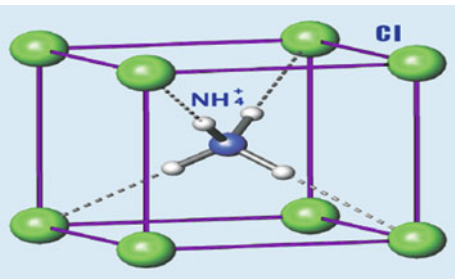

Fig. 1 Structure of the crystalline solid NH_4Cl

solders, metal oxide remover and also used in the textile industry and pottery (Chang 1998).

An example of the previous thing is the osmotic energy, which is obtained from the differences of salinity between the flows of freshwater in the seawater (Oviedo-Salazar et al. 2015).

This information allows us to verify that solar and chemical energy has great potential in Mexico to be explored and applied to new technologies that could be implemented as new ways of obtaining sustainable energy in cities. Therefore, the design and development of a prototype that uses these energies were proposed. The implementation of clean energy that is friendly to the environment guarantees sustainable and efficient development. The use of the prototype developed will generate electricity using a renewable energy source such as solar energy and a no renewable energy source such as chemical energy; the former will use solar radiation by 8 h in average, while the second will do 24 h, so the SOLARQUIM will generate electric power seven days a week during the whole day, which represents a remarkable advantage when the weather conditions are disadvantageous with cloudy days and/or precipitation, which happens every year in the period July–October of each year.

Is it feasible to develop a prototype of low-cost, friendly to the environment and whose efficiency does not decrease due to adverse weather conditions such as cloudy or precipitation?. If so, does the prototype use both solar energy (renewable) and chemical energy (no renewable) as energy sources, making it possible to generate electricity 24 h a day, 7 days a week?

The use of SOLARQUIM prototype will allow for the generation of 20 watts per hour (Wh) domestically.

The general objective to build this prototype is to reduce the emission of CO_2 by using solar and chemical energy.

At present, there are similar projects in the market such as:

At Yale University they conducted a study where it was concluded that the maximum energy that could be extracted by osmosis by delayed pressure using a seawater solution and feeding a river water solution is 0.75 kilowatt hours per cubic meter (kWh/m^3) (Academia de Ciencias Morelos 2014).

In Norway they have opted for energy by osmosis. They have even implemented the world's first osmosis power generation plant with a very modest capacity of 4 kW (Academia de Ciencias Morelos 2014).

Nomenclature

P electric power (W)
V volts (V)
R resistance (ohms)
A amperes (A)

2 Investigation Methodology

The methodology for the design and construction of SOLARQUIM is described below:

1. Development and planning of SOLARQUIM.
2. Measurement of the electrical energy generated by the three photoelectric cells.
3. Measurement of the electricity in NH_4Cl containing a solution of 100 ml of water and 2 g NH_4Cl contained in four aluminum cans of 255 ml.
4. Determine the ideal conditions for generating electrical energy in ammonium chloride chemical compounds whose main characteristic is the crystalline solid structure.
5. Select the battery charger that has the best charge control generated so that it supplies the voltage necessary for the operation of the two light emitting diode (LED) strips.
6. Evaluate if the generation of electric power of both systems is sufficient to recharge a 4.2 V battery.

2.1 Description of the Planning and Development of the Project

Technology prototype planning was developed as follows:

a. The experimentation of NH_4Cl solutions took place on January 16, 2019.
b. The evaluation of the photoelectric cells to determine the potential of average daily solar radiation according to the geographical area where the housing is located was carried out on January 17, 2019.
c. The selection of the lithium battery according to the potential of total volts generated by the chemical solutions and the photoelectric cells was carried out on January 18, 2019.
d. The selection of the battery charger was made on January 19, 2019.
e. Assembly of SOLARQUIM took place on January 20, 2019.
f. The SOLARQUIM functionality tests were carried out from January 21 to February 10, 2019.

2.2 Material and Cost for the Construction of SOLARQUIM

The developed prototype has a total cost of $29.00 corresponding to 13.70 and 15.30 variable and fixed costs, respectively, which represents a viable economic and

environmentally friendly option, since the optimal useful life of the solar cells used is 10 years (Table 1).

2.2.1 Chemical Solution

The evaluation of the crystalline solids in the NH_4Cl solution was carried out in the four aluminum cans of 255 ml, using an economic compact multimeter model MUL-005 to measure the voltage generated by the solutions connected in parallel (Fig. 2a, b).

The measurement of the voltage generated with the NH_4Cl solution was developed as follows:

a. Experiment day: January 16, 2019.
b. Time: 11:30 a.m.
c. Ambient temperature: 15 °C.
d. Humidity: 54%.
e. Solution ratio: 100 ml of water with 2 g of NH_4Cl.
f. Container: aluminum can of 255 ml.
g. Total measurement time: 3 h with 1 min.
h. Start time: 11:30 a.m.
i. End time: 2:31 pm.
j. The tips of the multimeter will be placed 1 min inside the chemical solution so that the values stabilize.
k. The four solutions were stirred 20 times to dissolve the NH_4Cl in the water.

The four solutions with identical chemical solutions generated a total of 2876 millivolts (mV) (2.876 V) in 3 h (Table 2). On average every hour 0.9586 V was produced with a resistance of 0.8 ohms. With this, the electrical potential that amounted to 1.148 Wh (Eq. 1) was calculated (Giancoli 2009).

$$P = \frac{V^2}{R} \tag{1}$$

2.2.2 Photoelectric Cells

The electrical energy generated by the photoelectric cells was measured from 12:00 pm to 3:00 pm on January 17, 2019, since the maximum solar insolation is reached in that period of the day, in the geographical region where the housing experiment was carried out. The location of the housing is as follows: San Luis Huexotla, Texcoco, State of Mexico (latitude 19°28′ 55.06″ N and longitude 98°51′ 30.75″ W, elevation 2320 m). The measurement of the voltage generated by the three cells were made with the compact multimeter MUL-005 which has an error of ±0.05 V.

The three photoelectric cells of the polycrystalline type were used (Fig. 3). The voltage generated by each cell is 5 V with 660 mA. The cells were connected in series to obtain an output voltage of 15 V and 1.980 A. With the above data, electric power of 29.70 Wh was obtained (Eq. 2) (Giancoli 2009).

$$P = VA \tag{2}$$

2.3 Electric Connections

The following elements (Fig. 4a, b) were connected to the electric current to check its operation:

Table 1 Materials used for the development of SOLARQUIM

Quantity	Material	Price (dollars)
1	Battery 4.5 V 140 mA	$7.57
1	Tp 4056 lithium battery charger litio 5 V 1st dual protection	$0.79
2	LED module 5050 of 5 LED 5 V	$0.32
1	Switch on/off red two pins 127 V 10 A	$0.37
3	Photocell of 1.2 V 140 mA	$3.18
4	Aluminum cans	$0.67 (package of 8 cans of 255 ml $3.79)
8 g	Ammonium chloride (NH_4Cl)	$0.24 (each gram of ammonium chloride costs $0.030 cents)
2 m	Unshielded twisted pair cable (UTP)-6	$0.56 every meter
Quantity		
1	Cautin	$6.85
1	Welding 100 g (60/40)	$7.40
1	Welding paste	$1.05
Total		$29.00

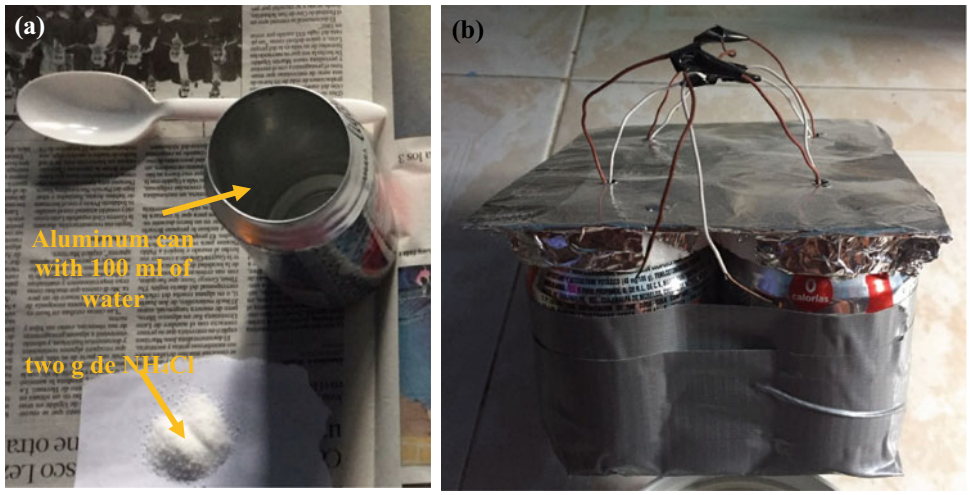

Fig. 2 **a** Materials of the solution, **b** solutions connected in parallel

Table 2 Voltage generated by the four solutions contained in four aluminum cans of 255 ml

Time (minutes)	Voltage (millivolts)	Temperature of the solutions (°C)
0	96	12.2
20	96	13.2
40	216	14.1
60	212	14.7
80	344	15.0
100	344	15.2
120	384	15.4
140	412	15.4
160	356	15.7
180	416	15.7
Total	2876	

Fig. 3 Photoelectric cells connected in series

- Lithium battery 5 V, 140 mA,
- Tp 4056 lithium battery charger li-po 5 V 1st dual protection,
- Two strips of LED 5050 of 5 LED 5 V,
- Red on/off switch two pins 127 V 10 A.

The solutions were connected with the photoelectric cells in parallel and the above was connected to the electronic circuit (Fig. 5a, b).

3 Analysis of Results

The four solutions generated 1.148 Wh and the photoelectric cells 29.70 Wh. In total, the SOLARQUIM produced 30.848 Wh (0.0308 kWh) if the cost of one kWh in the housing is $0.070, then with the use of the proposed prototype the family saves $0.0021, $0.0518 and $18.79 in one hour, one day and one year, respectively (Fig. 6).

One megawatt per hour (MWh) generated by the Federal Electricity Commission (FEC) generates 0.454 tons of CO_2 (SEMARNAT 2015). If we convert the kWh generated by the SOLARQUIM to MWh equivalent to 3.0848^{e-5} (0.000030848 MWh), then the SOLARQUIM prevents the

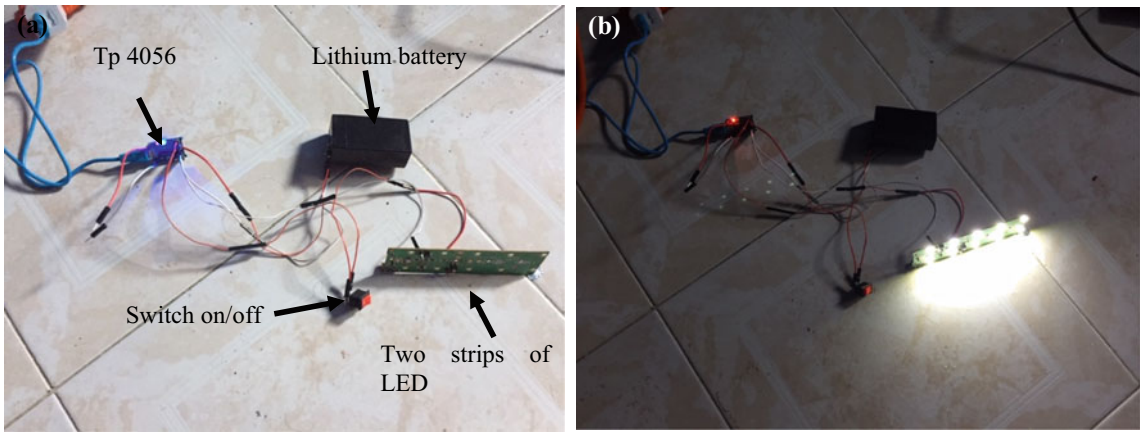

Fig. 4 **a** Electronic material. **b** Operation check

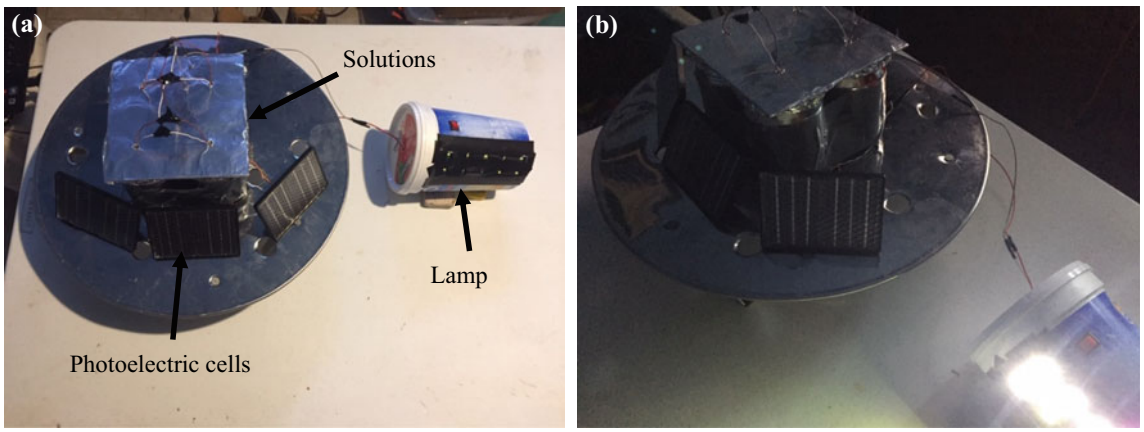

Fig. 5 **a** Construction of the SOLARQUIM. **b** SOLARQUIM in operation

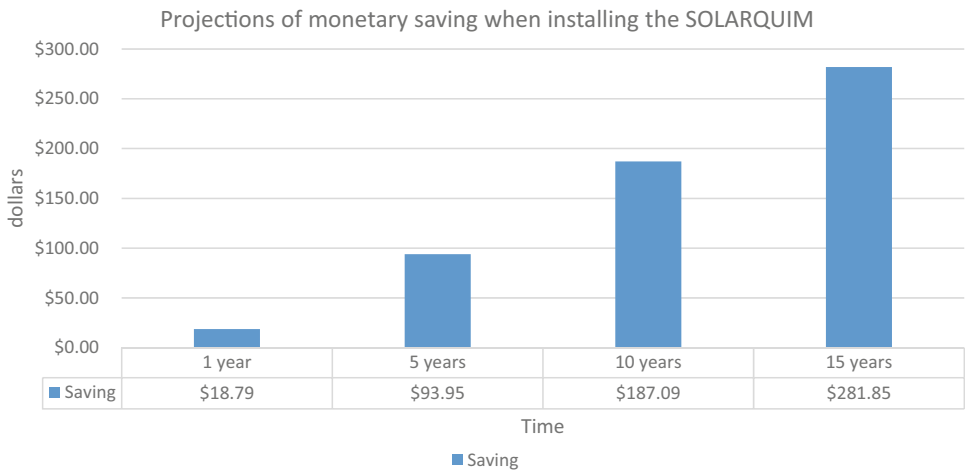

Fig. 6 Projections of monetary saving when installing the SOLARQUIM in a housing

emission of a 1.4^{e-5} ton of CO_2 (1.4^{e-2} kg of CO_2) in a day, in a year 5.11 kg of CO_2 (Fig. 7).

If SOLARQUIM is installed in one housing, the emission of 5.11 kg of CO_2 in a year is avoided while if it were installed in all the houses of the municipality of Texcoco that has 44,684 homes (INEGI 2010), 228,335.24 kg of emission would be discontinued. CO_2 in one year, while doing so extensively in the State of Mexico that has 3,687, 193 homes

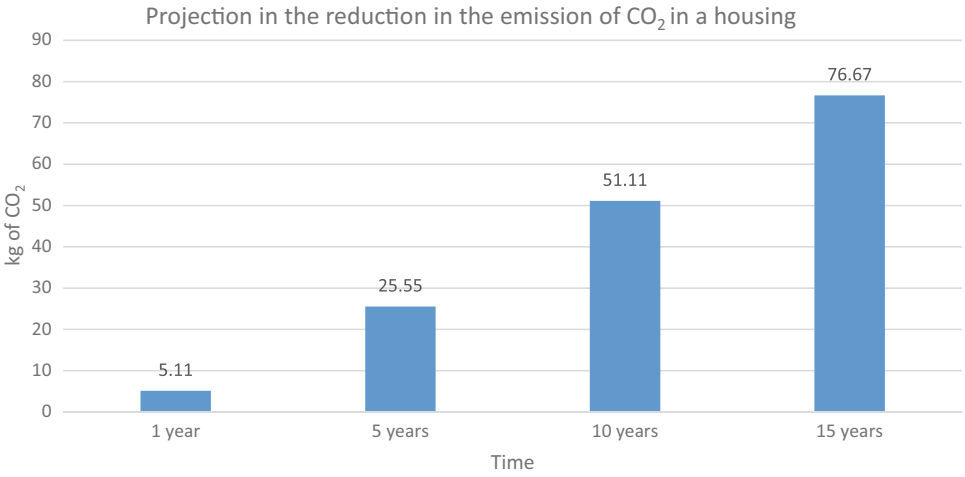

Fig. 7 Projections in the reduction in the emission of CO_2 when installing the SOLARQUIM in a housing

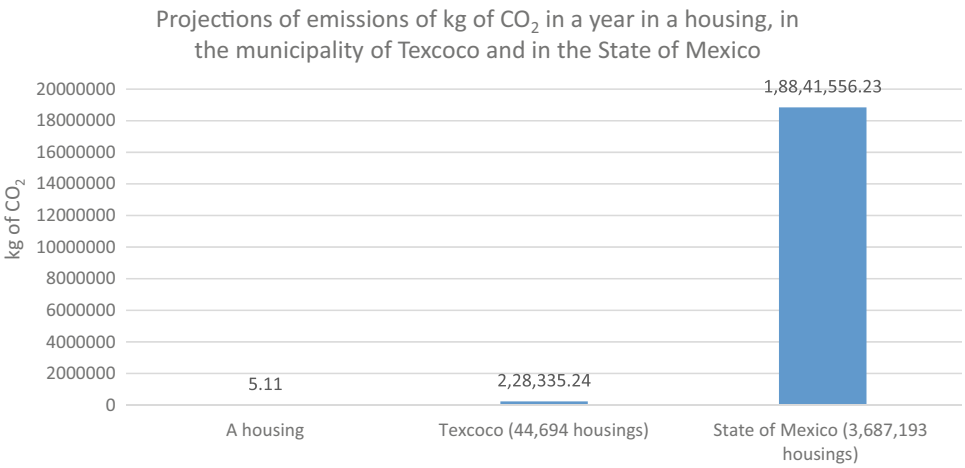

Fig. 8 Projections in the reduction in the emission of CO_2 when installing the SOLARQUIM in a housing, Texcoco and in the State of Mexico

(INEGI 2010), 18,841 × 10^{e3} kg of CO_2 in a year would cease to be emitted (Fig. 8).

4 Discussion and Reflections

In Mexico, the production of electric energy from solar energy is insignificant compared to other countries of similar latitudes, so its participation must be substantially increased. One of the feasible measures is to develop products derived from "social management" that must perform the institutions of secondary, higher and postgraduate education. The SOLARQUIM prototype is an economical alternative, friendly to the environment, easy to install, operate and maintain.

The prototype developed is a product that is not in the market and has a total cost of $29.00, being technically and financially viable, presenting opportunity areas for houses and commercial premises that are in cities, suburbs and rural areas with difficult access. The technological contribution of this prototype is a dual system of electricity generation based on a renewable resource such as solar energy and another of chemical origin with the electrical energy generated by the crystalline solid of NH_4Cl.

The SOLARQUIM is an innovative product in the market of dual electric power generation system that allows generation of 30.848 Wh, allowing the operation of two LED 24 h a day. If the photoelectric cells do not work by cloudiness or excessive precipitation, the solutions of NH_4Cl will allow its operation.

5 Conclusions

By using chemical and solar energy as clean energies to generate electricity, the reduction of GHG is promoted, since more than 70% of electricity generation in Mexico is obtained through the combustion of fossil fuels. For the above reason, the SOLARQUIM was designed and built.

The integration of SOLARQUIM in the housing located in San Luis Huexotla, Texcoco, State of Mexico, has the purpose of reducing a percentage in the emission of GHG,

which is a predominant factor in the CC. An improvement to the SOLARQUIM that must be made is the use of the lithium battery. Currently, lithium batteries have improved storage capacity, among others, compared to lead-acid batteries. But lithium batteries represent a risk for the health of the human being and for the environment; therefore, a management system for this type of batteries must be implemented, in order to control the irrigation they represent.

The SOLARQUIM generates 30.848 Wh domestically, making it possible to feed two strips of five LED each 24 h a day, 7 days a week. The above avoids emitting 5.11 kg of CO_2 per year if it is installed in a housing. At total homes in the municipality of Texcoco 228,335.24 kg of CO_2 are no longer released in a year, and for instance in all homes of the State of Mexico, 18,841,556.23 kg of CO_2 would be released in one year.

The cost of SOLARQUIM is $29.00 and the monetary savings in one year are $18.79 so that in one year and six months the investment to install dual electric power generation system will be recovered.

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Citizen Potholes e-Report System as a Step to Use Big Data in Planning Smart Cities in Malang City, Indonesia

Adipandang Yudono and Achmad Istamar

Abstract

Spatial planning ought to be founded on comprehension of the possibilities and impediments of the indigenous habitat and the financial advancement exercises, specifically zones, according to the present needs and future protection for the Earth (Hall, Urban and Regional Planning, Routledge, London, UK, 2002). A complex societal framework needs sharing among residents and elites to keep their living congruity up with social and natural changes. Information exchanges in spatial planning can be characterized as a political procedure to accomplish social agreement between various interests by giving the open chances to discourse with elites, for example, city councils and local government delegates, urban planners, and the community itself (McLoughlin, Urban and Regional planning: a Systems Approach, Faber and Faber, London, UK, 1969; Chadwick,.A Systems View of Planning: towards a theory of the urban and regional planning process, Pergamon Press, Oxford, UK, 1978; Meadowcroft, J. (1999). Planning for sustainable development: what can be learned from the critics? In Kenny, M., and Meadowcroft, J., (ed.), 1999, Planning Sustainability, Routledge, London, UK.). This study explored the urban planning system through Citizen Pothole electronic Report (e-Report), answering the challenges of implementing smart cities through the creation of a dialogue between the citizen and government through data analysis, text mining, and geovisualization in Malang City, Indonesia. The results of this study are that digital trends using data analysis, text mining, and geovisualization are welcomed by citizens and government representatives because it provided direction and recommendations in an effort to formulate urban policies with legalization through regulations to implement digital dialogue between citizens and governments toward the ubiquitous spatial planning in Malang City.

Keywords

Potholes • Sharing • Big data • Text mining • Geovisualization

1 Introduction

Spatial planning ought to be founded on comprehension of the possibilities and impediments of the indigenous habitat and the financial advancement exercises, specifically zones, according to the present needs and future protection for the Earth (Hall, 2002). Furthermore, spatial planning is the process of continuing to make decisions or choices on ways to utilize the existing resources as optimized as possible to achieve certain goals in the future (Conyers & Hills, 1984). In short, planning is the use of available resources to achieve future goals. Friedmann (1984) emphasizes planning as a series of collective actions (Friedmann, 1984).

A complex societal framework needs sharing among residents and elites to keep their living congruity up with social and natural changes. Information exchanges in spatial planning can be characterized as a political procedure to accomplish social agreement between various interests by giving the open chances to discourse with elites, for example, city councils and local government delegates, urban planners, and the community itself (McLoughlin, 1969; Chadwick, 1978; Meadowcroft, 1999).

The increasing number of population living in urban areas is in line with various life problems faced, i.e. environmental, social, and economic problems, which encourage people to develop knowledge and methods for solving urban

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problems in which the critical success factors are technological advances in the ability to process data and information. As time goes by, the understanding of data and information in formulating urban problems has undergone a paradigm shift. When technology was still limited, data and information were used to solve past urban problems, but with current technological advances, data and information are used to give a rapid response and predict the direction and the development an urban planning in the future. The development of data- and information-related technology at this time cannot be separated from the internet, data collector, and data visualization.

At present, almost all urban communities are connected to the internet (Shirky, 2008). Sharing aspects of people's lives are increasingly connected in the digital space, such as social interaction, public services, finance, and education (Bott et al., 2014). The character of low-cost digital space and the ability to shorten distance and time give access to individuals who have an interest in living in modern and harmony (Open Data Institute (ODI), 2015). In the current digital era, where the smart city is a hype for the agenda in cities and districts, innovation and utilization of technology related to urban management are key in efforts to create harmonization of society, government, businessmen, and nature (Kunzmann, 1999). Furthermore, data sharing among citizens may create volume, velocity, and variety of data under big data context. The euphoria of the Smart City realization does not only occur in wealthy countries but also in developing countries such as Indonesia.

As a developing country, cities in Indonesia have a variety of problems when it comes to managing urban areas. However, the euphoria of implementing smart cities can be felt in many cities in Indonesia, ranging from large cities to small cities. This also occurred in Malang City. Malang is the second-largest city in East Java Province after Surabaya. As a big city, Malang is inseparable from the problems of city management, including maintenance of road infrastructures, limited resources in the city council to conduct daily city monitoring, and limited urban management budget. To explore solutions to the city's problems, the innovation referred to in this study is the effort to integrate various forms of digital communication to create informative and communicative city planning and management between urban stakeholders through data analysis, text mining, and geovisualization studies. For this reason, this study explored the integration of the three digital communication methods under the Citizen Potholes e-Report System in Malang City, Indonesia.

2 Related Works

2.1 Case Study Area

Malang City was established on April 1, 1914 and is the second major city in East Java Province, Indonesia, after Surabaya as the capital city of East Java Province. Geographically, the area of Malang City is between 07°46′48″ and 08°46′42″ South Latitude and 112°31′42″ and 112°48′48″ East Longitude, with an area of 110.06 km^2 with an altitude of 440–667 m above sea level. As a big city, Malang cannot be separated from social and environmental problems, the quality of which is worsening. Now, the city receives many complaints from its citizens, for instance, pollution, litters, or requests for relocating street vendors who are located in the city square, traffic congestion, and road condition. Based on observations and literature reviews conducted by the researchers from local newspapers in Malang, predominant urban problem reports from the community received by the Malang City government during period at the end of 2018 until mid-2019 comprised public complaints related to potholes and damaged roads that disturb motorists (see Fig. 1). From this fact, potholes have become a new problem in Malang City. Potholes may damage the vehicles that pass by, which may be wheel damages and possible injuries to the people inside. This may lead to minor up to major accidents. Therefore, careful and agile detection of pothole reports is one alternative to determine proper road management policies and strategies.

Fig. 1 Some potholes issues in local Malang newspapers

2.2 Potholes

Potholes can be defined as bowl-formed gaps of different sizes in the asphalt surface. The least arrangement measurement is 150 mm. Roundabout potholes ought to have a base breadth of 150 mm. A 150-mm diameter circle should fit inside unpredictable formed potholes (Miller & Bellinger, 2003).

The measurement of potholes is done through assessing the number of existing potholes and area of the influenced region for every severity level. Pothole profundity is the deepest extent of pothole beneath the asphalt surface. On the off chance that a pothole happens inside a region of fatigue cracking, the area of fatigue cracking is subtracted by the pothole area (see Fig. 2). The base zone for a pothole is about 0.02 m^2. The real arrangement measurements and the real zone of the pothole will be recorded on the distress map sheets. Potholes not meeting the minimum arrangement measurement are to be drawn on the distress map sheets (Miller & Bellinger, 2003).

As a kind of asphalt trouble, potholes are significant pieces of information that show further imperfections of black-top streets and, therefore, precisely distinguishing these potholes is a significant assignment in deciding the best possible methodologies of black-top surfaced asphalt support and restoration (Ryu et al., 2015).

2.3 Data Analysis and Big Data

Data analysis is an effort or a way to process data into information, so that the characteristics of the data can be understood and are useful for solutions to problems, especially problems related to research (Judd & McClelland, 1989). Additional definition from another explanation on data analysis states that they are activities carried out to change the results of research data into information that can later be used in drawing conclusions.

Broadly speaking, data analysis techniques are divided into quantitative analysis and qualitative analysis. The difference between the two techniques lies in the data type. Data that are qualitative in nature predominantly study texts and picture format, while the data that are possible to be measured can be quantitatively analyzed. The context in this study used quantitative data analysis.

Activities in data analysis comprise data grouping based on variables and types, tabulating data based on variables from all respondents, presenting data from each studied variable, and performing calculations to answer the problem formulation and to test hypotheses that have been proposed (Lewis-Beck, 1995). The purpose of data analysis is to describe data, so that it can be understood which is then used to make or draw conclusions about the population characteristics based on obtained data from the sample. Usually, this is based on estimation and hypothesis testing (Lewis-Beck, 1995).

Big data is a term that describes a large volume of data, both structured and unstructured, which floods daily activities; however, it is not the amount of data that is important. What organizations do with the data that are important? Big data can be analyzed for a better understanding that leads to more optimum decisions and strategic business movements (Kitchin, 2014).

While the term "big data" is relatively new, the act of collecting and storing large amounts of information for analysis has finally been around for a long time. This concept gained momentum in the early 2000s when industry analyst Doug Laney articulated the big data definition that is currently becoming mainstream as three V:

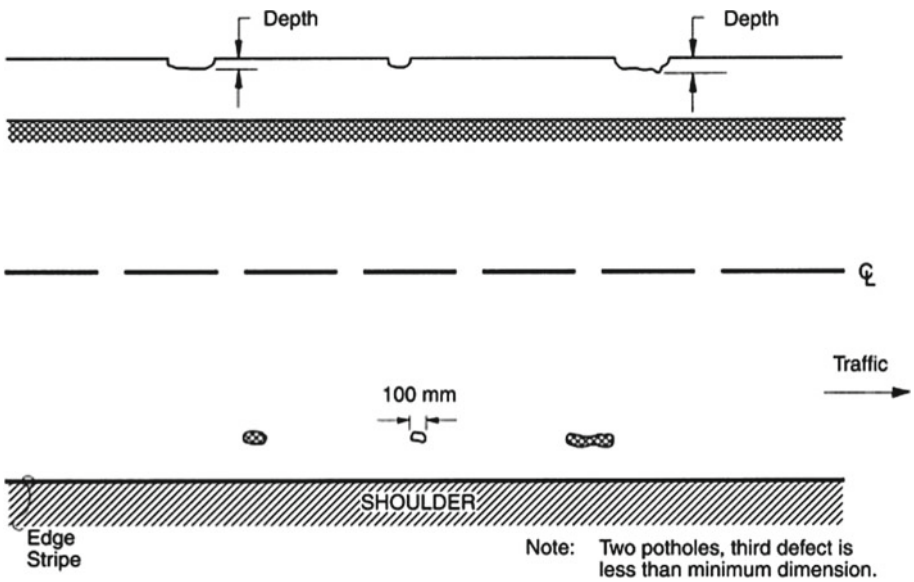


Fig. 2 Pothole Structure, *Source* Miller and Bellinger (2003)

- Volume. The organization collects data from various sources, including business transactions, social media, and information from data sensors or machine-to-machine. In the past, storing it would be a problem—but new technology (such as Hadoop) could ease this burden.
- Velocity. Data flow at an unprecedented speed and must be handled in a timely manner. RFID tags, sensors, and smart measurements drive the need to deal with the rush of data in almost real-time.
- Variety. Data are present in all types of formats—from structured and numeric data in traditional databases to unstructured text documents, e-mail, video, audio, stock ticker data, and financial transactions (Laney, 2001).

The relevance of big data with smart city is that big data offers an opportunity for governments in cities to gain valuable insights into a large amount of data collected from various sources. With population growing and the emergence of technologies such as the big data, the natural step that cities will take is to connect each sector within the city itself. There are millions of sensors installed, overseeing various things in the city. This smart city concept will enable us to utilize our resources, reduce energy consumption, and build cities with maximum efficiency. Big data is very important to understand how people in cities move, how energy is used, how various aspects of infrastructure interact, and more.

2.4 Text Mining

Text mining in Internet of Things (IoT) context has a role to filter such massive quantities of textual content to crucial message through automated extraction of information from unstructured text, and analysis and summarize of the extracted information (Berry & Kogan, 2010). Unstructured text is present in various forms and in huge and ever-increasing quantities of books, reports, documents, news articles, blog posts, social media (e.g. Twitter) (Feldman & Sanger, 2007).

The use of text mining in the context of spatial planning has a significant role in helping planners to make decisions in urban management. The trend of the digital revolution has drastically changed the way of life and civilization in the future. The phenomenon of change that can be observed is the acceleration of the process of urbanization throughout the world. In 2014, a study by the United Nations on the trends of world urbanization showed that for the first time in human history, more than half of the human population (54%) lived in urban areas.

Urban society is a complex system where the constituent actors include people, technology, and the environment that are interconnected and influenced by one another. The birth and development of urban centers that are urban in nature will always present new challenges, such as poverty, congestion, social inequality, crime, reduced natural resources, pollution, and health problems, all of which are urban problems. An urban population growth in the current digital era changes the culture that indirectly provides information through social media about the conditions in which people live. This is where the role of text mining is used in revealing important urban information when making spatial planning decision priorities.

2.5 Geovisualization

Spatial planning is an urban management program that is always used by the government and urban residents in activities so that there is a need for unlimited access to spatial information. Provision of information sources accompanied by the ease of accessing information by the government and the community in detail and in full is one form of fulfilling these needs. The method of communicating the right information is one strategy to provide information that has many data attributes.

Information visualization is one form of method in communicating information. The quality of information must be of a relevant nature, not obsolete (actual), free from errors (accurate), and reliable. Information visualization represents data that have been processed using various kinds of image processing devices (hardware, software, and brainware or human devices), which are then presented in visual forms. Visual forms can be text, images, colors, builds, diagrams, or combinations of the existing visual forms. One form of a combination of visual formations is geovisualization. Geovisualization is the presentation of data and information that refers to locations that have geographic coordinates while the attributes are detailed information from each available location (Dykes et al., 2005).

3 Methods

Various attempts have been made for developing a technique that can consequently identify and perceive potholes, for example, a 3D laser scanner method can distinguish potholes progressively. In any case, the expense of laser filtering hardware is as yet huge at the vehicle level. Moreover, manual survey and assessment are costly and tedious. As already mentioned in the Introduction, Indonesia is one of the developing countries that still struggling with the state budget allocation. Thus, this circumstance needs an alternative solution to give a rapid response with less cost. Herewith study, the researchers proposed an urban system

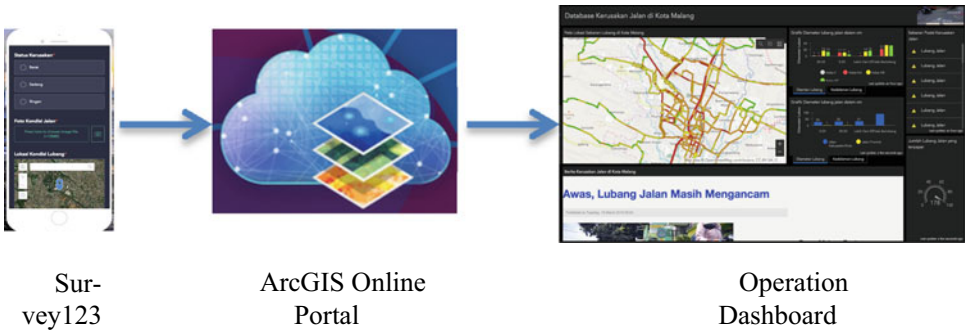


Fig. 3 The framework of GIS data collector and operation dashboard of citizen potholes e-Report system

through the creation of model for citizen potholes e-report that is connected to the government's urban monitoring dashboard.

This Citizen Potholes e-Report System uses two methods, namely (1) GIS Data Collector and Operation Dashboard and (2) Geo-text data collector and Operation Dashboard.

In the GIS Data Collector and Operation Dashboard, the researchers develop data collector based on geographic location using the survey123 for ArcGIS platform. Survey123 for ArcGIS is a GIS collector application from the Environmental Systems Research Institute (ESRI) provider to collect data in a simple form format and is based on geographic location. This GIS collector application can be used for various levels of stakeholders, ranging from owner business, organizations/communities, and public. To access Survey123, the user registers for an online ArcGIS account. But for public, the application can be accessed directly without registration by clicking the link or scanning the barcode that the researcher has published. After entering the application, the user can download the survey form to collect location-based data for providing reports. This platform can be operated both online and offline. In the case of offline reports, the completed survey form will be stored locally which when connected to the internet, users can send the data back to the ArcGIS server.

The next step, field data submitted by reporters will be sent to the ArcGIS online portal—a cloud-based mapping platform to create maps and share maps. ArcGIS Online is an ArcGIS product that uses the software as a service method. Tools provided by ArcGIS Online include: creating maps and scenes, accessing maps, ready-to-use apps, publishing data, collaborating and sharing maps, accessing maps from any devices.

To display field data obtained from reporters in the city council's monitoring dashboard, Operation Dashboard is applied. The Operation Dashboard for ArcGIS is a dashboard, which is a sort of a graphical user interface (GUI) that is applied to demonstrate and investigate the essential performance gauges, critical information, and metrics focuses related to a thematic field procedure based on geographical location. The dashboard is a component, which can be incorporated into the ArcGIS Online portal to assemble map-based dashboards. It contains different GUI tools such as home, map, legend, donut chart/pie chart, graph, zoom in/out. The tools can be associated and interlinked to one another ArcGIS application such as Survey123 for ArcGIS.

The GIS Data Collector and Operation Dashboard framework are shown in Fig. 3.

In the Geo-text Data Collector and Operation Dashboard, the researchers built the Citizen Potholes e-Report System with the Live Map platform under the ArcGIS Online hub portal. Live Maps is a configurable application format that gives the capacity to expend real-time information consumption from varying social media sources, for this case, the researchers used Twitter. This basic example of web application/map pulls a Twitter channel of the particular words. Filtering certain data on Twitter is conducted on the Live Map, which is then forwarded to the Operation Dashboard.

The Geo-text Data Collector and the Operation Dashboard framework are shown in Fig. 4.

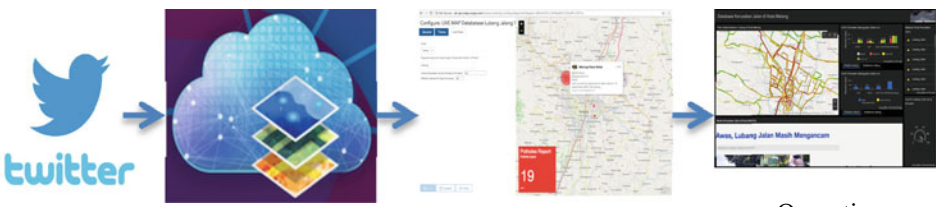


Fig. 4 The framework of geo-text data collector and operation dashboard of citizen potholes e-Report system

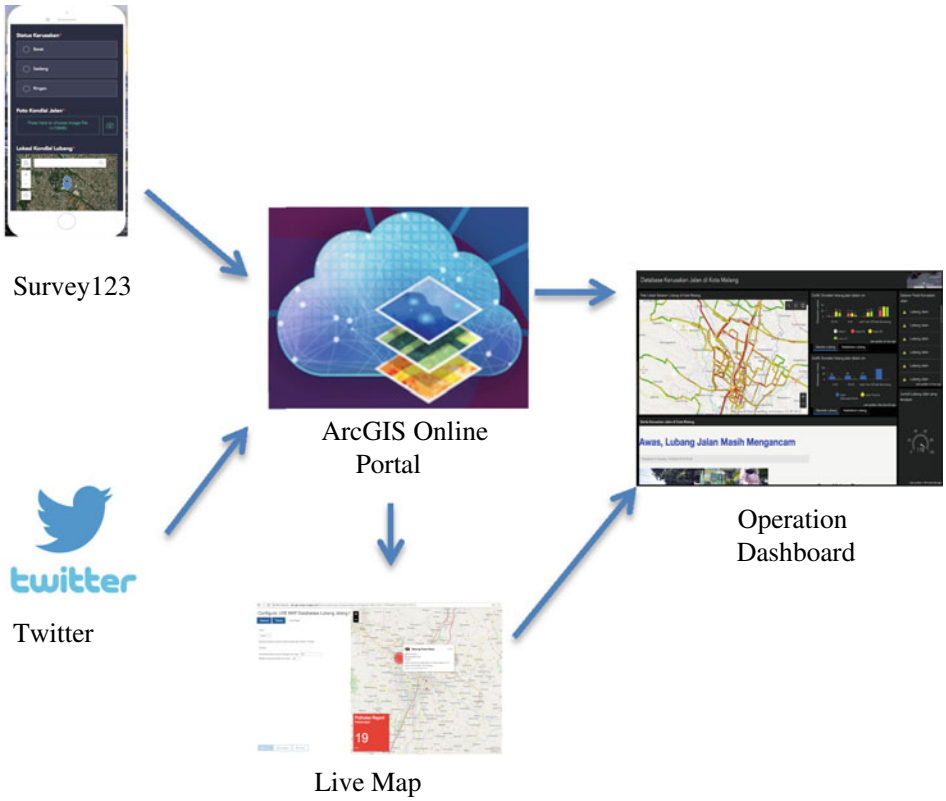


Fig. 5 The combine framework of the two methods for the citizen potholes e-Report system

The combined framework of the two methods for the Citizen Potholes e-Report System can be described as follows (Fig. 5).

4 The Proposed Citizen Potholes e-Report System

The objective of Citizen Potholes e-Report System stands on reporting urban problems, which, in this case, focusing on potholes, to city council for rapid response on road improvement priorities with less cost.

4.1 GIS Data Collector and Operation Dashboard

For the proposed method, the researchers took the case in the form of collecting information from the people reporting for potholes to the Malang City Public Works Agency. The media used in this information collection is a media the researchers created, a Geographical Information System (GIS)-based mobile application with the name *survey123* on the ESRI platform with variables and data types decided by researchers. Variables and data types in collecting potholes information can be seen in Table 1.

After the variables and data types were developed, then the GIS Potholes Data Collector application was launched to the public through providing weblink or barcode that is placed in official signs located in several places along the road. The user interface of the application is shown in Fig. 6.

The next step after citizens have access to the application is to fill the form for reporting potholes findings near their positions.

GIS-based data analysis of reports received from citizens for further analysis utilized the ArcGIS GeoAnalytics method. ArcGIS GeoAnalytics method gives a dispersed registering system that powers an accumulation of investigation devices for breaking down huge volumes of data and information. The researcher can envision, comprehend, and follow up data through regression, clustering, and aggregation. Furthermore, GeoAnalytics enables the researcher to pick up experiences that may somehow be covered up in our information, for example, trends, patterns, irregularity.

GeoAnalytics has target to the distinctive spatial investigation approaches the researchers can take with big data: examine model, identify positions, maintain data, compile data, practice closeness, and data enhancement. Regardless of whether the researchers have to finish an agile spatial merge, execute spatial regression analysis on different datasets, or discover regions of information bunching, the GeoAnalytics gives numerous choices to investigate

Table 1 Variable and data types for GIS potholes data collector

Variable	Data type
Name of reporter	Text
Time	Date and time
Location	Longitude and latitude position
Potholes depth	Number in centimeter (cm) (Estimation from reporter)
Potholes diameter	Number in centimeter (cm) (Estimation from reporter)
Damage status	Single choice: • Minor • Medium • Major
The type of transportations that pass the road	Multiple choices: • Car • Motocycle/bicyle • Truck/bus
Pothole picture	Picture

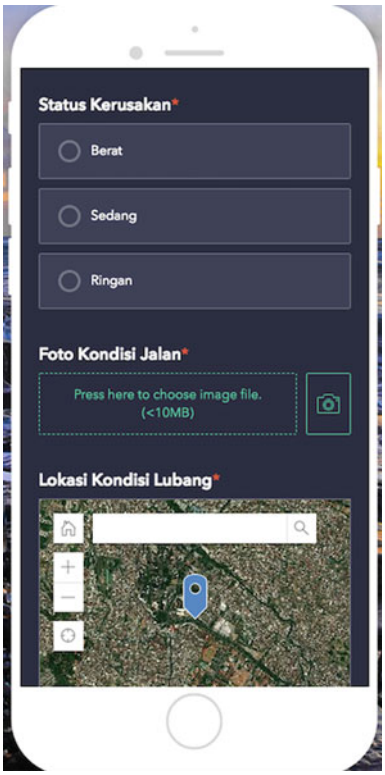


Fig. 6 GIS potholes data collector app in a smartphone

information. Notwithstanding the method, the researchers can modify work processes and investigations through Python, utilizing dispersed calculation and apparatuses.

In ArcGIS GeoAnalytics, the researchers set the priority of handling potholes by classifying the roads that have the biggest to smallest pothole numbers. Step-by-step, the big data analysis in GeoAnalytics follows this rule:

1. Arrange the input data
   Data that were already input by the public through Survey123 app were downloaded by the researcher through the Survey123 web portal (see Fig. 7).

2. Set up data file share
   A data record offer will make a big data list administration, which can be analyzed in the GeoAnalytics instruments.
3. Compile data file share
   This dataset has a different date and time fields. The researchers assess the dataset in the display to ensure that it utilizes the right fields. At the point when the display is first created, the geometry and time parameters go through the obtained areas.
4. Run analysis of potholes data through ArcGIS Online Portal
   The output of the data analysis for managing potholes refinement in Malang City will be presented in the form of geovisualization and tabular form as shown in Fig. 8.

From the results of data analysis on the managing potholes refinement prototype in Malang City, it can be concluded that the potholes priority for refinement is on the Candi Panggung street with 42 potholes, Joyoutomo street with 39 potholes, and Mayjen Panjaitan street with 38 potholes.

The next step was to configure the Operation Dashboard for ArcGIS. First, the researchers in this context have a role as the administrators who have signed up for ArcGIS Portal account. Afterward, we filled the title, tags and summary then created the Dashboard. In the beginning, the basic dashboard presentation was blank. There are fundamental

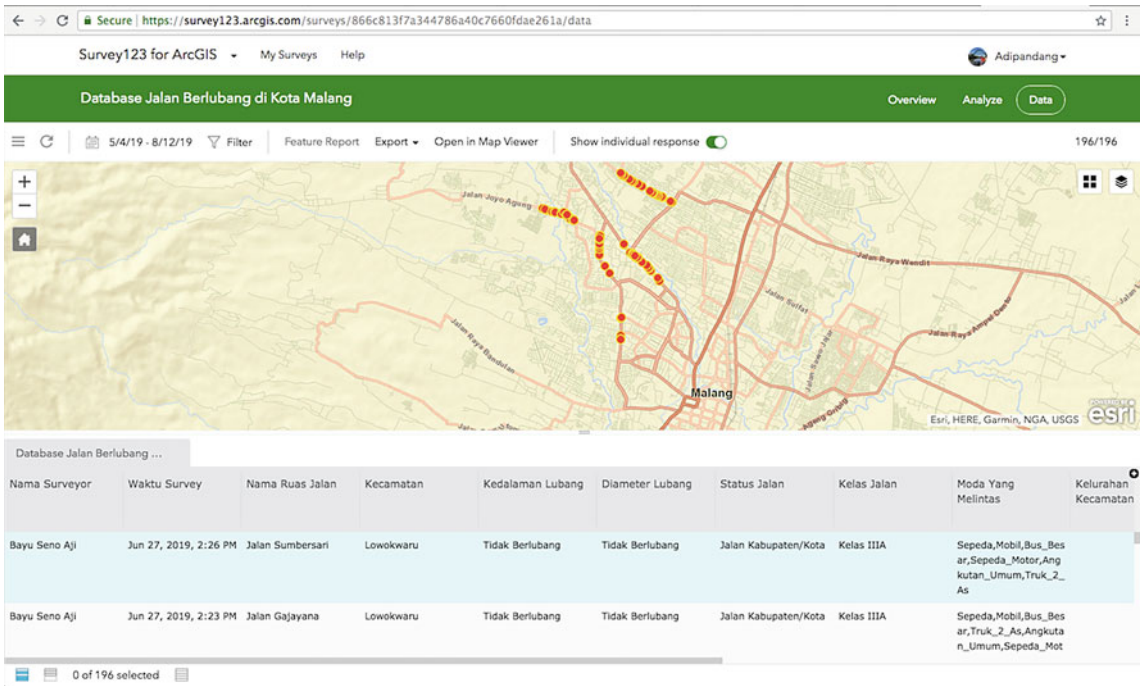
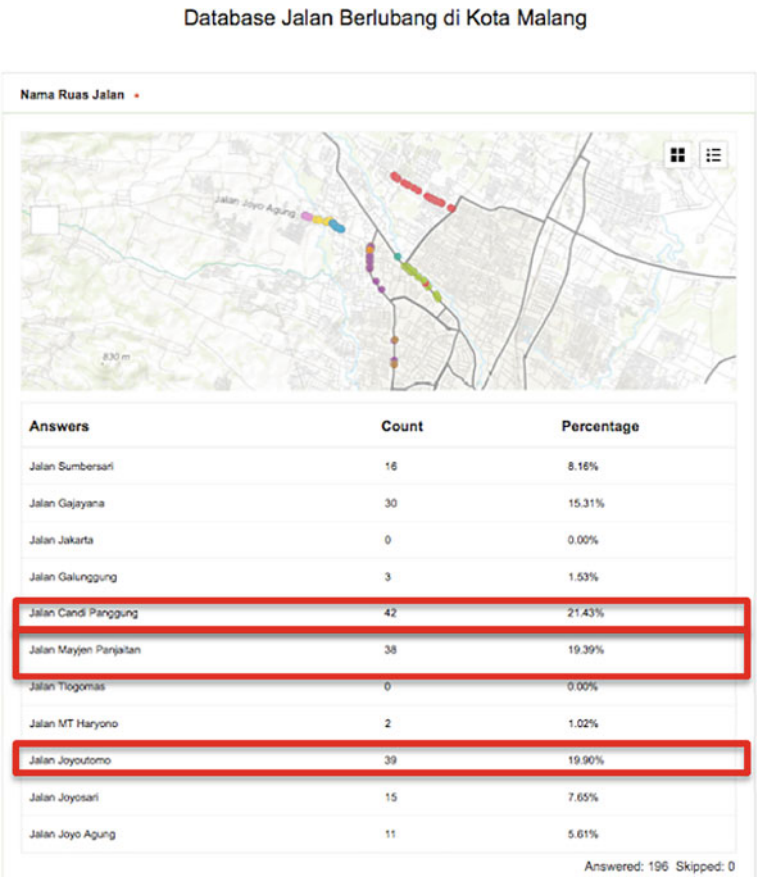


Fig. 7 Survey123 ArcGIS web portal

Fig. 8 Data analysis for road improvement priority decision in Malang city



three symbols on the dashboard. The first is to include the components in the dashboard, e.g. header, map, indicator, pie chart, gauge. The second symbol is utilized to manage the dashboard and the third gives the connection to share the dashboard and, furthermore, apply the topic (light or dark) for it.

After collecting the data using GIS Potholes data collector under Survey123 for ArcGIS platform, to display directly the collected data to Operation Dashboard, the researchers set up the map by connecting link file from the GIS Data Collector application to Dashboard. Therefore, at the same time users give information regarding the findings of potholes, the data submitted will, in real time, enter the administrator server dashboard.

4.2 Geo-Text Data Collector and Operation Dashboard

Discussion in this subchapter is still relevant to the previous subchapter with a case study in the form of collecting information from the public related to pothole reports through social media. This research used Twitter, associated with the context of geovisualization. In this open data and information era, urban community reports—both through official reports and social media—can provide an overview of urban situation that occurs in their environment living. Currently, the provision of information through social media is becoming popular, through posting on Facebook, Instagram, and Twitter. However, to find out the actuality and precision related to urban problem reports, it is necessary to filter the words that exist on social media and carry out statistical calculations in order to obtain the truths in the information. Therefore, the ability to text mining is needed in its analysis.

The first step in preparing a text mining analysis is filtering the word, as a keyword of the information is needed. The next step is exploring the geocode from Twitter in which the longitude and latitude of the information are presented to display the context of geovisualization.

Text mining steps include five stages, namely text preprocessing, feature generation, feature selection, mining, and analysis of results.

(1) Text Preprocessing
This stage starts by reducing ambiguous words and refers to the context of the case study, in this case, potholes. For example, in getting information about potholes, not only the words `potholes' are included in the category to be included but there are other words that enter such as `hole' and `road'. For this reason, the steps needed in this stage include:
- removing white spaces;
- replace a more general concept;
- removing inter-punctuation;
- removing numbers;
- named entity recognition;
- removing capitals;
- removing stop words;
- stemming (a process for removing common words from English).

(2) Feature Generation
This stage is used to familiarize text with researcher context. This stage decides which features the researcher would want to extract in the word frequency, length of sentence, number of verbs, word complexity.

(3) Feature Selection
This stage will specifically direct the words from Twitter that fall into the specified topic category, maximum variability, and linguistic features. The sorting of words that is included in the study context is deepened by the Chi-Square statistic with steps such as:
- Build a confusion matrix (the table used to describe the performance model (classifier) of data sets for which the true values are known)
- Calculate the Chi-Square statistic for each word
- Rank the words in descending order
- Select highest-ranking words

(4) Mining
This stage executes an algorithm from the rules that have been set in the previous three stages of extracting the information needed relating to the context of the case study related to potholes in Malang City.

(5) Analysis of Results
At this stage, there will be selected tweets from the context of Potholes in Malang City (one of the results is shown in Fig. 9).

To present the geographic position from Twitter, the next step is inserting the geocode on the related tweet. The geocode on Twitter is information on longitude and latitude, which marks the location in which tweets are posted. In this context, after the researchers filter the word in Twitter with the keyword “hole” and “road”, the application marks the geographic location of the geocode generated, provided that the smartphone from the user activates the Global Positioning System (GPS) (see Fig. 10).

With the above function, the researchers managed to get 99 tweets with the keyword “hole on the road” (Potholes) within 30 km radius from the center of Malang City. The final result of the text mining appearance of Twitter, with geovisualization performed on the webapp builder in the ArcGIS Online platform, will show information both in text and image with the geocode location marker provided (see

Fig. 9 The analysis result by filtering text through text mining in twitter

Fig. 11). This will help urban planners make decisions in managing potholes in Malang City.

5 Results and Discussions

In this study, the Citizen Potholes e-Report System was put into effect for a month in June 2019. Information collection activities did not only rely on waiting responds from the reporters, but they also consist of field observations to test the validity of the obtained data. In the trials conducted during the study, 197 reports were submitted (see Fig. 12).

In distinction to the two data collection methods used, namely, GIS data collector application and Geo-text data collector, predominant data collection used GIS data collector application method. During observations made in the study, all reports came from pedestrians and bicycle/motorcycle riders (see Fig. 13). There were no reports from car, truck/bus drivers, or passengers. This is possibly due to the ease of pedestrians and bicycle/motorcycle riders to retrieve pothole report data.

With respect to the duration of the form filling—based on interviews with several reporters—it took an estimate of 30–45 seconds to fill information in the Citizen Pothole e-Report form. Meanwhile, submitting data to the Operation Dashboard server took a 3–5 s relay time, which heavily depended on the internet speed access in the field. Furthermore, all data collection activities were carried out in the morning until the afternoon. This was due to the visual limitations in the night.

Based on observations and interviews with respondents, it was found that filling the form using the GIS data collector application method was very easy and fast when operating the application. In practice, the respondents were quite adept in filling out the form (see Fig. 14), although it is undeniable that the use of Twitter for e-report potholes was much more practical. But the obstacle often encountered in the use of the Geo-text data collector method with Twitter media was that the GPS settings on the smartphone used are frequently turned off, so the location of the potholes cannot be detected. Furthermore, there are several shortcomings of the app that the measuring accuracy still had false measurement and justification, due to the depth and diameter of potholes, in addition to the road damage status justification based on reporter perceptions.

Based on an interview with one of Malang City government representative, the results of the study show that the application of Citizen Potholes e-Report System has the potential to be developed into a big data platform to support decision-making processes at the official city council in determining the priorities for handling road improvements,

Fig. 10 A brief script of geocode on twitter

```
library(twitteR)
setup_twitter_oauth(consumer_key = "XX",
                    consumer_secret = "XX",
                    access_token = "XX",
                    access_secret = "XX")

tweetsList <- searchTwitteR("lubang jalan",
                            geocode = paste(latitude, longitude, "30km", sep = ","),
                            n = 3000)
```

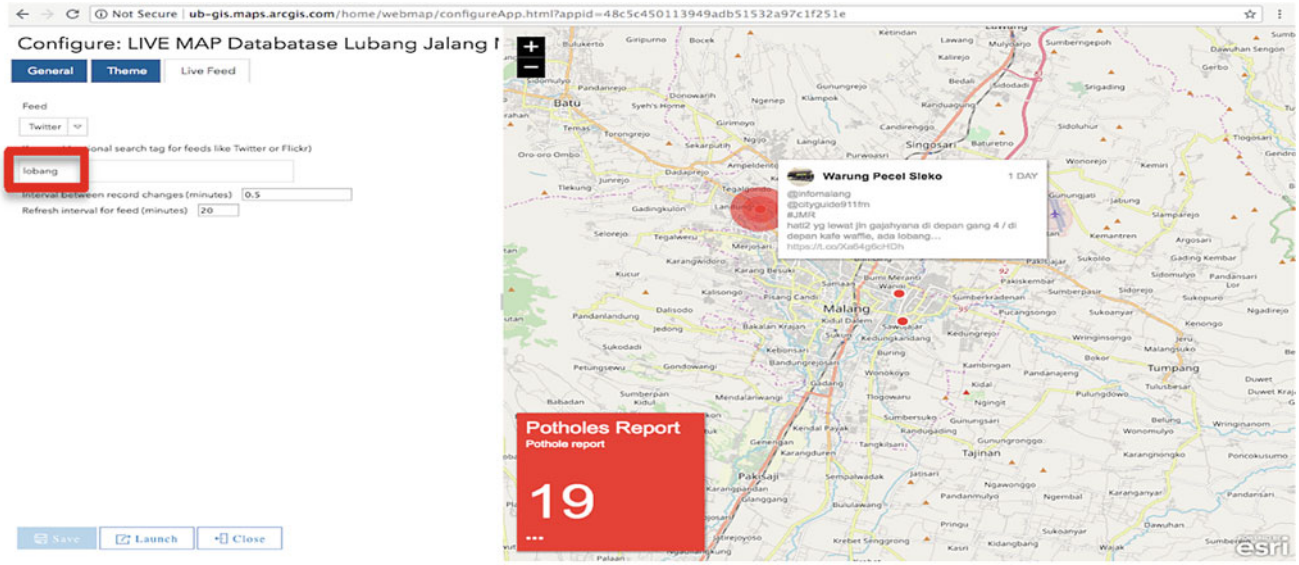


Fig. 11 Text mining and geovisualization of potholes report in Malang city through live map

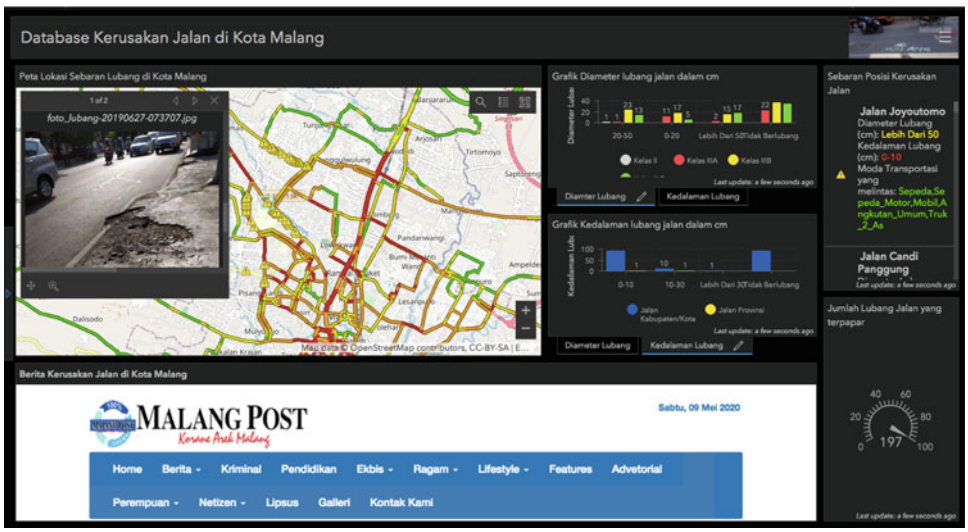


Fig. 12 The operation dashboard for citizen potholes e-Report system

with conditions for legalizations of the system under government regulations and massive involvement from urban communities. The application of technology for urban areas in smart cities is inseparable from the involvement of the urban community itself in providing data and information regarding urban problems. Based on a study conducted by Yudono and Yudiarso (2019), community involvement in a government program has four levels (Yudono & Yudiarso, 2019), which are as follows (see Fig. 15).

In order to create community involvement as a step toward smart cities, the urban communities' position is located at least on level 2, i.e. the form of information sharing. In this stage, the urban community takes the initiative to provide information related to the issues and problems in their surrounding environment to the government. This shows the stages of collaboration. As the initial move toward making receptive conditions, collaboration efforts have not ensured any dedication or duty regarding an individual, affiliation, or establishment.

6 Conclusion

In this research, the Citizen Potholes e-Report System is proposed as an innovation that uses less government's budget by integrating various forms of digital communication to create an informative and communicative platform between city councils and urban communities through data analysis, text mining, and geovisualization studies. The proposed system is divided into two methods: (1) GIS data collector and

Fig. 13 One of the pedestrians accessed the GIS potholes data collector to report his pothole finding

Fig. 14 The result of filling GIS potholes data collector form by one of the reporters

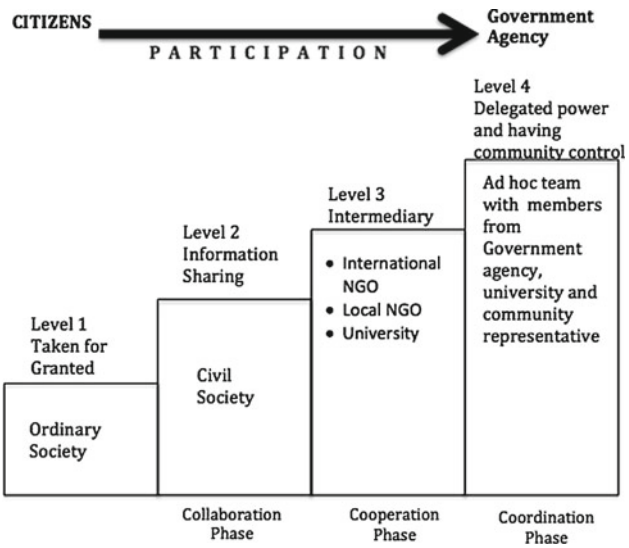


Fig. 15 A stepped model for community participation in government agency agendas. *Source* Yudono and Yudiarso (2019)

Operation Dashboard and (2) Geo-text data collector and Operation Dashboard. For GIS data collector and operation dashboard method, the researcher took the case in the form of collecting information from the public who reports to the Malang City Public Works Agency. In order to facilitate the media used in this information collection, the researchers created a GIS-based mobile application, named *survey123*, on the ESRI platform with variables and data types determined by researchers. The next method is the Geo-text data collector and Operation Dashboard. This method proposed integrated text mining, through Twitter, with geovisualization, through Operation Dashboard.

The results of the study show that the implementation of Citizen Potholes e-Report System has the potential to be developed into a big data platform to support decision-making at the official city council in determining priorities for carrying out road improvements, with conditions that accommodate massive involvements from the urban communities. The application of technology for urban areas in smart cities is

inseparable from the involvement of the urban community itself, through providing data and information in urban problems. Based on a study conducted by Yudono and Yudiarso (2019), community involvement to be involved in a government program has several levels. In order to create community involvement as a step toward smart cities, the urban communities' position is located at least on level 2, i.e. information sharing. In this stage, the urban community takes the initiative to provide information related to the issues and problems in their surrounding environment to the government. However, the researchers acknowledge that there are still limitations for this research and shortcomings of the system where the measuring accuracy still had false measurement and justification, due to the depth and diameter of potholes, in addition to the road damage status justification based on reporter perceptions. Therefore, this situation needs further research using high technology, for instance, computer vision and advanced artificial intelligence to measure accurate depths and diameter of potholes, justifying the road damage status automatically, although the suggested research will impact to higher cost.

All and all, the proposal of Citizen Potholes e-Report System is welcomed by citizens and government representatives because it provided direction and recommendations in an effort to formulate urban policies with legalization through regulations to implement digital dialogue between citizens and governments toward the ubiquitous spatial planning in Malang City.

Conflict of Interest The researchers declare that there is no conflict of interests regarding the publication of this paper.

Acknowledgements This study was conducted through the collaboration between academics (Brawijaya University) and an industry (ESRI Indonesia) as a GIS Software provider. The role of academics and industry in this research is: as academics, they created methods of Citizen Potholes e-Report System, whereas the industry helped by facilitating them in using their platform, namely Survey123 for ArcGIS and Operation Dashboard for ArcGIS. Herewith this paper, the researchers also thank you all my research assistants (Nateq, Bayu, and Catur) for their help during conducting this research.

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Adaptation and Resilience in Energy Systems

Major technological changes to reduce greenhouse gas emissions and mitigate climate change are transforming the energy supply sector. Efforts are under way to reverse the increase in greenhouse gas emissions (GHG) and lower the carbon footprint of development. However, with continuously arising challenges for energy generation, networks and demand, an understanding of how climate change is to affect other energy systems and services must be established. The exchange of knowledge and experimentation with new technologies to mitigate the effects and tackle existing challenges are ongoing with a focus on renewable and alternative energy sources, improved efficiency and loss reduction.New coordinated approaches to energy planning and implementation within the framework of the smart city concept have arisen as a way of improving energy efficiency. The authors of the chapter titled "The Impact of Modified Residential Morphologies on the Outdoor Micro Climate in Hot and Dry City of Erbil, Kurdistan-Iraq" focus in their research on energy efficiency for existing built-up urban structures by criticizing the current Modern Grid-Iron (MGI) planning grid used today in design and its neglect for urban microclimatic needs that have resulted in an increase in energy demand. The authors use ENVI-met, to predict the microclimate in the MGI urban pattern in Erbil, Iraq and explore techniques that increase natural ventilation of buildings and reduce the need for energy consumption. Similarly, in "Examining the Thermal Properties of Full-Scale Test Modules on the Overall Thermal Performance of Buildings", thermal properties of full-scale test modules are examined to show the main parameters' influence on thermal performance of buildings using an evaluation tool known in Australia as AccuRate.With a constantly and massively changing climate, the earth faces newly found challenges and need for resilience in its energy systems. To achieve long-term solutions, a shift to an energy system that is based on renewable energy and high energy efficiency and is resistant to disruptions is crucial. The chapter on "Achieving Energy Efficiency Performance and Urban Connectivity Development in Saudia Arabia through Renewable Energy Resources and Sustainable Transportation—Case Study Asir Province" explores the potentials of the Asir region in Saudia Arabia for energy efficiency and water resources to enhance its economic resources and social needs. The authors in their research tackle the country's high consumption of energy through its means of transportation and building energy consumption as it is approximately 1.7 times higher than in Europe per capita. It is an attempt and call to install sustainable means of transportation to enhance Saudi's lifestyle, save fuel consumption and enrich urban connectivity development.Following in the same footsteps, the author of the chapter titled "Disaster-Resilient Building: Lesson Learned from a Building Performance Evaluation of Meuraxa Hospital in Aceh, Indonesia" not only investigates the existence and operation of sustainable or energy-efficient systems for energy and water consumption but also carries out a detailed post-disaster evaluation of the Meuraxa Hospital, located in the Aceh Province in Indonesia, to evaluate its performance after it was reconstructed after destruction due to a tsunami and earthquake hit in 2004. The evaluation post-reconstruction is completed using three main variables: Built Environment and User Building, Building System Levels and Disaster Risk Management (DRM). A modified AEDET toolkit is used and interviews with key persons along with field observations were integrated. The author makes significant observations on how local meets can be met and the ways in which a building can be designed and constructed using a flexible and sturdy structure to withstand a disaster.

The Impact of Modified Residential Morphologies on the Outdoor Microclimate in Hot and Dry City of Erbil, Kurdistan-Iraq

Ali Mohammad Salih and Steven Dudek

Abstract

In 1991, the Iraqi Kurds established an autonomous state of Iraqi Kurdistan. Erbil, the state's capital, rapid expansion has moved away from using the principles of design in a hot dry climate. This organic morphology has been superseded by a modern grid-iron (MGI) planning grid to accommodate motor vehicles. The alignment of these MGI has been driven by geometry rather than referencing urban microclimatic needs and has increased energy demands. This paper uses ENVI-met to predict microclimate in the MGI urban pattern of Erbil, focusing on the prediction of dry-bulb temperature (T), mean radiant temperature (MRT) and wind speed (WS). These predictions were compared to weather stations located in the urban development of Erbil, in common with other researchers; good agreement was achieved during the day time, less so during the night time. Using ENVI-met, the orientation and street canyon widths have been investigated to achieve the highest WS around buildings. These higher WS can be utilised to increase natural ventilation of buildings, this will decrease the need for mechanical cooling leading to a reduction in energy consumption. With low rainfall and limited water service provision, a blue/green environmental strategy was not possible, and due to limited possibilities to manipulate the urban street canyons to provide shade, meant that the possibilities of reducing the T and the MRT were restricted. To reduce the MRT, the use of external shading mesh was explored. This reduces the Sky View Factor and, therefore, limits solar gain. The ENVI-met climatic model demonstrated a significant reduction in the MRT.

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Keywords

Urban microclimate • ENVI-met validation • Modification urban morphology • Shading meshes • Mean radian temperature

1 Introduction and Literature Review

In 1991, the Iraqi Kurds established an autonomous state of Iraqi Kurdistan and it has flourished in stark contrast to the remainder of Iraqi and Syria (see Fig. 1). The capital of Kurdistan is the historic city of Erbil, centred on the citadel, a 32-m high-walled mound, covering 10 ha (Abdulkareem, 2012). At first sight, the citadel appears to be located on high ground surrounded by a relatively flat plain. This is an illusion; the citadel's height has been gained through layer upon layer of construction stretching back some 7,000 years (Akram, Ismail, & Franco, 2015). Within the citadel and the districts to the South, located adjacent to the main entrance, an organic urban street pattern exists, dictated by climate, availability of construction materials and transport needs (Al-Hashimi & Bandyopadhyay, 2015). With economic and political stability, Erbil has expanded dramatically, with an urban development plan that consists of a series of concentric ring roads, with the citadel at their centre (Alkmuhtar, 2016). Urban planning of the areas formed by these concentric ring roads has taken the form a grid-iron street pattern, with road widths suitable for modern cars. The orientation of these grid-iron street patterns does not account for the designing of dwellings' in a hot dry climate. Whilst the urban areas have expanded rapidly since 1991, the same cannot be said for the amenity infrastructure shown in Fig. 2. This has resulted in dwellings being poorly sited to minimise the impact of a hostile microclimate and the electrical energy needed to make them habitable unavailable at the peak time of demand, the hot summer period (Ayoob Khaleel & Ibrahim, 2010).

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Fig. 1 Kurdistan-Iraq map

This urban development is producing an environmentally unsustainable city. The inhabitants resort to mechanical cooling to achieve thermal comfort within their dwellings. This results in high demand for electrical energy, which the grid cannot supply. The shortfall is bridged by diesel generators, whose exhaust produces poor air quality. What is required is an environmentally sustainable city, in a hot dry climate, this would provide the inhabitants of the city with an urban microclimate that reduces the need for mechanical cooling. This would reduce the need for diesel generators and improve air quality.

The objective of this paper is to effectively numerically model the urban microclimate of the modern grid-iron developments of the city. Once an effective numerical model has been developed, urban design strategies to reduce the impact of the hot dry climate on the urban microclimate of the city are investigated.

Resent developments in urban climatic modelling have enabled researchers to investigate the impact of urban morphology on the urban microclimate. ENVI-met, a holistic three-dimensional hydrostatic model has been used by researchers to investigate urban microclimates (Chow & Brazel, 2012b). This paper uses ENVI-met to predict the urban microclimate of these grid-iron street patterns and how these can be orientated and manipulated to lessen the impact of the hot dry climate on the individual dwelling. ENVI-met is very much a research tool and care must be exercised in its use, so the first part of this paper is devoted to assessing the accuracy of the microclimatic predictions. This is done by modelling a portion of modern Erbil that surrounded a weather station and then comparing the predicted air temperatures at the weather to those measured at the weather station.

Having gained confidence that ENVI-met can be used successfully to predict urban microclimatic variables, the orientation and street canyon widths have been investigated to achieve the highest wind speeds around buildings. These higher wind speeds can be utilised to increase natural ventilation of buildings, this will decrease the need for mechanical cooling leading to a reduction in energy consumption and will lead to more energy-efficient designs (Radhi, Fikry, & Sharples, 2013). However, the wind speeds in these urban canyons will always be low, due to the surface roughness of the urban environment and lack of climatic drivers to increase the wind speed in the region (Andreou, 2013). To reduce solar gain, the use of shading devices was explored, and these had the potential to reduce the mean radiant temperature within the urban canyon.

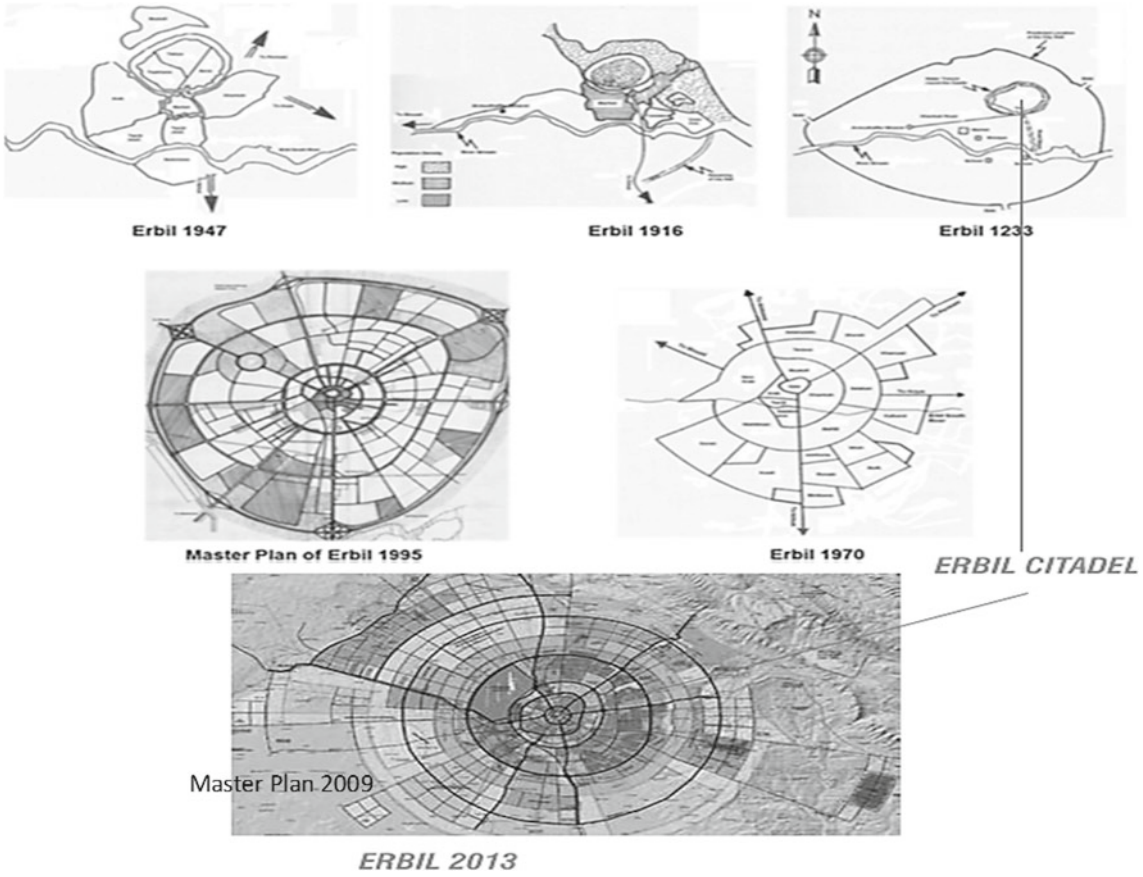

Fig. 2 The urban development of Erbil City where the Citadel is always constituted the focal plot through the history. *Source* KRG (2009)

2 ENVI-Met

ENVI-met is a three-dimensional program that simulates and analyses the microclimate urban environment. The typical resolution of ENVI-met microclimate model is 0.5–10 meters (Huttner, Bruse, & Dostal, 2008). It uses fluid dynamic fundamental laws to calculate the dynamic of microclimate during the day and night for urban areas (Huttner, 2012). ENVI-met can accurately simulate the physics of atmospheric boundary layer of any urban area around the world (Bruse, 2004a). Simulation is normally between 24 and 48 h, with 10 s as the maximum time step. The model also can present the energy balance for all types of urban surfaces; buildings and plants. ENVI-met can simulate the interactions between urban elements, such as weather, soil, plant and buildings on the urban scale (Bruse, 2004b). Every single structure or buildings, vegetation and soil layers can be simulated. ENVI-met contains the following sub-models (Huttner, 2012):

1 D boundary model represents the boundary conditions between 0 and high 2500 m.

3 D atmospheric model represent building structure, plants. 3D/1D soil model represents soil temperature and moisture content in different layers.

3 Validation

To assess the accuracy of the ENVI-met predictions, weather data were obtained from a Central weather station (CWD), which is located in the south-east of Erbil near the city centre (Erbil Citadel) on latitude 36.17° and longitude 44.01°, as shown in Fig. 3. The CWS had originally been sited outside the city, but the city's rapid expansion had engulfed the weather station, making it ideal for this validation exercise. Microclimate measurements in CWS obtained for three summer months. CR 1000 data-logger used for CWS and connected with numerous sensors and equipment.

The CWS basic installation in the site with tower is shown in Fig. 4. It programmed to start recorded data from 00:00 am to 23:00, so 24 h a day. The sensors set to save data every 15 min in one Excel file including all microclimate variables. Table 1 lists the accuracy of the sensors fixed on the CWS tower.

Fig. 3 Erbil city urban configuration with the red circle represents central weather station

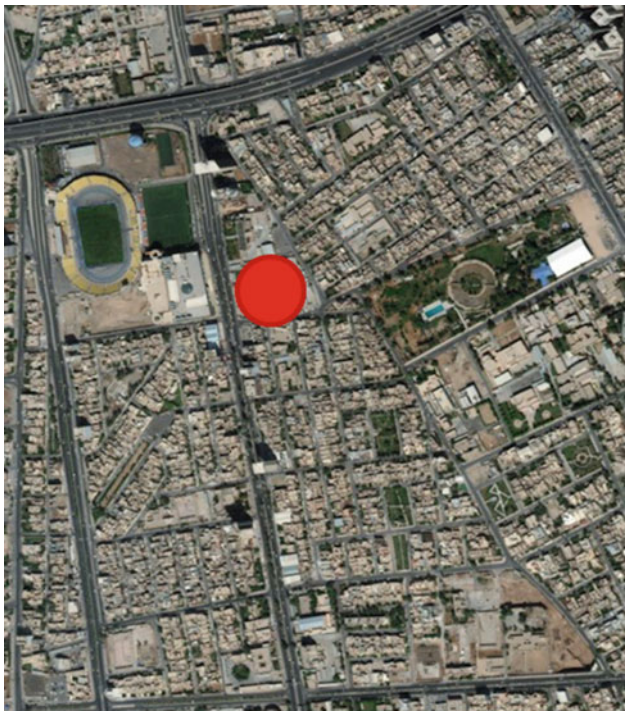

Fig. 4 Microclimate weather data tower. Sensors and data logger installed in the site

Figure 5 shows the ENVI-met 4.1.0 model of this urban area and Table 2, the initial input variables used in the model. ENVI-met model input data accepted only one value for wind speed (v) for all 24 h (1 day) and 24 values for air temperature (Ta) for all 24 h. So, the validation was based on air temperature rather than wind speed. In addition, the validated process employed two methods; first, by direct comparison between modelled and measured dry-bulb temperature; second, the study used the Willimott methodology, which depends on the Index of Agreement (d) between modelled and measured data. This method is widely used for ENVI-met validation as shown in these studies (Chow & Brazel, 2012a; Hedquist & Brazel, 2014; Kong et al., 2016; Zhao, Sailor, & Wentz, 2018).

The performance of the ENVI-met model was assessed in two ways:

1. Comparison between measured air temperature, the observed value, and modelled air temperature, the predicted value, at a 2 m height, is shown in Fig. 6.
2. Using root mean square error (RMSE) and the index of agreement (d); Eq. 1.

This method used is described in full by (Willmott, 1982).

Equation 1. Index of agreement between modelled and predicted data

$$\text{Index of Agreement d} = 1 - \left[\sum_{i=1}^{n}\left(pi - oi\right) \wedge 2 / \sum_{i=1}^{n}\left(|Pi| - |Oi|\right) \wedge 2\right) \quad (1)$$

The index of agreement (d) is a standardised measure of the model prediction error, a value of "1" indicates a perfect agreement while a value of "0" would express no agreement. A "good" model could be defined as one where the systematic error approaches zero and the unsystematic error approaches the root mean square error (Kong et al., 2016). Willmott proposed that the systematic error could be described by

$$\text{Mean Square Error systematic} = N^{-1}\sum_{i=1}^{n}(P\wedge i - Oi)2$$

And the unsystematic error by

$$\text{Mean Square Error unSystematic} = N^{-1}\sum_{i=1}^{n}(Pi - P\wedge i)2$$

By taking the square root of both MSEs and MSEu, these differences can be redacted to the units of temperature.

[insert Fig. 4 here] Table 1 The central weather station microclimate sensors types and accuracy

Parameter	Unit	Instrument	Accuracy
Solar radiation	Flux density KW/m^2	LT 200 X	±3% typical within ±60 °C
	Total flux MJ/m^2		
Temperature	°C	HMP 50	±0.8 within −10 °C to 60 °C
Relative humidity	%		±3% RH within 0 to 90%
Wind speed	m/s	Sensor 05106	±0.3 m/s within −50 °C to +50 °C
Wind direction	Degree		±3° within 0 to 360°
Soil temperature	°C	108 Temperature Probe	≤ ±0.01 °C to ±0.5 °C within −35 °C to +50 °C

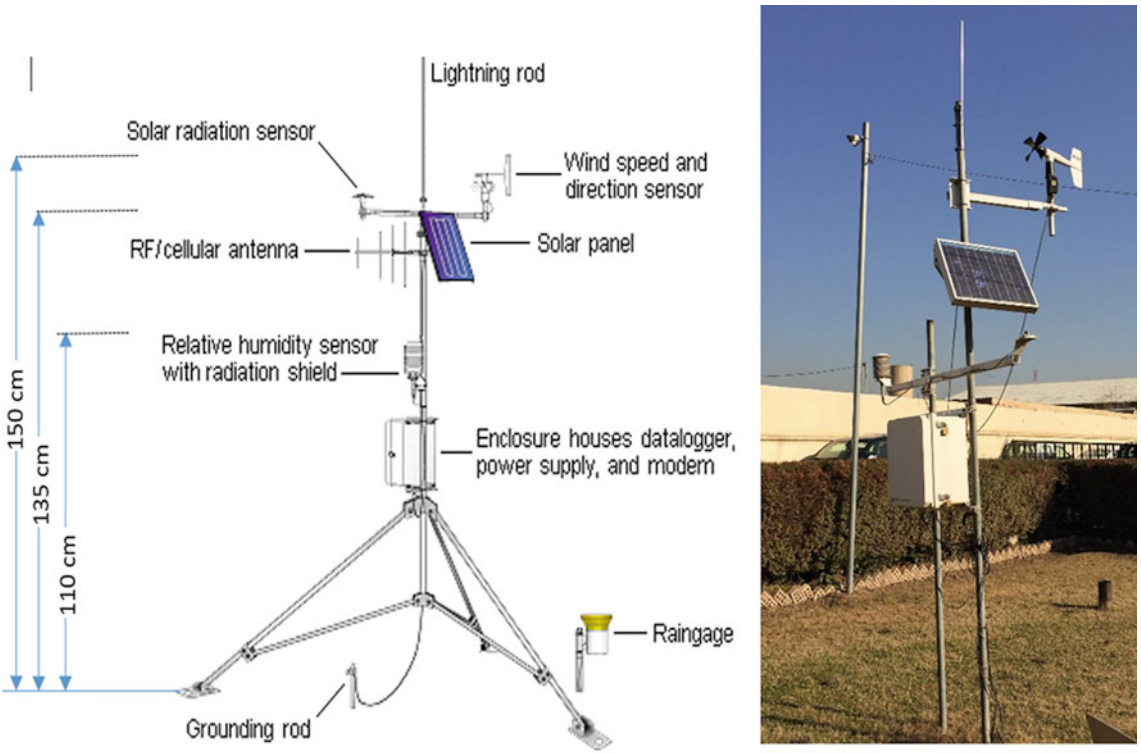

Fig. 5 Erbil city urban configuration modelled through ENVI-met

Figure 6 shows the air temperature plots from the Central Weather Station, the observed value and the ENVI-met, the predicted value, from 8:00 to 01:00. The predicted maximum and minimum are below and above the respective measured values and this is in line with other researchers that have found that ENVI-met model underestimations the minimum and maximum temperatures (Chow & Brazel, 2012a). ENVI-met appears not to predict the night-time air temperatures very well, so two data sets were analysed, the full 24 h and a data set encompassing the day time period of 7:00 to 18:00, sunrise to sunset. The ENVI-met (P) modelled data showed generally "good agreement" compared to observed data from the Central Weather Station (O), (r2 = 0.75) for 24 h and (r2 = 0.92) for day time (07:00 to 18:00). In addition, the index of agreement is (d = 0.85) and (d = 0.99) for both 24 and day time period is respectful.

The root mean square error systematic error (RMSEs) and unsystematic (RMSEu), a lower magnitude for the former is desired, Table 2 gives the comparison for the two data sets, and it is clear the ENVI-met produces satisfactory results for the day time period as opposed to the full 24-h period. Table 3 gives the analysis of errors from measured and observed air temperatures.

Table 2 The initial input variables used in the validation model

Parameter	Units	Values
Initial air temperature	C°	36.33
Wind speed in 10 m height	M/S	0.5
Wind direction	0 from the north and 180 from south	225°
Relative humidity in 2 m height	%	14.5
Specific humidity at model top	2000 mg/kg	5
Maximum air temperature at 15:00	C°	41.87
Minimum air temperature at 05:00	C°	27.66
Soil temperature in the depth of		
00–5 cm	(K)	311.23
20–50 cm		306.07
50–200 cm		300.77
Below 200 cm		298.81

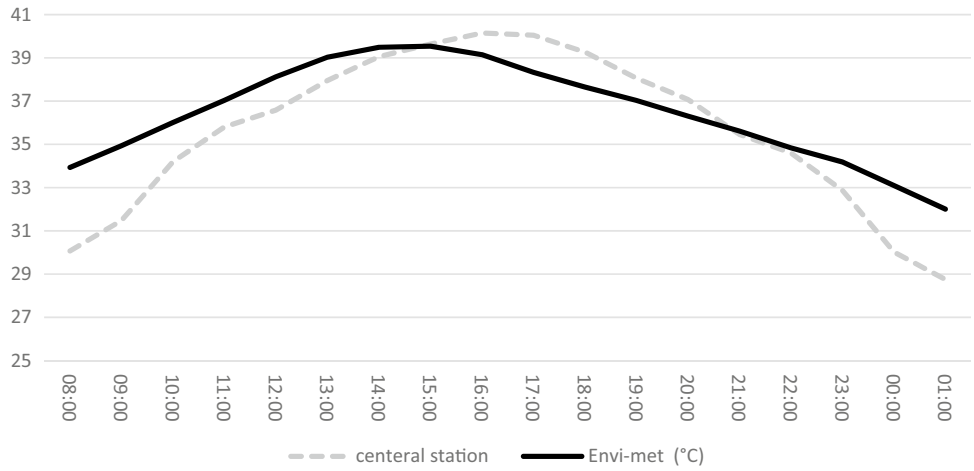

Fig. 6 Observed and predicted air temperatures' for a 24 h period in July

Table 3 ENVI-met results for the day time period and full 24 h

Assessment period	Index	24 h	Day time (07:00 to 18:00)
Correlation coefficient	r2	0.757	0.92
Mean bias error	MBE	1.020	2.30
Mean average error	MAE	2.62	2.41
Systematic root mean square error	RMSEs	4.04	3.79
Unsystematic root mean square error	RMSEu	2.107	0.33
Index of agreement	d	0.85	0.99

Having gained confidence in using ENVI-met to predict day time climate conditions satisfactorily, the next step of the research was to analyse a proposed urban area of Erbil and to explore ways in which the urban form can be manipulated to increase wind speeds and reduce air temperature.

The new case study is a proposed design scenario for research application only and reflects the grid-iron morphology. The validation urban site close to the central weather data station is located adjacent to a World Heritage Site (Erbil citadel) and interventions would neither be

practicable nor is this site representative of modern developments in Erbil.

4 Results

1. **Microclimate for Real Case Study**.

Figure 6 shows the urban layout and the three stars show the positions where the canyon wind speeds were extracted from ENVI-met, before, in the centre and after an open space at a height of 2 m from the ground. Figure 7, an urban grid with the canyons' aligned North–South and East–West, the grey blocks are built forms and the green are open areas, redstarts in Fig. 7 show where data were extracted from ENVI-met.

Three wind directions were chosen, from the South, from the West and from the South West, winds from the South and West are aligned with the canyon layout. Figures 8 and 9 show the canyon wind speeds for the respective wind directions.

In Fig. 8, the wind direction is at right angles to the canyon, and low canyon wind speeds occur on either side of the open space, the open space is aligned with the wind

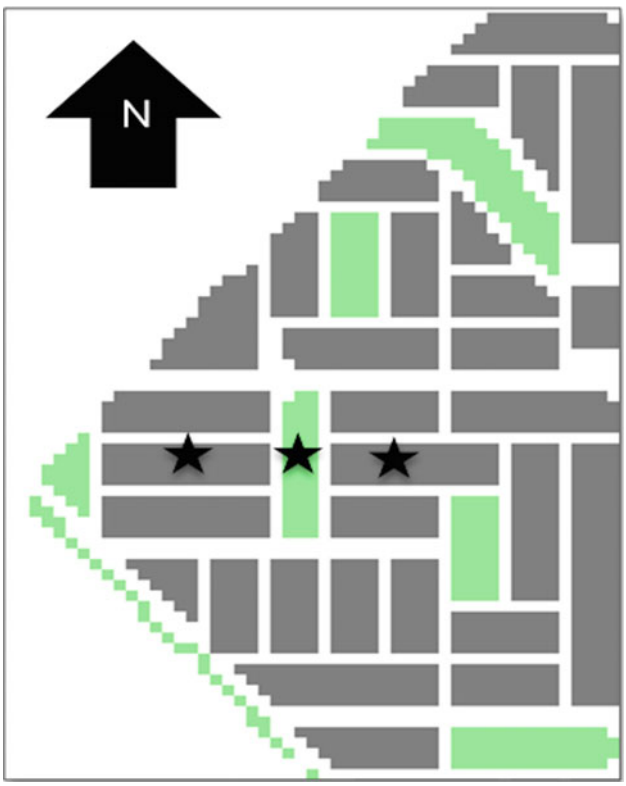

Fig. 7 Grid-iron morphology of an urban area of Erbil city

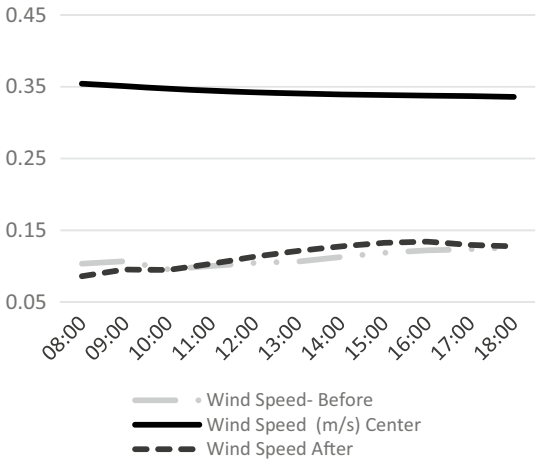

Fig. 8 Canyon wind speeds: wind direction from the South

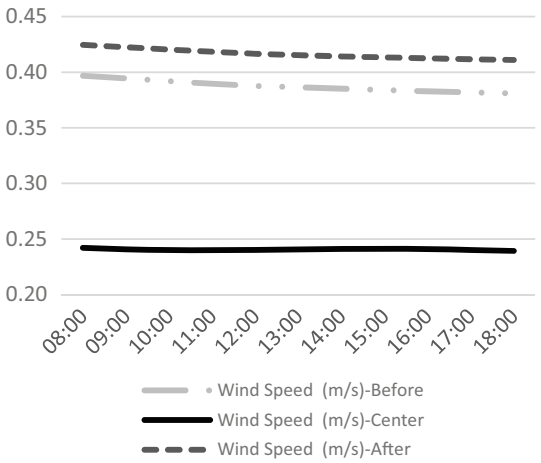

Fig. 9 Canyon wind speeds: wind direction from the West

direction and has a higher wind speed. In Fig. 9, the wind direction is parallel to the canyon, higher wind speeds occur on either side of the open space, whilst the open space has a lower wind speed.

The reduction in wind speed in the open space caused the greater flow area offered by the space. Figure 10 shows that when the wind direction is not aligned to the urban canyon grid, lower wind speeds are predicted along the orthogonal canyons but more even flow is recorded along the canyons. The simulation results compared quantitatively and qualitatively with measured data and previous studies (Aforz, Arch, & Islam, 2014; Chow, Pope, Martin, & Brazel, 2011; Kong et al., 2016; Van Esch, Looman, & de Bruin-Hordijk, 2012). However, the difference predicted here is small; a slight increase in wind speed is achieved when the street canyon is aligned with the wind direction and more even wind speeds are achieved if the wind direction is at 45° to the canyon alignments.

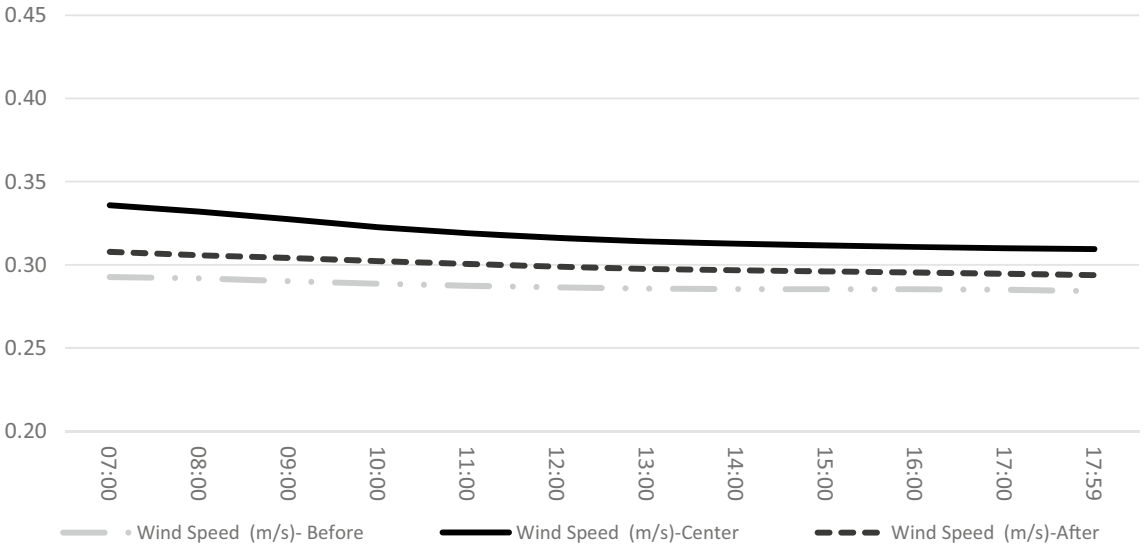

Fig. 10 Canyon wind speeds: wind direction from the South West

2. **Microclimate for a Proposed Design Scenario**.

Three interventions were made in urban fabric depicted in Fig. 6; the first was to add more open spaces, second to increase the east-west canyon widths with the extra open spaces and third inset open spaces within urban blocks with the extra green spaces; Fig. 11 shows these configurations, were image ***a*** shows the original urban grid, ***b*** the addition of two green spaces, ***c*** the widening of the east-west canyons and ***d*** open spaces inserted into the urban blocks.

Figure 12 shows the predicted wind speeds at the three locations given in Fig. 7 (before, middle and after open space), and Fig. 14 shows the air temperatures at these locations for the four urban configurations, a, b, c and d. In terms of wind speeds, only when open spaces are inserted in the urban blocks, there is a change in the predicted wind speeds (see Fig. 13). As for air temperature, there is very little variation between the four urban forms (see Fig. 14).

Fig. 11 Original and three proposed design scenarios (**a, b, c and d**)

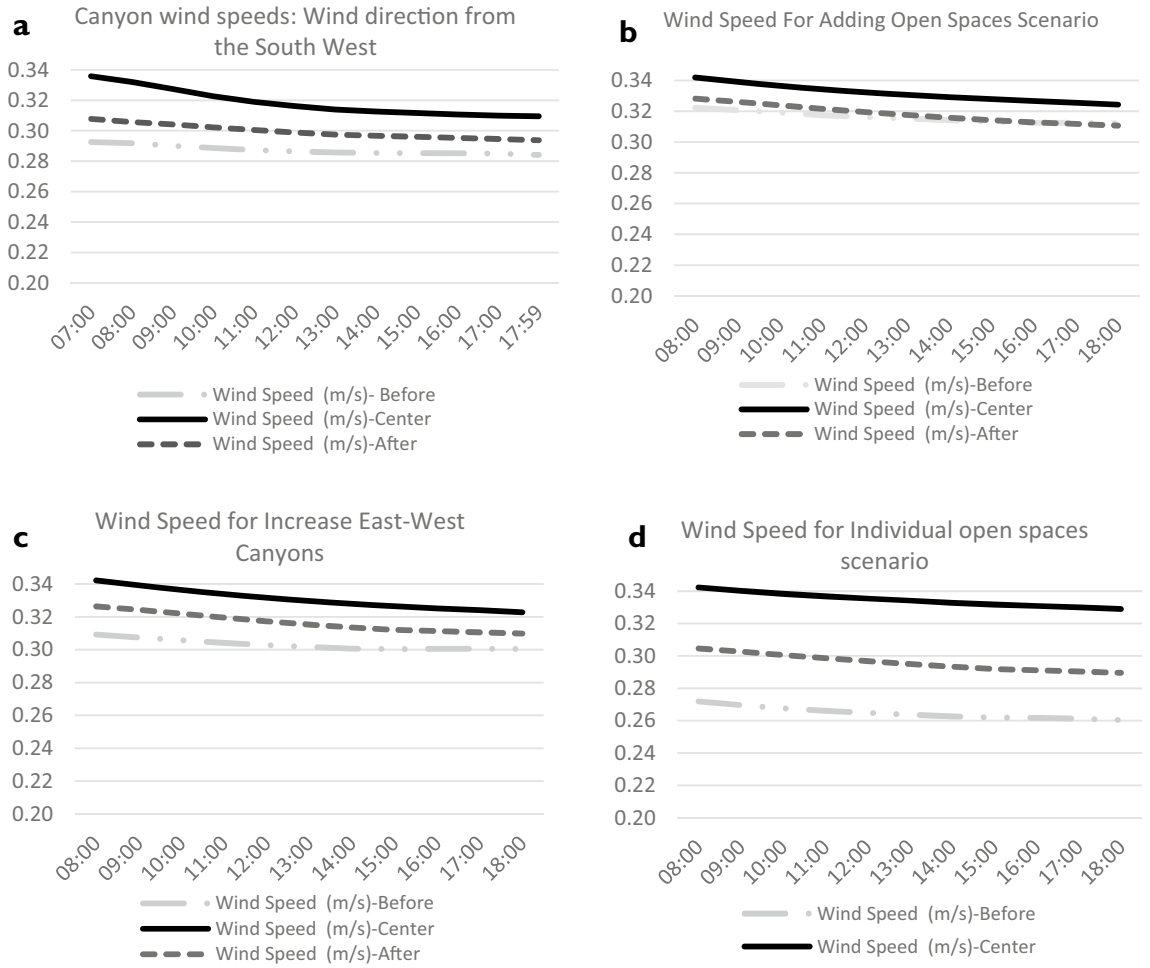

Fig. 12 Predicted wind speeds for all configurations, original urban grid, addition of two green spaces, widening of the East West canyons and open spaces inserted into the urban blocks

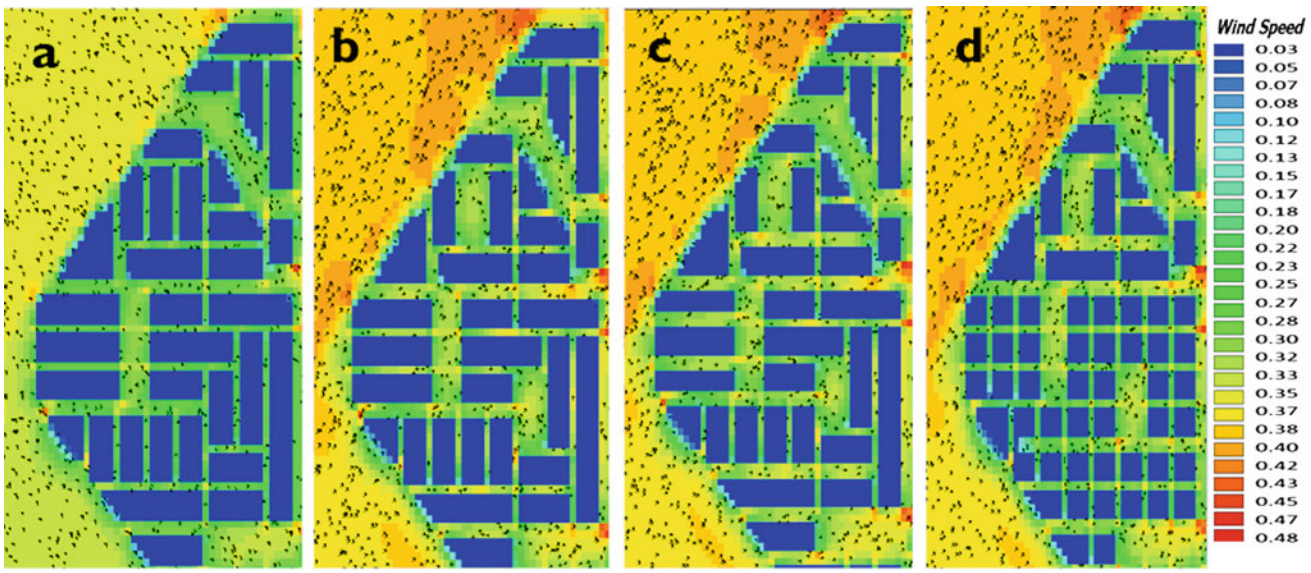

Fig. 13 Predicted wind speeds for all configurations for all interventions using ENVI-met

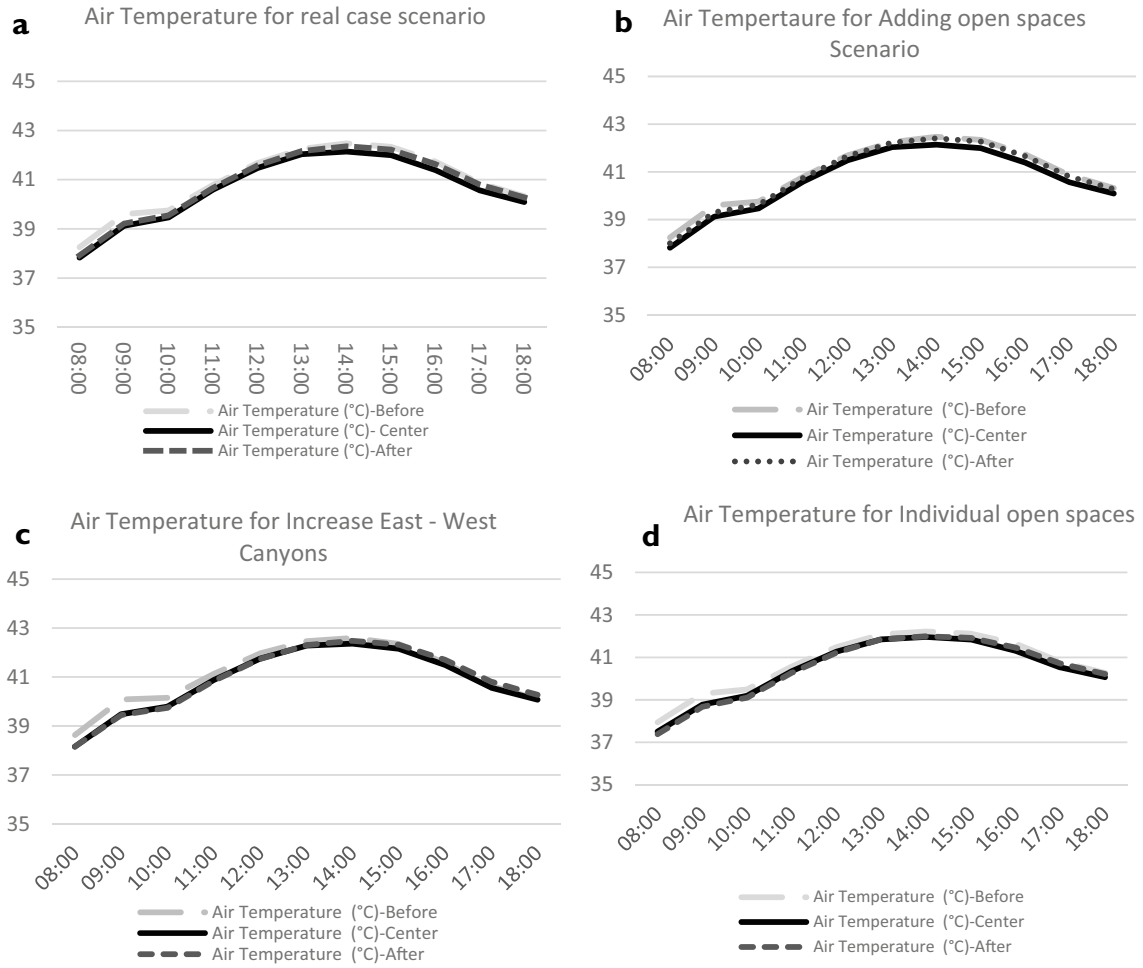

Fig. 14 Predicted air temperatures for all scenarios (**a, b, c and d**)

3. **Strategies to reduce air and mean radiant temperature**.

Erbil is located in a hot dry climate, and in such a climate, the most effective way of reducing air temperature would by via evaporative cooling either by having open water, with or without fountains or planting, a blue–green strategy (Husami, 2007). However, the availability of water is limited, low rainfall occurs in the region and this is coupled with a lack of water collection and distribution to the ever-expanding urban fabric of Erbil (Rasul, Balzter, & Smith, 2016). The only other cooling strategy available would be to provide shading, whilst this will not affect the air temperature, it will impact the mean radiant temperature and result in the urban environment receiving less solar energy (Elnabawi, Hamza, & Dudek, 2015). Shading could be provided by natural means, via the planting of trees but would require time to mature, to have an instant impact the researchers propose using a shading mesh suspended above the building fabric. Shading meshes are used in residential and industrial buildings, such as car parks, playgrounds and swimming pools (Abdel-Ghany & Al-Helal, 2011). To investigate the impact of a shading mesh, an open space in the urban area was used. The mesh had a transparency of 50%, this would allow sufficient daylight to pass through whilst intercepting a significant portion of the solar energy and the mesh was suspended 8 m above ground level, this would allow sufficient space of wind flow through the urban space. For the purposes of this study, the open space was divided into two with one half shaded and the other remained open, ENVI-met was used to calculate the mean radiant temperature and wind speed in the centre of the two halves (see Fig. 16).

Figure 15 shows the impact that the shading mesh has on the mean radiant temperature and Fig. 17 shows how the wind speed is affected.

Figure 15 shows that the shading mesh does reduce the mean radiant temperature during the day (see Fig. 18), and not surprising, has no impact once the sun has set (see Fig. 15). Figure 16 shows that with the mesh at 8 m above

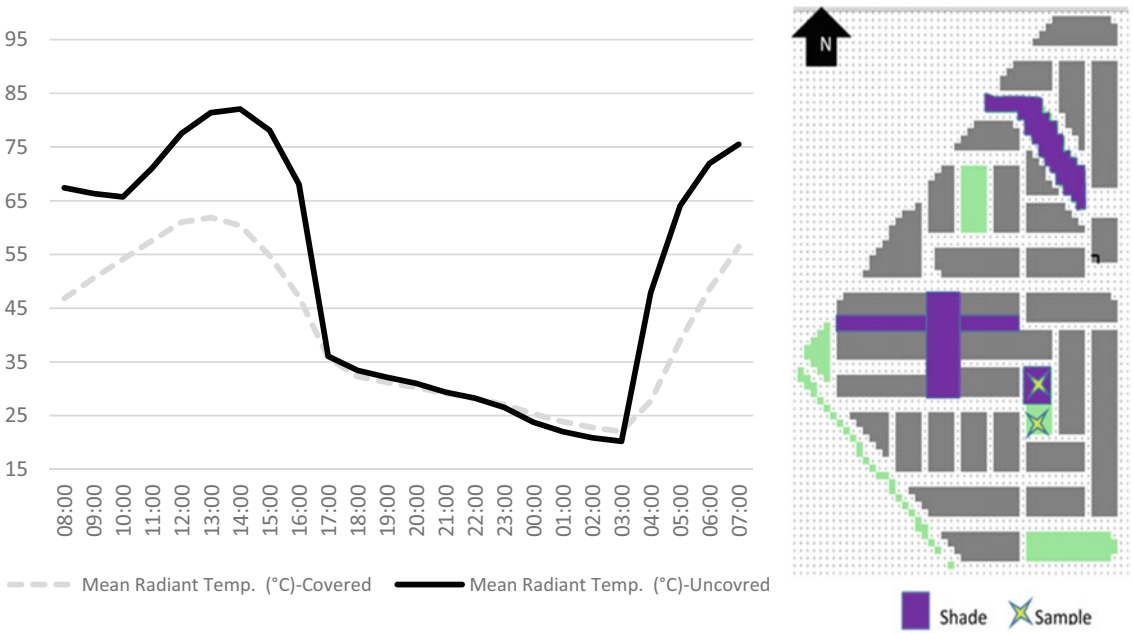

Fig. 15 Mean radiant temperature for the open space with and without shading mesh

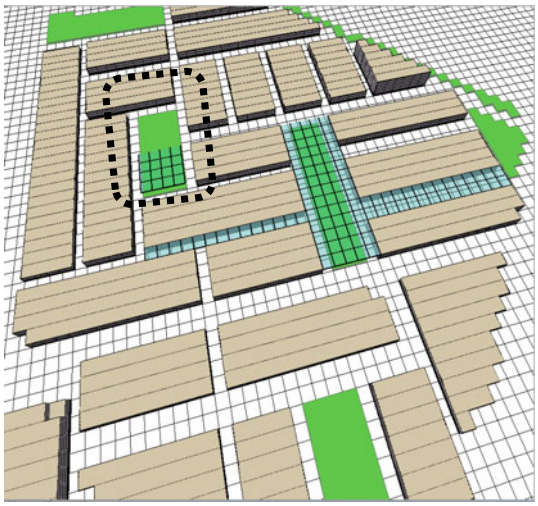

Fig. 16 Shading mesh model using ENVI-met

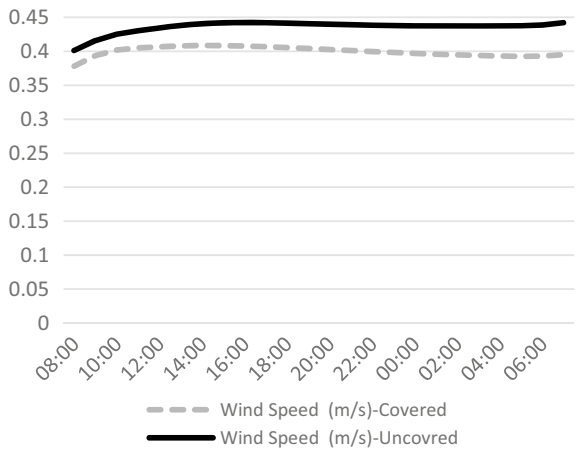

Fig. 17 Wind speed for open spaces with and without shading mesh

ground level, there is only a small reduction in wind speed and ENVI-met results are shown in Figs. 17 and 19.

5 Discussion and Conclusions

Urbanisation and new developments have a significant impact on the urban microclimate of the city. To understand the urban microclimate in hot dry climate, a systematic analysis of urban morphology impact on urban air temperature and wind speed were modelled.

This study aimed to reduce the total energy consumption by manipulating urban morphology to modify the urban microclimate. The local microclimate condition within an urban area is influenced by the form of buildings, open spaces and vegetation, which leads to a complex interaction between the urban elements. Moreover, it is difficult to analyse and predict an urban microclimate without on-site measurements, this methodology is well studied by researches (Chow & Brazel, 2012b; Tsoka, Tolika, Theodosiou, Tsikaloudaki, & Bikas, 2018). Therefore, the present study depends on a meteorological data from inside urban area and validation process for actual morphologies using ENVI-met, a numerical climate model. The local weather data station,

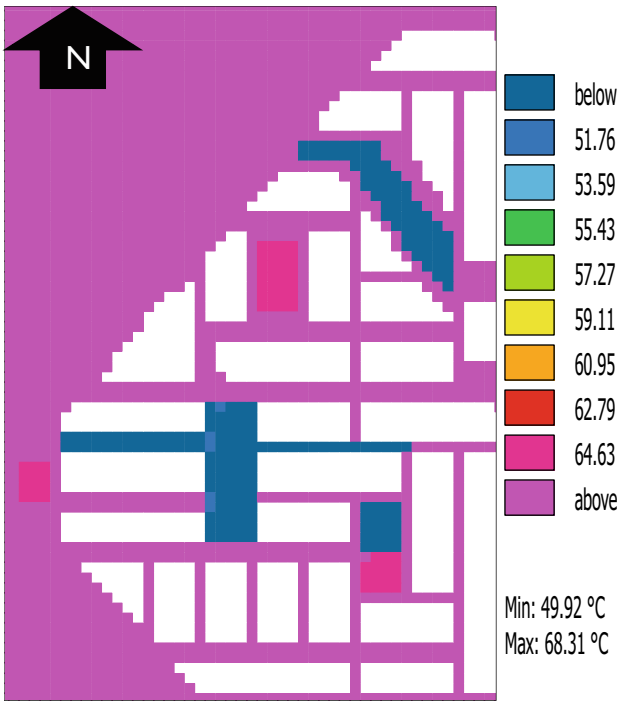

Fig. 18 Mean radiant temperature for covered and uncovered open spaces

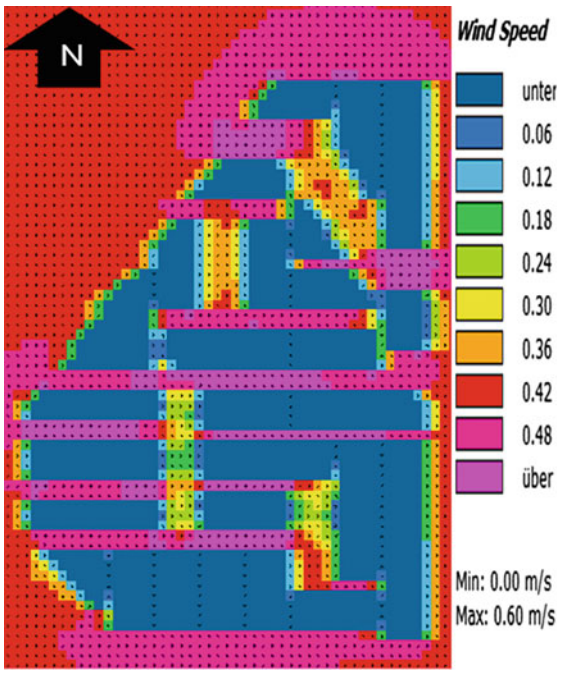

Fig. 19 Wind speed distribution at 12 noon

which is located near Erbil citadel, was employed to model the urban microclimate for the validation process is with high urban density (see Fig. 5).

The model was run for more than 24 h, but only the first 24 h was used due to the limitations of the software. The result was validated by two methods; first, by direct comparison between modelled and measured dry-bulb temperature; second, the study used the Willimott methodology, which depends on the Index of Agreement (d) between modelled and measured data. The validation process for Erbil microclimate simulations involved both overestimation and underestimation of modelled data compared to observed data and this corresponds with other studies (Chow & Brazel, 2012b; Middel, Häb, Brazel, Martin, & Guhathakurta, 2014; Yang, Zhao, Bruse, & Meng, 2013).

ENVI-met has successfully been used to model the urban climate of Erbil, the capital city of Kurdistan. Good agreement was achieved when modelling the day time temperatures', whilst night-time agreement was less so.

As a principle, reducing urban outdoor air temperature leads to a reduction of the energy consumption for cooling loads. This study is concerned with modifying the urban microclimate through manipulating the grid-iron morphology (see Fig. 11). Three urban interventions were proposed: adding more open spaces; increasing the east-west canyon widths with the extra open spaces; and, covering open spaces within the urban blocks with the shading mesh as an active strategy. To modify the urban microclimate of grid-iron morphology sufficiently, a few climatic options can be applied, for instance, maximise wind speed, minimise air temperature and reduce mean radiant temperature (solar gain). In addition, street geometry (H/W ratio) and canyon orientation to improve wind speed and outdoor thermal comfort are widely studied in a hot dry climate (Balslev, Potchter, & Matzarakis, 2015; Hedquist & Brazel, 2014; Shishegar, 2013; Van Esch et al., 2012).

ENVI-met was then used to model the day time climate of a new proposed urban area of Erbil (see Fig. 11), by orientating the grid-iron pattern so that the direction of the prevailing wind strikes the grid at an angle of 45° proved to yield the highest wind speeds in the urban grid as a whole. If the prevailing wind is parallel to either grid direction, the wind speed in the streets perpendicular to the prevailing wind direction is low as the wind is channelled down the streets parallel to the prevailing wind direction. These results correspond with other studies carried in hot dry climate regions (Andreou, 2014; Bourbia & Awbi, 2004; Johansson, 2006; Morad & Ismail, 2017; Taleb & Abu-Hijleh, 2013).

Because of the geographical position of Erbil and the urban surface roughness, the wind speeds in the urban areas are low, various interventions were modelled to increase wind speeds but had very little impact. The most promising was a significant increase in the open spaces around the urban blocks; however, it was not possible to increase wind

speeds just to reduce the impact the urban form has on the wind speed.

The current study found that local urban microclimate for modern grid-iron morphology mainly depends on solar radiation and secondary on wind speed in hot dry climate, especially in summer time. Without evaporative cooling, it is difficult to reduce air temperatures in the urban areas, but by providing shading, the mean radiant temperature could be reduced during daylight hours without impacting on wind speeds.

6 Recommendations

In hot dry climate cities, shading considers as one of the most important strategies to modify the outdoor microclimate. This study shows the importance of applying the shading mesh as a sustainable strategy to modify the urban microclimate in canyons and open spaces. On this basis, it can be used as design guidelines for architects and urban planners during the design or renovation of the existing urban areas. The recommendations can be outlined as below points:

1. Rotate the canyon direction by 45° from the prevailing wind directions.
2. Shading mesh with a 50% shading coefficient can improve the outdoor thermal comfort for open spaces (canyons and open spaces) and provide sufficient daylight.
3. The north–south direction is the most appropriate for housing blocks in terms of sufficient solar radiation and wind speed.
4. Shading mesh can be used to cover urban canyons and open spaces in the summertime. This reduces the impact of direct solar radiation and increases the thermal comfort level for pedestrians.

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Examining the Thermal Properties of Full-Scale Test Modules on the Overall Thermal Performance of Buildings

Aiman Albatayneh, Dariusz Alterman, Adrian Page, and Behdad Moghtaderi

Abstract

R-value, thermal mass and other thermal properties have a direct effect on the thermal performance of buildings. This paper examines the thermal properties of full-scale test modules to show that the main parameters influencing the thermal performance of buildings in order to improve overall thermal performance and reduce the level of heating and cooling are required to maintain the thermal contentment of occupants. The main evaluation tool used in Australia, AccuRate, was used to evaluate vetted thermal building properties to enhance energy efficiency scores by finding suitable thermal structures to upgrade the efficiency of houses and reduce energy consumption. For the real house test modules located in Newcastle (Australia), it was discovered that the insulation of the walls (higher R-value) increased overall thermal performance, whilst the floor insulation increased the thermal performance of the modules by reducing the thermal mass of the floor and trapping the summer heat inside the module, while the R-value is not the only thermal performance forecasting device. For internal brick walls with a darker colour, the thermal mass of the interior walls is significantly increased.

Keywords

R-value • Thermal mass • Energy saving • Buildings thermal performance

1 Introduction

The building sector makes a significant contribution to climate change. Buildings' energy consumption accounts for approximately 40% of the total energy (Roodman et al. 1995) used for the operation and construction of structures that emit a third of global greenhouse gas emissions (Macedo et al. 2008). Confining greenhouse gas (GHG) emissions and then decreasing them needed the design of energy-efficient buildings that inevitably lead to sustainable structures that save energy and emit less GHG.

The primary building components are walls; floor; roof; insulation; glazing; doors and windows. The walls are the main components of any building and are constructed from different materials such as (Reardon et al. 2010);

Cavity Brick (CB): Which have a high thermal mass but may need insulation as they are frequently hot in summer and cold in winter, especially in long heatwave conditions.
Insulated Cavity Brick (InsCB): If the cavity brick wall is insulated, the inner thermal mass (internal brick layer) is sheltered from external temperature fluctuations, and this becomes highly effectual in adjusting temperatures inside the structure because it has a higher thermal mass.
Brick Veneer (BV): Walls with a brick skin outside of a timber or stud frame are not ideal for the thermal mass location. In summer, the bricks heat up and then radiate heat into the building, while in winter, they remain cold and absorb heat from the building.
Insulated Brick Veneer (InsBV): The brick veneer wall is insulated by an insulation layer either between the inner and outer skins or between each stud. Insulation is critical in

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shielding the interior of the building from the external temperature environment, which is intensified by the contribution of the external brick skin.
Lightweight Timber Framed: A low mass construction consisting of an external stud frame with cement sheets and internal plasterboard. It relies on insulation to preserve thermal comfort. Effective for hot-humid climates, where the night temperatures are only slightly below the daytime ones, allowing the buildings to cool quickly.

Floor, created mainly from concrete slabs, is covered by carpet or timber for better insulation in cold climates. Suspended timber floors are an environmentally friendly alternative choice for sloping sites and flood-prone areas. These types of floors also provide extra space for pipes and ease of inspection under the building, especially for termites.

Roof and Ceiling: The roof is constructed from concrete, clay or metal materials, so insulation is critical to reduce heat loss in winter and heat gain in summer as 25–35% of losses/gain occur through the plasterboard ceiling.

Insulation: Insulation minimizes heat gain and heat loss through the roof, walls and floors. Insulation acts as a blockade to heat flow, measured by R-value (resistance to heat flow) in m^2K/W, where a higher R-value means better insulation. Different insulation types include (Reardon et al. 2010).

Bulk Insulation: Contains pockets of caught air within its structure to resist convection and conduction heat transfer. It should be dry and not be compressed. The main two types of bulk insulation are batt insulation and blanket insulation.
Reflective Foil Insulation: Contains a highly reflective surface and very low emissivity to resist radiant heat transfer. However, it needs an air gap of at least 20–25 mm and any dust accumulated on the foil surface will reduce its performance.

Glazing: Glazing provides a view, natural light, connection to the outdoors and adjustable ventilation. There is a wide variety of glass products available on the market and these are of two important types:

Double Glazed: Losses from glazing (single-glazed low insulation) are often greater than solar gains and daylight energy savings combined. In winter, a higher transmission of solar radiation is desirable, but with minimum losses by conduction.
Double glazing with the air between the glazings replaced with Argon will reduce convective heat losses and the overall heat losses further. Double-glazed windows allow radiation to penetrate to allow their usage in north-facing windows to allow winter sunshine and other windows that need proper sunshade (Reardon et al. 2010).

Low Emittance Glass: Allows visible transmission but Low Emittance Glass condenses solar heat gain in winter. Low-Emittance (Low-E) coatings are microscopically thin, practically invisible and are primarily used to reduce the U-value by reflecting long-wave radiation (heat) (Reardon et al. 2010). Low Emittance glass can minimize solar radiation entering the building, meaning it is unsuitable for north-facing windows but can be used for other windows.

Window Frame Materials: Aluminium is a good conductor and causes more rapid heat loss/gain, while the timber is a better insulator. Polymer window frames have better moisture and decay resistance and are a viable option.

Airtight Construction Design: Using weather strips for doors and window will reduce air leakage and save more energy, especially in colder zones.

Studying and analysing the current building material properties will theoretically advance the thermal functioning of a building by the selection of suitable building materials. The thermal functioning of buildings can be advanced by considering building thermal properties. The two main thermal properties of building supplies are the thermal mass and the thermal resistance (R-value). The primary difference is that R-value is the thermal resistance to the heat flow, where a higher R-value means more resistance to the heat flow (better insulator), while the thermal mass is the ability to absorb, store and release energy, which results in a delayed heat transfer and reduced temperature vacillation inside the structure. Using thermal mass in buildings depends on the climate, building components/types and configurations, which can significantly reduce annual energy demand.

The main purpose of thermal mass is to absorb and store the solar heat throughout the day and later release the thermal energy, which enhances thermal comfort and reduces energy costs by averaging the day/night (diurnal) extremes. The applicable use of thermal mass can make a big difference to thermal contentment and power bills and are favourable where there is more than 10 °C variance between the day and night outdoor temperatures (Fugate 2018).

Internal resources have a direct implication on the thermal mass of a structure. For example, covering a high mass material with a lightweight material diminishes its effectiveness as a thermal mass (e.g., carpet or wooden flooring over a concrete slab). On the other hand, high energy emittance to thermal mass is achieved by covering a high mass material with denser material, such as ceramic tiles over a concrete slab. Thermal mass can be achieved by using heavy soil or masonry materials in floors, walls and ceilings. To work most effectively, the mass in floors, walls and ceilings must be exposed, with no carpets or floor coverings or bare walls and bare ceilings.

Thermal mass is useful in environments with a high diurnal range, such as hot dry climates, by allowing night ventilation in which comfortable average night temperatures cool the interior mass of the building with night breezes or by closing it during the heat of the day to keep it warm. Thermal mass can also be used in winter in temperate climates to store winter heat during the daytime through north-facing windows. The north-facing windows should be double glazed to minimize heat losses, especially at night.

Reliance solely on thermal resistance (R-value) leads to substantial inaccuracies in energy demand, since the thermal inertia of building components has a profound effect on building heating and cooling loads (Zhu et al. 2009).

Although the R-value is a central thermal property of a building's material, the active thermal reaction of a wall (or building interior) to external thermal fluctuations cannot be effectively characterized due to its static nature. The influence of large daily temperature fluctuations and the influence of thermal mass on the performance of the wall are also unable to be captured. Consequently, the R-value by itself does not capture all the characteristics involved in heat exchange throughout the building (Alterman et al. 2012).

Different methods have been established to determine the overall heat transfer coefficients (U-values). One method is the steady-state measurement of thermal properties with a "hot box". The other method is the dynamic simulation of a "test cell", where the "test cell" is fabricated in a way that enables the calculation of the thermal properties of a building's components from simple temperature measurements, with no need for the measurement of input and output powers (Leftheriotis and Yianoulis 2000). But the test cell does not consider the high thermal mass that results in imprecise estimation of the thermal properties under real weather conditions. However, the accuracy of results must be compared by applying dynamic conditions (Leftheriotis and Yianoulis 2000).

Using 2 m × 2 m samples, a calibrated hot-box unit is used to dynamically and statically characterize different types of identical walls. A numerical analysis is carried out to obtain the thermal performance of a wall in static and dynamic structures. The accurate assessment of heat losses through the walls of buildings requires the inclusion of thermal inertia, thus, it is vital to have a wall's dynamic thermal characteristics (Sala et al. 2008).

Comprehensive research on the performance of the various wall systems used in Australian housing at the University of Newcastle has established that predicting the thermal performance in buildings cannot use R-values alone with no consideration to the thermal mass (Page et al. 2011).

Contrary to the common perception, the overall thermal performance in all weather conditions could not be defined only by the thermal resistance (R-value) of walls because that parameter is not the only prognosticator of a building's thermal performance (Page et al. 2011). For example, page 101 of the DCCEE 2011 manual states: "The higher the R-value the better the thermal performance", this is not highly accurate as in some cases the higher R-value results in better building insulation but not better thermal performance.

There are some other physical properties that manipulate the thermal functioning of structures such as emissivity, absorptivity, reflectivity and transmissivity. These mainly depend on the surface colour, material properties and thickness of the component.

Emissivity is the segment of energy emitted via the surface compared with that emitted by a black body and is an indicator of the effectiveness of a surface to emit thermal energy. A black body is a perfect emitter of thermal energy (emissivity = 1).

The total amount of radiation energy falling on a surface can be divided into three parts: absorbed, reflected and transmitted. Absorptivity is the fraction of radiation energy absorbed by a surface compared with the total energy radiation energy. Reflectivity is the fraction of reflecting radiation to the total energy. Transmissivity is the fraction of the transmitted energy to the total energy and is a measure of the capacity of a material to transmit radiation. The sum of absorptivity, reflectivity and transmissivity is equal to 1 ($\alpha + \rho + t = 1$).

The success of the R-value as a single predictor was postulated only in lightweight wall systems (low thermal mass) and not in high thermal mass walls. This is regardless of the fact that the wall's R-value is not the only correct definition of a structure's thermal performance, energy demand and thermal comfort (Page et al. 2011).

Insulation increased the surface wall temperature and reduced the interior wall temperature (Walker and Pavía 2015). Some materials were experimented, which can be integrated with conventional structural components to create different building sections with solar energy absorbing/dissipating ability. These combinations can be also assessed for wall insulations and ceiling panels depending on the climatic conditions (Wolff et al. 2015). The design of hollow clay bricks made of paper waste, for example, helps to improve thermal performance further (Sutcu et al. 2014). The incorporation of phase change materials (PCMs) in building fabrics is an effective way to reduce energy consumption and the risk of extreme heatwaves in non-air-conditioned buildings (Palyvos 2008).

Convection is strongly dependant on wind direction; the convective heat loss coefficient is at its highest for upwind walls, followed sequentially by roofs, crosswind walls and downwind walls (Orme 2001). In this sense, air infiltration composes a significant source of convection in the building sector where the air is exchanged between inside and outside through cracks and other unintentional openings. Besides reducing the thermal comfort of building occupants, this

convection places an extra energy demand. Thus, controlling the infiltration rate through airtight design and the implementation of effective construction retrofits is identified as one of the vital components for reducing energy consumption in both new and existing buildings. Various studies have been carried out to estimate the effect of infiltration on residential energy demand. Prior investigations have evaluated the energy wastage through ventilation processes, which found that greater than 30% of energy is consumed in residences (Aurlien 2013). A study conducted in a moderately cold climate indicates that heating demand increases about 10 kWh/m^2• each year due to air infiltration (Thomsen et al. 2010). In a temperate climate, the building air leakage is estimated to raise the heating loads from 5 to 20 kWh/m^2• per year (Ramakrishnan et al. 2017).

The use of a higher thermal mass material or painting of the inner walls with a darker colour improves the overall thermal performance of the building at the same level, but darker colours require more lighting energy and are not visually attractive. This paper examines the thermal properties of full-scale test modules to show that the main parameters influencing the thermal performance of buildings in order to improve overall thermal performance and reduce the level of heating and cooling are required to maintain the thermal contentment of occupants and also to examine the effect of R-value on the building thermal performance.

2 Methodology

The effect of different thermal properties will be applied on different house testing modules located in Newcastle, Australia.

2.1 Full-Scale Test Modules

Over the last decade, the Priority Research Center for Energy at the University of Newcastle, Australia, has undertaken an extensive research programme on the thermal performance of Australian housing. The research involves the construction of four full-scale housing modules and monitoring of the modules' thermal performance in a range of seasonal conditions. Summers are mild to warm and winters are cool. The need for heating in the winter climate is higher than the need for cooling in the summer. The main characteristics of a temperate climate are a high-temperature range (day/night) and four different seasons:

Autumn: ideal human comfort range
Winter: mild winters with low humidity that surpass the human comfort range
Spring: ideal human comfort range
Summer: Hot to very hot summers with moderate humidity exceed the comfort range of humans. The temperature at night in the summer months is lower than 20 °C. Allowing the cool night air to air out the structure in the summer to cool the air and disperse heat during the day.

The modules have been selected to indicate typical Australian building forms. All modules were built at Callaghan Campus, Newcastle University (longitude 151.71 and latitude −32.92 (south)). All modules had an exact design with a 6 m × 6 m square floor plan, refer to Fig. 15.1, and are 7 m apart, to decrease wind obstruction and minimize shading.

These construction materials are shared by all modules;

In the southern wall, a heavily lined door to jettison any loss of heat and facilitate access to the module. "In the northern wall of each module, a 6.38 mm laminated translucent glass window in a light coloured aluminium frame" (Albatayneh et al. 2016a, b; 2017a, b, c, d).

10-mm plasterboard ceiling with R3.5 glass wool batts between rafters. Concrete and clay tile roof with sarking. The roof in all full-scale test modules was heavily insulated to minimize/eliminate heat losses or gain.

Since all modules share the precise design and most building materials except for the wall systems, each module is named based on its wall system. Each module has different R values, refer to Table 15.1.

"Cavity Brick Module (CB)"

"The wall for the CB module consists of 2 × 110 mm brickwork skins with a cavity of 50 mm; the internal walls were covered by 10 mm", refer to Fig. 15.2 (Albatayneh et al. 2018c).

"Insulated Cavity Brick Module (InsCB)"

"Walls for InsCB; 2 × 110 mm brickwork skins with 50 mm cavity (R1 polystyrene insulation attached to the cavity side of the inner brick skin) and the inner wall covered by 10 mm internal rendering", refer to Fig. 15.3 (Albatayneh et al. 2015).

"Insulated Brick Veneer Module (InsBV)"

"InsBV walls consist of: External brickwork skin of 110 mm; internal timber frame with reflective foil of low glare and batts of R1.5 glass wool covered by 10 mm plasterboard", refer to Fig. 15.4 (Albatayneh et al. 2016b)

"Insulated Reverse Brick Veneer Module (InsRBV)"

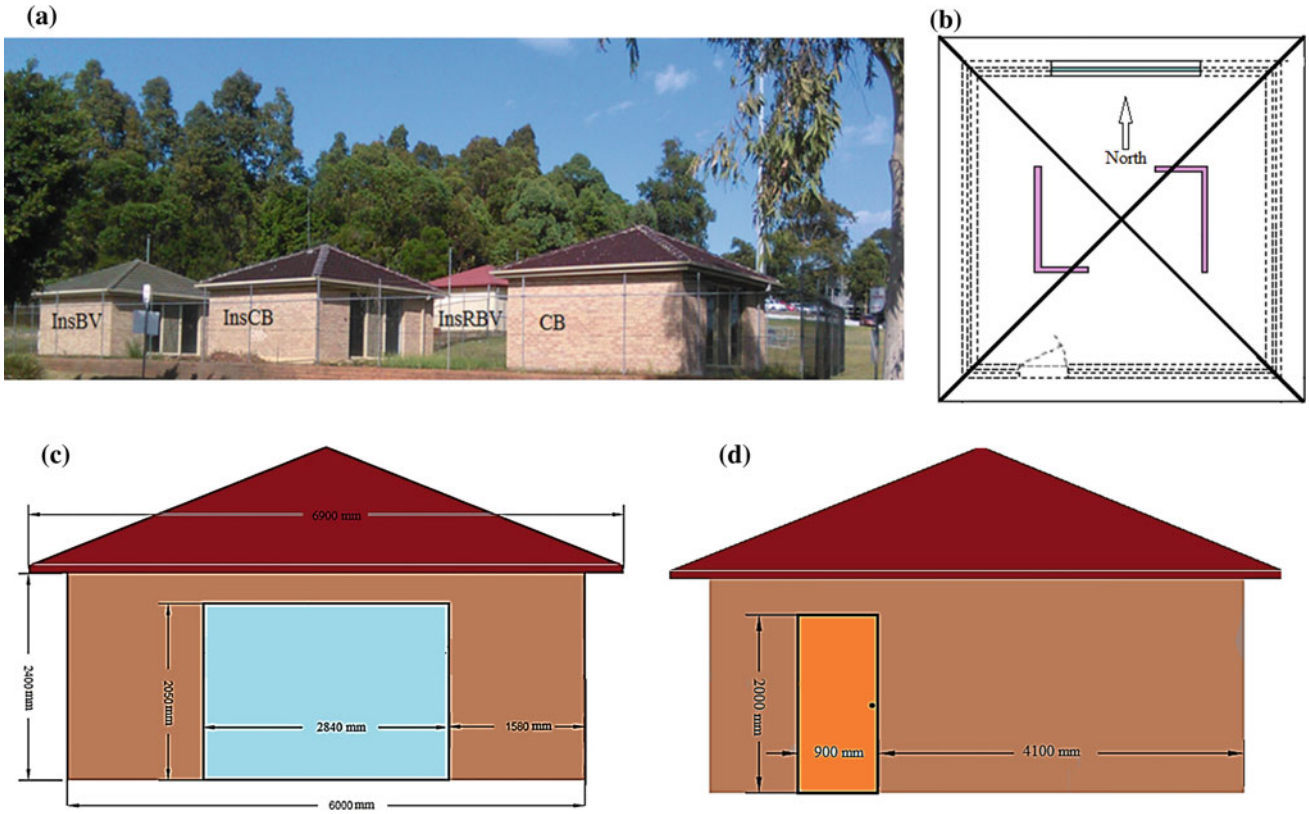

Fig. 15.1 **a** Real modules, **b** top plan, **c** north side, **d** south side (Albatayneh et al. 2018a, b, c, d, e, f, 2019a, b)

Table 15.1 R-values of module walling systems (Albatayneh et al. 2017b, 2018b)

Walling system	R-value (m^2K/W)
Cavity brick (CB)	0.44
Insulated cavity brick (InsCB)	1.30
Insulated brick veneer (InsBV)	1.58
Insulated lightweight (InsRBV)	1.57

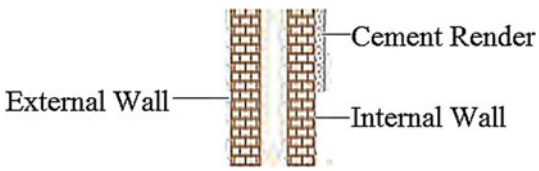

Fig. 15.2 Walling system for cavity brick module

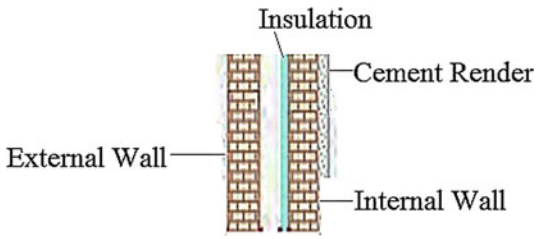

Fig. 15.3 Walling system for insulated cavity brick module

"External walls; 2–3 mm acrylic rendering on 7 mm fibro-cement sheets isolated by R1.5 glass wool batts. Internal walls; brick skin of 110 mm covered by internal rendering of 10 mm" refer to Fig. 15.5 (Albatayneh et al. 2017c).

"Sensors were installed in all modules to measure internal temperature and external weather conditions. The data were recorded every 5 min for the whole testing period".

All modules are in "free-floating" manner where the indoor air temperature is influenced by the external atmosphere. The internal air temperature was documented in the structure at a height of 1200 mm and all modules are airtight without ventilation during the period studied (Albatayneh et al. 2017d, 2018d).

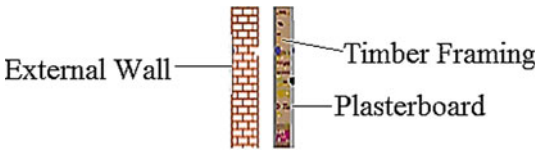

Fig. 15.4 Walling system for insulated brick veneer module

2.2 AccuRate

AccuRate Sustainability (V2.3.3.13 SP1) is evaluation software that calculates the yearly heating and cooling energy requirements for residential buildings in Australia. The building's value is rated from 0 to 10, where more stars mean better performance (Albatayneh et al. 2018e, f).

For each climate zone, energy requirements have been set to assign star ratings to allow a fair comparison of buildings across climates. The energy requirements for heating and cooling are calculated per hour over a period of 1 year. Table 15.2 shows an example for the area of Newcastle (zone 15), where the higher the stars the lower the energy requirements.

The R-value only does not capture all the modules involved in heat exchange where higher R-value does not necessitate better thermal performance. For example, the highest thermal improvement came from changing the walls from cavity brick to insulated cavity brick (not the highest R-value), which improved the AccuRate star rating (bands) by 2.2 even changing the walls from insulated brick veneer (R-value = 1.58 m^2K/W) to insulated reverse brick veneer (R-value = 1.57m^2K/W) enhanced the thermal performance by 1 for the AccuRate star rating, a clear indication that R-value is not the only determiner of thermal performance, refer to Table 15.3 (Albatayneh et al. 2019b; Al-Addous and Albatayneh 2019).

3 Results and Discussion

The best walling system, in terms of thermal performance in a temperate climate (Newcastle area), is insulated cavity brick (InsCB) in comparison to the rest of the walling systems. For this reason, the InsCB module will be used as a base module for the rest of the improvements.

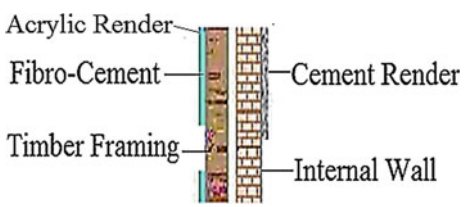

Fig. 15.5 Walling system for insulated reverse brick veneer module

For the floor, measurements of the ground temperature below the floor slab at a depth of 1 m for 1 year are shown in Fig. 15.6. This indicates that the ground temperature in summer (20–24 °C) was cooler than the building itself, resulting in heat transfer between the building and the ground (heat sink) and lower cooling energy being required. In winter, the ground temperature ranged between 16 and 20 °C, which was higher than the outside air temperature but was close to the building's internal air temperature, so the effect of the ground temperature on the cost of heating the building will be insignificant.

Floor insulation (R-value = 1.0 m^2K/W) for the InsCB module will trap the summer heat inside the modules resulting in higher cooling energy. This will decrease the AccuRate star rating from 8.7 to 8.4 (Table 15.4). Insulating the floor also prevents it from absorbing winter sun through the northern window that eliminates the benefits of the floor thermal mass.

Insulating the floor will cost more and will not drastically enhance the overall thermal performance of the module, so insulating the floors will not be considered in the next module improvements. Internal walls in the modules required less cooling energy than heating energy where the worst thermal performance for the buildings occurred in the winter months. Therefore, to increase the overall thermal performance in the buildings, the focus should be on the winter months. One of the methods to increase the thermal mass inside the building is to use high thermal mass materials that store winter sun/heat entering the modules throughout the day time and release it at night time, refer to Fig. 15.7.

Thermal mass is useful in climates with a large diurnal range, which causes the internal temperature to stay closer to the mean temperature, but if the mean temperature is too cold or hot, thermal mass will be insufficient.

Using a material with a high thermal mass will store more heat in winter and improve the overall building's thermal performance. For example, Rammed Earth 300 mm walls with a thermal delay of 10–12 h, elevated temperatures during the day reach internal surfaces and store heat in internal walls and release it after 10–12 h at night (Reardon et al. 2010).

For illustrative purposes only, higher thermal mass material will be applied to improve the thermal performance (e.g., Rammed Earth 300 mm). This will improve the overall ratings for the buildings from 8.7 to 8.9 stars and minimize the cooling energy. On the other hand, using lower thermal mass materials (such as plasterboard on stud walling) will reduce the overall thermal performance from 8.7 to 8.4 stars, refer to Table 15.5.

Internal colour and different physical properties influence the thermal functioning of the building. Using darker colours for internal surfaces will increase the absorptivity from 50%

Table 15.2 Annual energy requirements for each star rating (MJ/m^2 annum)

One stars	Two stars	Three stars	Four stars	Five stars	Six stars	Seven stars	Eight stars	Nine stars	Ten stars
349	232	159	114	86	67	50	34	19	6

Table 15.3 AccuRate ratings for the various walling systems

Walling system	R-value (m^{2}K/W)	AccuRate star rating
CB	0.44	6.5
InsBV	1.58	7.3
InsRBV	1.57	8.3
InsCB	1.30	8.7

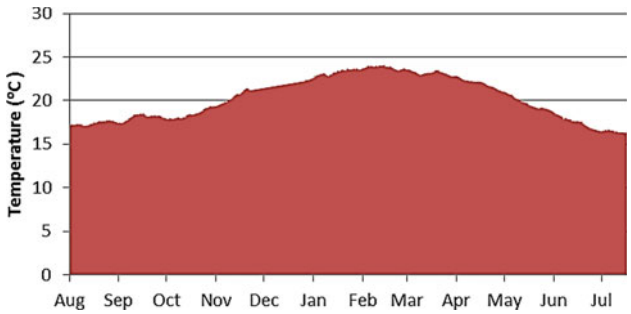

Fig. 15.6 Ground temperatures at 1 m under the modules

Table 15.4 The AccuRate ratings for insulated/uninsulated floors

Modifications	AccuRate star Rating
Uninsulated floor for InsCB (R-value = 0 m^{2}K/W)	8.7
Insulated floor for InsCB (R-value = 1.0 m^{2}K/W)	8.4

for a medium colour to 96% for the colour black, and painting the internal walls and the floor will increase the heat absorbed from the north-facing window and will reduce the heating required for colder months.

Changing the internal brick walls' colour to a darker colour will result in the same star rating in AccuRate as changing the internal wall material to 300 mm of Rammed Earth. Therefore, changing the internal colour to a darker colour will increase the AccuRate rating to 8.9, refer to Table 15.6, also painting is a lower cost option.

In this research, the darker colour option was used to study the consequences on the thermal performance, but in real life, darker colours have issues such as not being as visually pleasing to most people and required more lighting than lighter colours, which result in more energy consumption.

The capacity of a surface absorptivity to absorb the incident radiative heat is affected by thermal conductivity, density, heat capacity with an inverse relation with all of them, but thermal conductivity goes through expulsion relation with surface factors' time lag and also it depends on thermal diffusivity with an expulsion relation.

In this study, the use of a superior thermal mass material or painting the internal walls with a darker colour (higher absorption) will improve the overall thermal functioning of the structure at the same level, but darker colours require more lighting energy and are not accepted by a broad range of occupants.

4 Conclusion

The overall building thermal performance could not only be delineated by the R-value (thermal resistance) of the walls, since this variable is not the only factor of the thermal functioning of the structure (Reardon et al. 2010). In any design process where insulation is not always advantageous, thermal materials are important for the use of suitable structures because the modules discussed here improve the thermal functioning of the modules, but insulating the floor increases the overall thermal performance of the modules.

Applying higher thermal mass material to the inner walls will improve the overall thermal functioning of the structure. Painting the original internal walls with a darker colour (black) will give the same results as changing the wall material, but darker colours require more energy for lighting and are not as visually pleasing.

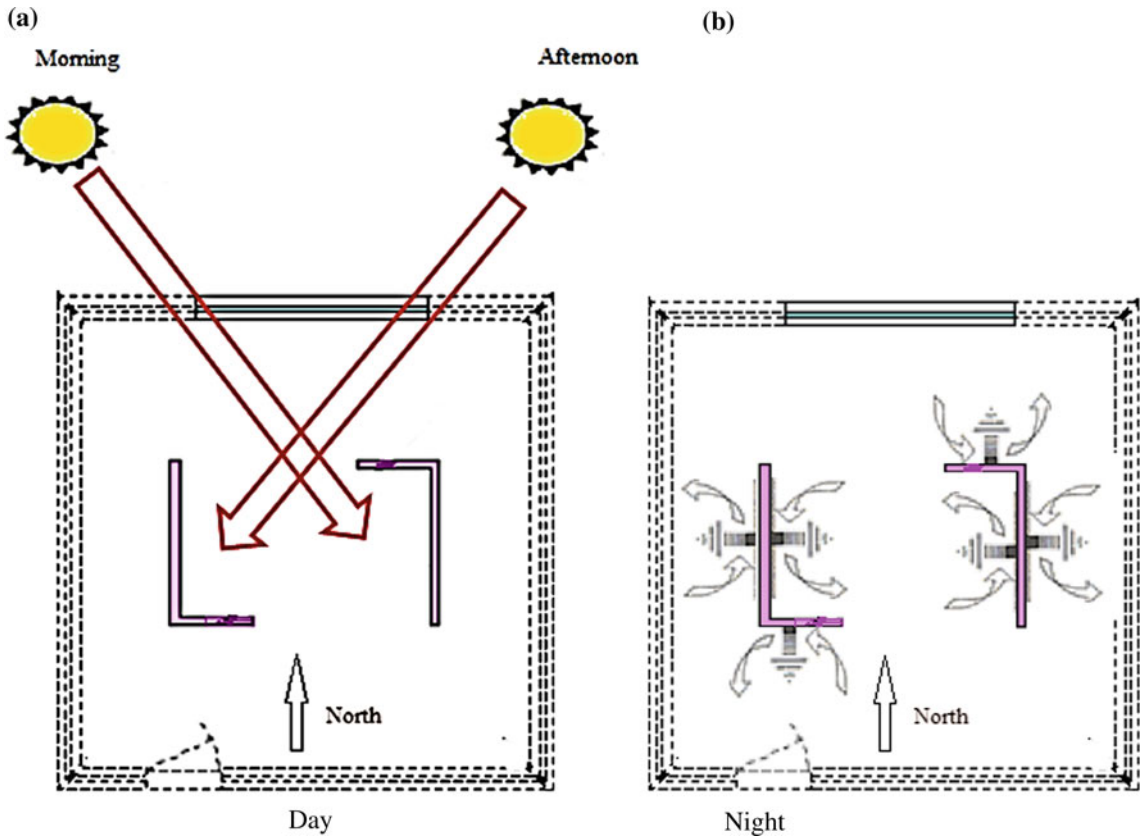

Fig. 15.7 Illustrative picture of the internal walls and the thermal mass inside the module during a day in winter

Table 15.5 AccuRate ratings for different internal wall materials

Modifications	AccuRate star rating
Brick internal wall for InsCB (original module)	8.7
Rammed Earth 300 mm internal wall for InsCB	8.9
Plasterboard on stud internal wall for InsCB	8.4

Table 15.6 AccuRate ratings for different internal colours

Modifications	AccuRate star rating
Brick internal wall for InsCB (absorptivity = 50%)	8.7
Internal wall for InsCB (absorptivity = 96%)	8.9

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Disaster-Resilient Building: Lesson Learned from a Building Performance Evaluation of Meuraxa Hospital in Aceh, Indonesia

Aulina Adamy

Abstract

The post-disaster evaluation of buildings during occupancy should indicate whether the reconstruction has succeeded in acting as a catalyst for recovery and whether further requirements for assistance are needed. Among other structures, hospitals are considered the most essential assets in disaster management. Located near the coastal area, Meuraxa Hospital is one of the public hospitals, which was destroyed by a tsunami and earthquake in 2004. The hospital was rebuilt in a new location within the city far away from the shoreline. The aim of this study is to evaluate the building performance of Meuraxa Hospital following its post-disaster reconstruction using three main variables: Built Environment and User Building, Building System Levels, and Disaster Risk Management (DRM). The sample units are individuals including hospital staff and visitors selected through probability sampling. In 2012, Meuraxa Hospital had 269 staff and 183 patients for a total of 452 people; the sample size was 107 respondents. This study used a modified AEDET toolkit proven to be valid and reliable in a previous study by the same author. The modification goal is to meet the local needs by adding a building system representing local regulations and DRM for the post-disaster context. The scales of performances for the questionnaires are adopted in full from the AEDET system using a descriptive statistic with the average score for each variable. Additionally, interviews with key persons and field observations were integrated for a comprehensive analysis. The total score for Built Environment and Building User is 3.61 ("accepted"), for Building System, it is 3.69 ("accepted"), and for DRM, it is 3.53 ("accepted"). Meuraxa Hospital is a collaboration project with multiple donors including Indonesia, Austria, and Hungary. Each donor built a separate building in one compound. Two major criticisms resulted: First, the donors refused to facilitate hospital management space, which does not make sense as such space is necessary to operate a hospital. The second involved the failure of the semi-stilt design applied, which was difficult to maintain and became a burden because waste and rainwater were collected under it. In general, the performance of the hospital building is acceptable. The lesson learned was that each donor has different quality control standards during construction, and this results in a variety of building qualities in one compound project. Hospital management is one of the main activities in a hospital that should be accommodated, and designing public buildings with semi-stilts is not recommended as maintenance is difficult. In the context of tsunami and earthquake risks, designing and building use strong construction, a flexible structure, and multistory buildings are more significant.

Keywords

Disaster • Resilient • Building performance evaluation (BPE) • Hospital, Indonesia

1 Introduction

Post-disaster projects following the earthquake and tsunami that struck Aceh Province in Indonesia in 2004 are still considered among the largest reconstruction programs in the developing world, with about 2,200 projects across all sectors (Athukorala 2012). Figure 1 shows the source of the earthquake and the impact of the tsunami waves; Aceh is the closest area to the epicenter. However, after reconstruction, the Aceh government faced numerous challenges including incomplete handovers of the process in reconstruction project cycles (The Aceh Institute 2010); budgeting operation

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Fig. 1 Earthquake and Tsunami on 26 December 2004 located near Aceh province (Banda Aceh is the capital city). *Source* Verghese (2016)

and maintenance assets that were not fully allocated (Transition Sector 2009); and some assets that were not functionalized due to inappropriate building design or poor-quality construction (The Aceh Institute 2010); in addition, there was a lack of human capacity to maintain and operate the assets (Government of Aceh 2011).

Among all types of public buildings and facilities, according to the World Bank (Jha et al. 2010) and the Federal Emergency Management Agency (FEMA 2007), hospitals are considered one of the most essential assets for disaster management. In contrast, efforts to identify the most-prevalent design quality that would facilitate patients' quality of care as well as the quality of work-life for healthcare providers have been less recognized (Henriksen et al. 2008). In Indonesia, few studies have focused on the physical performance of hospital buildings and the fact that the quality of hospital services remains relatively poor (Alfansi and Atmaja 2009).

As one of the poorer provinces in Indonesia (Evans 2010) and as a result of long-term sociopolitical conflict (Reid 2006), healthcare facilities in Aceh Province were far from adequate. Table 1 shows the number of healthcare infrastructures and facilities destroyed by the 2004 disaster in Aceh and repaired afterward.

The number of healthcare facilities being repaired far exceeds the number of hospitals and healthcare services damaged by the earthquake and tsunami. It should be noted that, even before the natural disasters, healthcare facilities were in a state of neglect, and the need for such facilities has increased substantially in the aftermath (BRR NAD-Nias 2009).

Thus far, quality issues remain in disaster-relief projects and the problems continue during the occupancy phase, when most building users are left to face the problems alone. In order to understand these challenges and identify solutions for disaster-related building reconstruction problems, it is first necessary to examine the performance of post-disaster reconstruction buildings (Deprez and Labattut 2009). If a building is not productive, then it cannot be sustainable; this highlights the need for feedback on building performance to ensure that a building provides maximum benefits throughout its lifecycle (Sharpe 2019; Preiser et al. 2017). The aim of this study is to evaluate the performance of Meuraxa Public Hospital, located in Banda Aceh, the capital and largest city in Aceh Province, as a sample case of post-disaster reconstruction projects in Indonesia following the 2004 tsunami.

1.1 A Building Performance Evaluation (BPE) for Post-disaster Reconstruction Projects

Rehabilitation and reconstruction are the two most expensive activities in the disaster management process (Hayat and Amaratunga 2014). Reconstruction takes longer compared with other phases (Joakim 2008a, b) and, according to Hidayat and Egbu (2010), plays a critical key role in disaster management because the quality of constructed houses or buildings and infrastructure during the reconstruction phase will influence their vulnerability when a future disaster strikes (Lindell 2013). Thus, it is important to explore building evaluations in the reconstruction phase in order to influence vulnerability and sustainability for future disaster resilience (Abulnour 2014).

A BPE entails the process of systematically comparing the actual performance of buildings, places, and systems to explicitly documented criteria for their expected performance (Preiser and Vischer 2005; Preiser et al. 2017). Disaster risk management (DRM) as a discipline can be

Table 1 The effects of the earthquake and Tsunami on health facilities in Aceh

Health facilities	Destroyed	Damage	Repair/revitalized[a]
Hospitals	32	9	28
Local Health Clinics	259	64	211
Assisting Local Health Clinics	830	174	276
POLINDES (village polyclinic)	2283	700	395
Village Polyclinics	21	5	
Office of Health Service	4	1	Data not available
Medical Laboratories	3	3	Data not available
Office of Harbour Health	3	1	Data not available

Source Wibisana and Bitai (2009)
[a]BRR NAD-Nias (2009)

conceived of as a program of interventions whose focus extend from predisaster through the disaster to the post-disaster period and is arguably included in a BPE since it can be applied in every stage of the building cycle that also reflects the disaster timeline. In this study, the BPE for post-disaster projects is delineated as shown in Fig. 2.

The primary stages in the evaluation process of every building project are illustrated in Fig. 3. The evaluation process involves an assessment against a value measure. According to Baird (2009), for this to occur, four elements must be presented: a set of standards that will be used to measure the actual performance; a unit of measurement to quantify and qualify every performance; the actual performance as the outcome of the data collection; and a judgment as an analysis between the actual performance and the standard (Baird et al. 1996).

1.2 BPE Tools: Achieving Excellence Design Evaluation Toolkit (AEDET)

BPE tools vary in nature, size, and level of interactivity and, thereby, are suitable for different building conditions and organizations (Brooks and Viccars 2006). Leaman (2003) identified over 150 techniques available worldwide, and Brambilla and Capolongo (2019) reviewed several versions of evaluation tools with POE methodologies designed specifically for hospital environments. The leading industry tools for performance measurement include Design Quality Indicators, the Design Excellence Evaluation Process, Housing Quality Indicators, the Building Research Establishment Environmental Assessment Method (BREAM), the Leadership in Energy and Environmental Design (LEED), the Building Quality Assessment (BQA), and AEDET.

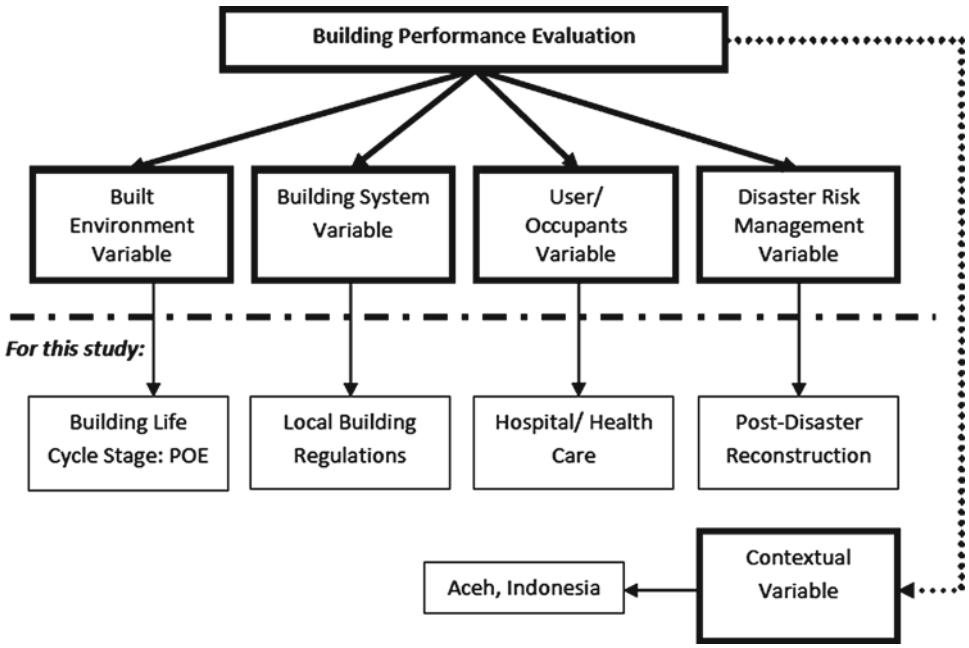


Fig. 2 Post-disaster reconstruction BPE conceptual framework in this study. *Source* Adamy (2014)

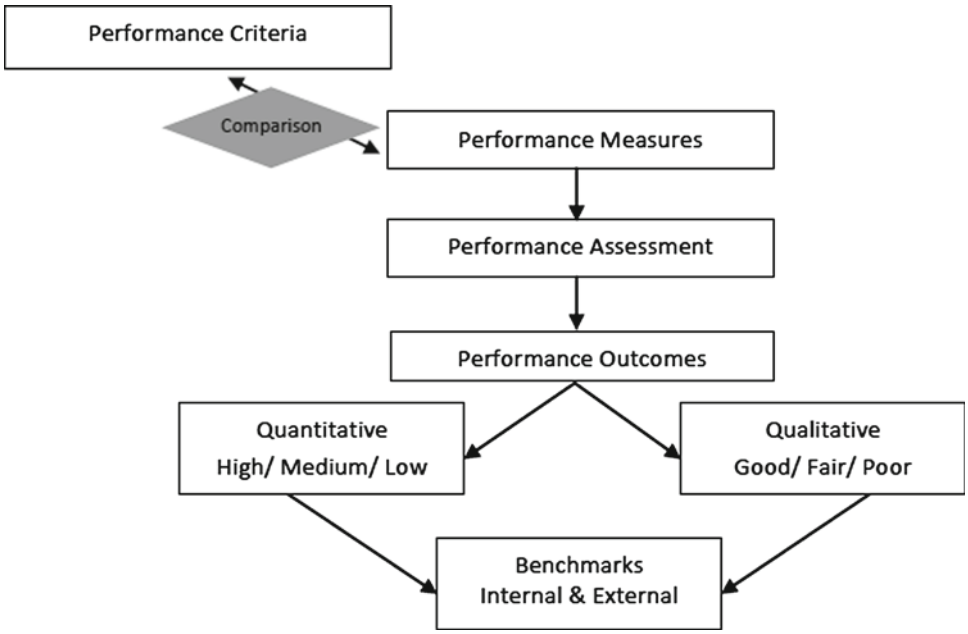


Fig. 3 The performance evaluation concept flowchart. *Source* modification from Douglas (1996)

Leading industry tools are commercially available measures that have been validated to the extent that they are used in practice and have a proven track record (McDougall et al. 2002).

This study adopted the AEDET for evaluating hospital buildings for several reasons. First, AEDET is the only tool that focuses on hospitals (Talib et al. 2013). BREAM and LEED are applicable to all types of buildings, but using a toolkit designed for a specific building type results in greater confidence (Harputlugil et al. 2011). Second, AEDET is also a toolkit proven for general adaptation, unlike the BQA (Harputlugil et al. 2011). Finally, as noted by Talib et al. (2013), among the numerous building performance assessment types, the AEDET is the single comprehensive approach developed to explore the efficiency of healthcare building performance in regard to quality, impact, and function considered crucial for facility management effectiveness.

The AEDET, which originated in the UK, is part of a benchmarking tool used to assess trust in measuring and managing the design quality of healthcare facilities (AEDET 2008). It delivers a profile that indicates the strengths and weaknesses of a design or an existing building and can also be used for initial proposals through post-project evaluations (NHS 1993).

However, the AEDET should not be applied automatically to Indonesia's healthcare services because of that country's different climatic conditions and adaptive reuse of buildings as healthcare facilities. The toolkit has proven to be a worthwhile evaluation for hospital buildings internationally (Harputlugil et al. 2011; Henderson et al. 2010) and has been tested beyond the UK in developing countries, with the caveat that local adaptations are necessary (Taylor et al. 2014). Other studies have also modified the AEDET to meet local conditions, such as several post-occupancy evaluation studies on healthcare conducted in Malaysia (Abbasa and Ghazalib 2011, 2010), Australia (Talib et al. 2013), and Africa (Peta 2007). Therefore, for it to be effective, the AEDET must be modified to be relevant to local building regulations in Indonesia and a post-disaster context. Originally, the AEDET evolved from three main sections—impact, build quality, and functionality; these were divided into 10 assessment criteria (Fig. 4). Additionally, two more variables were included: Building System, representing local regulations, and DRM for a post-disaster context. An early output was a BPE framework for a post-disaster

Fig. 4 Three main sections in the AEDET. *Source* (NHS 1993)

reconstruction hospital building in Indonesia with 3 variables, 26 criteria, and 72 items.

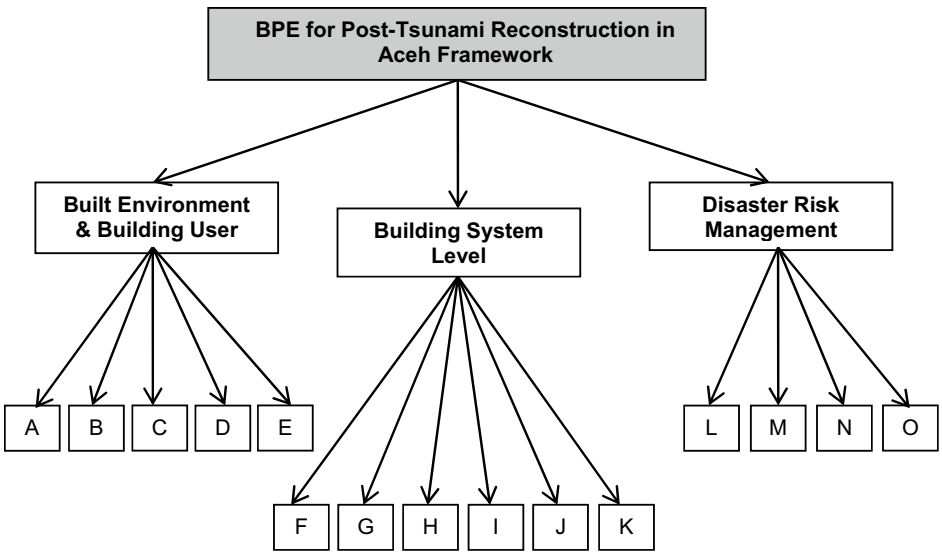
Two steps were taken to measure the validity and reliability of this new proposed framework. The first was to use the Relative Importance Index (RII) test to score the 15 most important criteria. Here, five criteria from the AEDET were removed due to low scores: Character Design & Innovation, Urban Social Integration, Space, Construction, and Utilization (Adamy 2014). Second, the new conceptual framework was categorized as a hierarchical construct model (HCM) with a reflective–reflective relationship with three-order levels and was analyzed using the software SmartPLS version 2.0. SmartPLS path modeling allows for the conceptualization of a hierarchical model through the repeated use of manifest variables (Guinot et al. 2001; Tenenhaus et al. 2005). This two-step process is part of the previous study (see Adamy and Abu Bakar (2018) for detail).

In regard to a final result, the new model is valid and reliable after deleting 14 items that were considered satisfactory with the evidence of adequate reliability, convergent validity, and discriminant validity (Adamy and Abu Bakar 2018). This new modification comprising 3 variables, 15 criteria, and 58 items is fully adopted in this study, as illustrated in Fig. 5. It is considered a modified evaluation toolkit recommended for use only in Indonesia, but it has the potential to be applied to other countries that align with the criteria and indicators.

1.3 Meuraxa Regional Public Hospital

Before the tsunami struck the city of Banda Aceh, Meuraxa Hospital was located in the Meuraxa district near the coastline. As this area suffered severe damage and devastation, the hospital was also destroyed. There were eight hospitals in Banda Aceh at that time, but Meuraxa Hospital was the only one damaged so extensively that it had to be categorized as a structural collapse (Pusponegoro and Sujudi 2016). It is also the only one to have been relocated and completely rebuilt in the city. The new location is closer to the city's center, about 7.2 km from its original location, and is now part of Tsunami Memorial Park (Fig. 6).

No documents related to the hospital's building evaluation before the disaster are available. As noted earlier, there are very few studies that focus on the physical performance of hospital buildings in Indonesia (Alfansi and Atmaja 2008, 2009); moreover, in Aceh, that is still a matter of conflict (Reid 2006; Soesastro and Ace 2005). According to the hospital's official website, Meuraxa Hospital was first built by the community in the Meuraxa district, and in 1997, it was handed over to the government (Humas and IT RSUD Meuraxa 2020). Figure 7 shows the original hospital facade from the main road. The hospital comprised two buildings, each with two stories, in a 15,800-m^2 compound. The first building's size was 1,100 m^2, and the second was 2,000 m^2. The original location was about 350 m from the edge of the



Notes: A= Building form & material, B= Building quality performance, C= Engineering, D= Access, E= Staff & patient environment, F= Safety, G= Health, H= Comfort, I= Easiness, J= Control & environment impact, K= Architecture, L= Sustainability, M= Disaster resilience, N= Functionality, and O= Local institution capacity.

Fig. 5 Aspects and variables under BPE for post-disaster reconstruction Buildings. *Source* Adamy and Abu Bakar (2018)

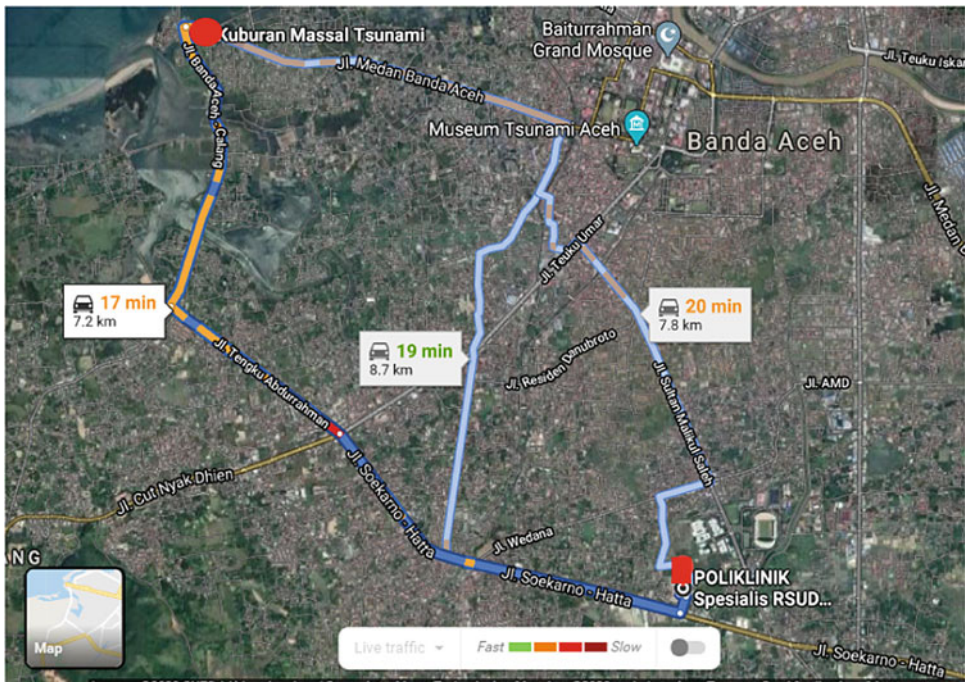


Fig. 6 The Google map showing the distance from the original location of the Meuraxa Regional Public Hospital closer to the shore before it is removed to the new location in the middle of the city. *Notes* Red circle is the original location of the Mueraxa Regional Public Hospital, red square is the new location in the city, and blue rectangle is the closest road connection between the two locations

Fig. 7 Meuraxa regional public hospital before the tsunami *Source* Humas and IT RSUD Meuraxa (2020)

sea, which is considered inappropriate based on Indonesian National Regulations.

In 2012 (during the evaluation conducted), Meuraxa Hospital was categorized as a C-type public hospital with a total bed capacity of 184. Of all hospital types, the C type represents the majority of Aceh's healthcare facilities during the post-tsunami reconstruction period (BRR NAD-Nias 2009). Figure 8 shows the facade of the rebuilt hospital in its new location.

Fig. 8 The new Meuraxa regional public hospital after the tsunami *Source* Adamy (2014)

2 Methodology

For this study, evaluation research was conducted as an element of applied research (Johnson and Christensen 2000); most studies in the built environment are categorized as applied science (du Toit and Mouton, 2013). Based on the time frame, the design was a cross-sectional study to capture a picture of aspects of social life, including population characteristics, individual attitudes, values, beliefs, and behaviors (Blaikie 2001).

As part of Phase I, the AEDET was modified and proven to be valid and reliable in the previous study by Adamy and Abu Bakar (2018). Following up, an evaluation study conducted in Phase II uses the modified toolkit as the questionnaire. The final calculation represents building performance scores. Interviews with key persons (hospital director, deputy director, facility manager, and environment manager) and field observations were included. In a future study (Phase III), there is a need to repeat the evaluation with the same toolkit at other hospital buildings in order to gain a better understanding of the larger perspective of disaster resilience in the context of hospital-building performance in Indonesia. This three-phase scheme is illustrated in Fig. 9; the present article covers only the study in Phase II.

Three kinds of users are identified: occupants, visitors, and owners (Kernohan et al. 1992). For the purposes of the present study, the population is divided into two groups: hospital staff and hospital visitors. The population of Meuraxa Hospital is 269 staff, with an average of 66,032 patients per year (2012), approximately 5,503 patients per month or 183 patients per day. The total population is 452 people comprising 269 staff and 183 patients. Based on Krejcie and Morgan (1970), the sample size in this hospital is 205 respondents; a total of 107 (48.6%) people participated in this survey.

The type of data in this section is classified as ordinal data, using a 5-point Likert-type scale on an Excel spreadsheet, originally from the AEDET (2008):

- Scale 1: scores from 0 to 1.4 = total rebuild (red color);
- Scale 2: scores from 1.5 to 2.4 = unacceptable in its present condition (red color);
- Scale 3: scores from 2.5 to 3.4 = below the accepted standard (orange color);
- Scale 4: scores from 3.5 to 4.4 = acceptable (green color); and
- Scale 5: scores from 4.5 to 5 = high degree of satisfaction (green color).

3 The BPE Results for Meuraxa Public Hospital

The hospital-building performance was evaluated for three aspects: Built Environment and Building User, Building System, and DRM. A total of 15 criteria are included under these three. Based on the AEDET, each aspect score depends on the mean ($\bar{x}$) of all criteria that fall within each aspect. The performance score for each aspect is discussed next.

3.1 Built Environment and Building User Performance

There are five criteria under Built Environment and Building User: Access, Engineering, Building Quality, Staff and Patient Environment, and Building Form and Material (Table 2). Detailed scores for each item within each criterion are available in Annex A.

Table 2 displays the total score for Built Environment and Building User for Meuraxa Hospital in green or accepted with a mean of 3.61. Although considered acceptable, the Engineering factor is considered below the accepted standard. Several important findings from the interviews and observation related to this aspect are as follows:

- Engineering: The low-performance score aligns with the results of the interview with the facility and infrastructure manager. This respondent admitted that the installation maintenance of the hospital division is unable to meet the building engineering service at the maximum requirement because it is supported by only four staff members, three of whom are lacking in regard to qualifications and commitment and have educations equal to or below a diploma. The manager also criticized the lack of financial support for the engineering system in the hospital.
- Access: There are adequate parking spaces close enough to be accessed by public transportation and the main road

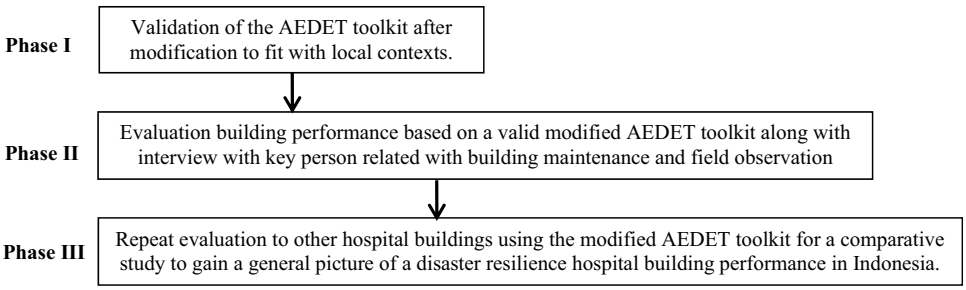


Fig. 9 The study methodology scheme. *Note* Phase I is finished and published in Scopus Indexed journal

Table 2 Built environment and building user performance score at Meuraxa public hospital

Criteria	0	1	2	3	4	5	$\bar{x}$ Score	Color	Definition
Access							3.78	Green	Accepted
Engineering							3.39	Orange	Below accepted standard
Building quality							3.68	Green	Accepted
Staff and patient environment							3.65	Green	Accepted
Building form and material							3.55	Green	Accepted
Total $\bar{x}$							3.61	Green	Accepted

but no special lane for ambulances. The access is adequate for pedestrians, but there is no access for disabled and elderly visitors. There are two gates located in front of the hospital compound; one is usually closed, while the other facilitates access for staff, patients, ambulances, and service vehicles, e.g., waste disposal. According to the AEDET (2008), it is preferable to segregate access appropriately.

- Building quality: This criterion does not perform well, due especially to inappropriate building weather and age. The hospital compound comprises several buildings constructed by different donors. The low quality of the BRR's products is obvious compared with the buildings constructed by the Austrian and Hungarian governments. Most of the elements built by the BRR, including in-patient buildings and corridors, already show damage (see Fig. 10).
- Building form and material: The building form is human scale; some of the blocks have appropriate orientation; and the entrance is obvious. The main buildings have adequate exposure to natural light as most rooms have windows.
- Staff and patient environment: There are few pleasant views inside and outside the buildings as the only garden available is in the pediatric building. The rest of the views are dominated by stagnant water and debris under the buildings' semi-stilt structure (see Fig. 11). Based on the interviews with the managers, the donors used semi-stilts for buildings to avoid flooding but did not provide any solutions for managing debris under the narrow stilts.

Fig. 10 Damaged corridors. *Picture Source* Adamy (2014)

Fig. 11 Water stagnant and debris under the semi stilts buildings *Picture source* Adamy (2014)

3.2 Building System Performance

There are six criteria under the Building System component: Safety, Health, Control, Environmental Impact, Easiness, Comfort, and Architecture (Table 3). Detailed scores for each item are available in Annex B.

The total score for Meuraxa Hospital is shown in Table 3 as acceptable with a mean of 3.69 represented by green; however, there are two factors with low mean scores: "control of environmental impact" (3.58) and "architecture" (3.52). The highest is the "health" criterion with a score of 3.89. The highlights include the following:

- Safety: The fire resistance attribute is available, but it is not clear if the system works (see Fig. 12). According to the facility manager, the fire alarm system has been deactivated as the positions of the fire alarms are too low and can be reached by children, who used to play with it and trigger the alarm. The buildings also have a lightning

Table 3 Building system performance score at Meuraxa public hospital

Criteria	0	1	2	3	4	5	$\bar{x}$ Score	Color	Definition
Safety							3.66	Green	Accepted
Health							3.89	Green	Accepted
Environment impact							3.58	Green	Accepted
Easiness							3.73	Green	Accepted
Comfort							3.75	Green	Accepted
Architecture							3.52	Green	Accepted
Total $\bar{x}$							3.69	Green	Accepted

Fig. 12 Fire resistance equipment. *Picture Source* Adamy (2014)

Fig. 3 The only garden available in the paediatric block *Picture source* Adamy (2014)

resistance system to protect from strikes and adequate places for gas installment; however, some samples show poor electrical installment, such as using non-electrical tape.

- Health: There are no indications of dangerous material used or stored in the buildings. Most rooms are not air-conditioned, although the weather in Banda Aceh is warm and humid, especially in the dry season. However, as the buildings are surrounded by corridors and rooms have an ample number of windows, the wind flows in easily to create ventilation.
- Environmental Impact: There is no accessible report for environmental management and monitoring. The hospital has a medical waste incinerator provided by the Austrian and Hungarian governments, but it was damaged during construction. Banda Aceh's government replaced it with a new one in 2012. The facility manager stated that the hospital uses proper water sanitation treatment. The environmental problem they are facing is not being able to remove the standing water under the stilted buildings with only a meter-high access.
- Easiness and Comfort: The connections between rooms are accessible, but facilities for elderly and disabled people are unavailable. There are no complaints related to noise and vibration. There is not enough space for waiting rooms either in the main building or at the pediatric building; this causes problems during peak hours; a lack of adequate seating means that some visitors have to sit on the floor.
- Architecture: There is not enough garden space. The only garden is in the pediatric building (Fig. 13). Perhaps the space related to the semi-stilt structure can be transformed into gardens. There is no outstanding architecture design in this hospital as designed with conventional architecture.

3.3 Disaster-Risk Management Aspect

There are four criteria under DRM: Functionality, Local Institution Capacity, Disaster Risk Reduction, and Sustainability (Table 4). Detailed scores for each item are shown in Annex C.

Meuraxa Hospital's score for DRM is acceptable and represented by a green color with a mean value of 3.53. All the scores are acceptable yet only slightly above the accepted

Table 4 DRM performance score at Meuraxa public hospital

Criteria	0	1	2	3	4	5	$\bar{x}$ Score	Color	Definition
Functionality							3.50	Green	Accepted
Local institution capacity							3.52	Green	Accepted
Disaster resilience							3.56	Green	Accepted
Sustainability							3.54	Green	Accepted
Total $\bar{x}$							3.53	Green	Accepted

standard. Some of the important findings of the interview and observation of the DRM aspect are as follows:

- Functionality: The newly rebuilt hospital was relocated to a safer area far away from the beach and closer to the city, meaning a low risk for tsunami and flooding damage. However, there is still a potential risk of an earthquake in the future. As discussed in the safety criterion, some buildings built by the BRR agency exhibit a low-quality structure that can be unsafe in the event of an earthquake. This includes construction that is not standardized according to building codes, a lack of special infrastructure to reduce vulnerability, and no building inspections, especially for hazard assessment.
- Disaster-Risk Reduction: The buildings constructed by the Austrian and Hungarian governments are provided with signage for the direction of evacuation during an emergency (see Fig. 14). However, there are no records of the hospital's management having conducted any emergency-simulation drills (in 2012). There are also no records of building assessments after several small earthquakes struck Banda Aceh in recent years. It is also unclear if the staff and visitors or even the patients are aware of evacuation procedures and gathering areas (see Fig. 15). Both groups of respondents confirmed that the hospital has a back-up power system in the event of an electrical shut down. This indicates an adequate source of power to operate during an emergency period.
- Sustainability: There is no indication of a sustainable system either for energy or water consumption. The hospital was built using a conventional architectural design and a lack of innovation. Nevertheless, items such as access (except for those who are disabled and/or elderly) are adequate. Several soft-copy files of as-built drawing documents are available, but maintenance and operational manual documents for the building are missing except for those related to medical equipment. Based on an interview with the managers, the Austrian and Hungarian governments provided 1 year of assistance for maintenance and operational supervision. This knowledge transfer was helpful for the staff before the hand-over of the building and its full occupancy.
- Local Institution Capacity: According to the respondents, the management can operate and maintain the hospital buildings technically and financially. However, based on field observation, ongoing maintenance improvements are required such as facilities that need to be repaired and upgraded. The government is providing a new building block for the hospital that was still under construction in 2012.

Fig. 14 Evacuation signage. *Picture source* Adamy (2014)

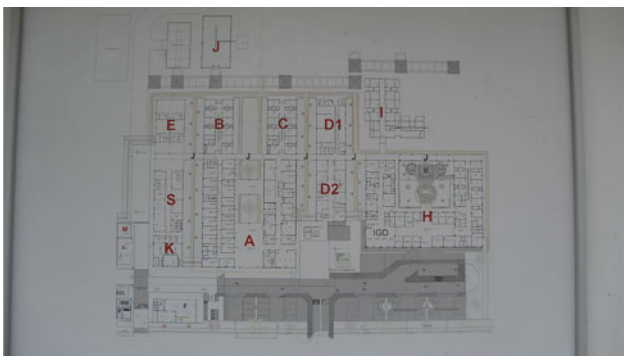


Fig. 15 No sign for emergency route in the hospital map. *Picture Source* Adamy (2014)

4 Conclusion

The building performance results of each aspect are as follows: the Built Environment and Building User are acceptable with a mean value of 3.61; the Building System is acceptable with a mean value of 3.69; the DRM is also acceptable with a mean value equal to 3.53. In general, the performance of the Meuraxa Hospital building is categorized with a green color (acceptable) with a total mean score value of 3.61. There was no performance evaluation from the previous hospital building before the disaster. Therefore, this building performance evaluation is compared with building codes and national regulations. The conclusion is that this new hospital building built by several donors performs better than the previous one, although it does not fully meet the proper standards for a hospital building.

Meuraxa Hospital is a case of reconstruction by multiple donor projects. It was a collaboration between the local government, BRR Aceh–Nias; the Austrian government; and the Hungarian government. Usually, a collaboration project during post-tsunami reconstruction in Aceh did not build the whole facility in the same compound together. Instead, each donor has chosen several buildings that they will build with their funds. Learning from the Meuraxa Hospital case, it is obvious that buildings built by foreign donors have better quality compared to those built by the local government (BRR Aceh–Nias). Nevertheless, there are two major critiques of the buildings designed and built by foreign donors. First, they failed to incorporate space for hospital management and administration in the hospital design. This lack of space disrupts hospital operations. It does not make sense to build a hospital without considering the needs of hospital management. The second problem is the failure of the semi-stilt design applied in the hospital because it is difficult for maintenance and is a burden for hospital management.

The typical design for a hospital in Aceh is a large complex with buildings spread out horizontally and connected by long corridors due to land availability. Technology for high-rise building construction remains uncommon here. Meuraxa Hospital was built with a conventional architectural design, a lack of innovation, and no sign of sustainable-concept application. For example, related to "energy-efficient" and "non-polluting," the hospital has no sustainable system management and is not equipped with a standard medical-waste processor. This aspect needs more attention during the hospital design process. Proper medical-waste management should be a basic requirement before any hospital is allowed to operate. This study recommended architectural innovations for post-disaster reconstruction because this is an opportunity to build a better building.

Meuraxa Hospital shows a lack of preparation for operating in emergency situations. This includes good building quality, staff trained to work under an emergency, and practiced annual simulation. The building-structure quality and design should be able to accommodate this purpose including providing clear signage for evacuation, back-up power that is sufficient, and a building that is able to operate during an emergency. However, in the last few years, the hospital has conducted several disasters and emergency-response simulations. It is recommended that a new BPE be conducted for this hospital, especially since it recently received Plenary Accreditation in 2017 and Islamic Sharia Accreditation in 2018. It is important to compare any new scores with previous scores and to analyze the relationship between BPE scores with hospital accreditation and the application of Sharia in hospital management.

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Appendix 1

See Table 5.

Appendix 2

See Table 6.

Appendix 3

See Table 7.

Table 5 Built environment and building user detail score at Meuraxa hospital

Criteria	Variables	Mean	Std. dev.
Access	Ambulance access approach	3.95	0.589
	Goods and waste disposal vehicle	3.60	0.970
	$\bar{x}$	**3.78**	N = 107
Engineering	Engineering system	3.56	0.838
	Engineering system standardisation	3.02	1.073
	Energy efficient	3.27	0.957
	Emergency backup	3.69	0.994
	$\bar{\bar{x}}$	**3.39**	N = 107
Building quality	Building operation	3.76	0.763
	Finishing	3.56	0.860
	Building weather age	3.71	0.824
	$\bar{x}$	**3.68**	N = 107
Staff and patient environment	Level of privacy	3.60	0.878
	View in out building	3.47	0.965
	Outdoor access	3.75	0.837
	Comfort control	3.69	0.985
	Building understandable	3.69	0.679
	Attractive in appearance	3.44	0.903
	Toilet	3.87	0.848
	Facility staff	3.71	0.991
	$\bar{\bar{x}}$	**3.65**	N = 107
Building form and materials	Human scale	3.66	0.857
	Sunlight and wind accessibility	3.67	0.833
	Quality material	3.50	0.945
	External colours texture	3.36	0.983
	$\bar{\bar{x}}$	**3.55**	N = 107

Table 6 Building system detail score at Meuraxa hospital

Criteria	Items	Mean	Std. dev.
Safety	Building Structure	3.50	0.935
	Fire Resistance	3.59	0.824
	Lighting System	3.78	0.861
	Electricity	3.83	0.795
	Gas	3.58	0.858
	$\bar{x}$	**3.66**	$N = 107$
Health	Building Material	3.73	0.695
	Sanitation	3.93	0.809
	Lighting	3.98	0.789
	Ventilation	3.91	0.807
	$\bar{x}$	**3.89**	$N = 107$
Control and environment impact	Environment Regulation	3.51	0.769
	Environment issues	3.45	0.849
	Building regulation disaster zone	3.79	0.762
	$\bar{x}$	**3.58**	$N = 107$
Easiness	Easy to access	3.75	0.631
	Connection between rooms	3.82	0.627
	Disabled and elderly	3.62	0.876
	$\bar{x}$	**3.73**	$N = 107$
Comfort	Vertical and horizontal	3.74	0.604
	Air condition	3.73	0.819
	Vibration	3.77	0.734
	$\bar{x}$	**3.75**	$N = 107$
Architecture	Façade	3.46	0.816
	Interior	3.56	0.767
	Green	3.34	0.941
	Signage outdoor lighting	3.72	0.844
	$\bar{x}$	**3.52**	$N = 107$

Table 7 DRM detail score at Meuraxa hospital

Criteria	Items	Mean	Std. dev.
Functionality	The building service	3.68	0.722
	Escape building	3.34	0.999
	Access for evacuation	3.54	0.780
	Emergency situation	3.44	0.779
	Basic maintainability	3.48	0.731
	$\bar{x}$	**3.50**	$N = 107$
Local institution capacity	Technical	3.49	0.769
	Operational Maintenance	3.61	0.786
	Financial	3.45	0.849
	$\bar{x}$	**3.52**	$N = 107$
Disaster Resilience	High alert disaster zone	3.75	0.859
	Hazard assessment	3.32	0.967
	Hospital built in disaster zone	3.60	0.799
	$\bar{x}$	**3.56**	$N = 107$
Sustainability	Energy consumption	3.52	0.851
	Water consumption	3.43	0.933
	Innovation design	3.53	0.828
	Waste management	3.69	0.851
	$\bar{x}$	**3.54**	$N = 107$

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Achieving Energy Efficiency Performance and Urban Connectivity Development in Saudi Arabia Through Renewable Energy Resources and Sustainable Transportation—Case Study Asir Province

Wael A. Aboneama

Abstract

This paper aims to find out the reduction of energy consumption by applying only one item of renewable energy devices. Also, it attempts to reveal the benefits of using means of sustainable transportation on Saudi's social lifestyle for a specific province which is Asir. Saudi Arabia is looking to enhance its economic resources and social needs. They announced their vision based on specific dimensions; social, economic, and urbanization. Asir province is in the southwest of the Arabian peninsula. It has many potentials for energy efficiency and water resources. Unfortunately, the most important mean of transportation in Asir and all of Saudi Arabia is the private car. The whole country suffers from high energy consumption. It is approximately 1.7 times higher than in Europe per capita. Houses in Asir and the whole of Saudi Arabia consume more energy and there is no implementation for renewable energy resources or devices. They can save the building's energy consumption and protect the ecology through renewable resources and its devices. On the other hand, installing sustainable means of transportation will enhance Saudi's lifestyle besides saving fuel consumption. Saudi's vision is based on urban connectivity development and social enhancement for all sectors that need to apply sustainable development.

Keywords

Energy efficiency performance • Urban connectivity • Renewable energy, sustainable transportation • Asir

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1 Introduction

Saudi Arabia is looking to enhance its economic resources and social needs by 2030. They announced their vision on the 25th of April 2016 based on specific dimensions; social, economic, and urbanization. Saudi Arabia has an approximate land area of 2,150,000 km^2 (Salman et al. 2016). Most of this land is desert and suffers from the long-distance between its regions. It has one of the most stable economies in the world which is based mainly on petroleum production. In the 2030 vision, Saudi Arabia is looking to create new urban areas to support its economy and develop existing cities. Sustainability, energy efficiency, and urban connectivity are not options for its vision. They should be the keyword for any development in this country as a result of its challenges and potentials. Saudi Arabia should plan its vision based on the consideration of its ecology, social, and economic needs as the main target for creating new urban areas and developing existing cities. Saudi Arabia has a big potential to produce energy from renewable resources. On the other hand, Saudi Arabia has some challenges such as population growth, oil production dominance on its economy, rural development, poverty of potable water resources, and the heat harshness of its climate. Saudi Arabia's vision 2030 aims to enhance and upgrade its economical and social planning, ensure to benefit from all its natural resources, and generate renewable energy from its resources (IRENA—International Renewable Energy Agency 2014). It has the biggest solar power potential in the world, also excellent wind speeds. As well, waste energy production and hydropower such as in Asir.

Asir region location is in the southwest of Saudi Arabia. It has an area of 76,693 square kilometers and an estimated population of 2,211,875 in 2017 (General authority, statistics in S. A 2017). Historically, Asir economy is based on food production and agriculture as a reason for its average annual rainfall. Asir province has the potential of natural water resources based on rainfall. On the other hand, Arabian

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countries have poverty of sustainable development, in particular, the Arabian Peninsula. Saudi Arabia has a total amount of 292.80 billion KWh of electric energy consumption per year (Mosly and Makki 2018). That means it has an average of 9,072 kWh per capita. Saudi Arabia's electricity consumption increases exponentially. For example, the increase in only five years (2011–2016) was 30% from 219.66 to 287.44 TW. (Pazheri et al. 2012). Challenges increase year by year. The only way to confront all challenges is a sustainable way of thinking and using renewable energy instead of crude oil reserves tools.

2 Literature Review

2.1 Electric Consumption in Saudi Arabia

Saudi Arabia is facing a real dilemma which is electricity consumption. It has increased by 8% annually in the first decade of the twenty-first century. The problem becomes more harmful in the summer and the electricity demand increases more than 93% between 2004 and 2013 (from 28 to 54 GW) (Pazheri et al. 2012). In this decade, the demand for electricity registered a remarkable increase by over 6% annually, which requires more oil and natural gas production Figs. 1 and 2 (Ourworldindata 2017). It is predictable for the electricity demand to be increased and reach the level of 120 GW by 2032 (United Nations Industrial Development Organization 2016). Homes in Saudi Arabia are registered for the highest level of electricity consumption with 50% of its total electricity production. The rest of the production ratio can be divided between industry, commercial sector, and government agencies (18%, 11%, and 12%, respectively). In all sectors, air conditioning dominates the highest level of consumption with 70% of the total production. The summer consumption scores double the winter average (United Nations Industrial Development Organization 2016).

Saudi Arabia's electricity consumption records a progressive record that reaches the level of 25 duplication usage during the twenty-five years from 1975 to 2000. In 2001, the consumption was 24 GW. If the consumption remains at the same level, it is predicted to rise to 60 GW by 2023. They need to invest more than 90 billion dollars to meet their demand. They need to plan and work on a new plan for generating energy from renewable resources and using sustainable devices and means of transportation. The authorities have signed for generating energy from waste by 300 million US dollars (C. I. A. 2011). The whole country suffers from high energy consumption. The electricity production is 9,839.64 kWh per capita meanwhile it is 5,928.63 kWh per capita in Europe, which means 1.7 higher (Worlddata 2015).

2.2 Renewable Energy Technologies

Renewable energy resources are existing in abundance in Saudi Arabia. (Chimres and Wongwises 2016). Solar energy, wind power, geothermal, hydro from dams, and other resources, biomass, and wave energy are several types of renewable energy resources not only in Saudi Arabia but also in all Arab worlds, particularly the Arabian Peninsula.

2.2.1 Solar Energy

Saudi Arabia has the biggest potential for generating clean energy using photovoltaic (PV) cells. It has the opportunity to be the hub for solar energy development in the Arabian peninsula (Salam and Khan 2018). Solar energy is considered as one of the most useful sources of renewable energy for its cheapness, abundance, and endless. Solar energy remains in the first class of renewable energy resources

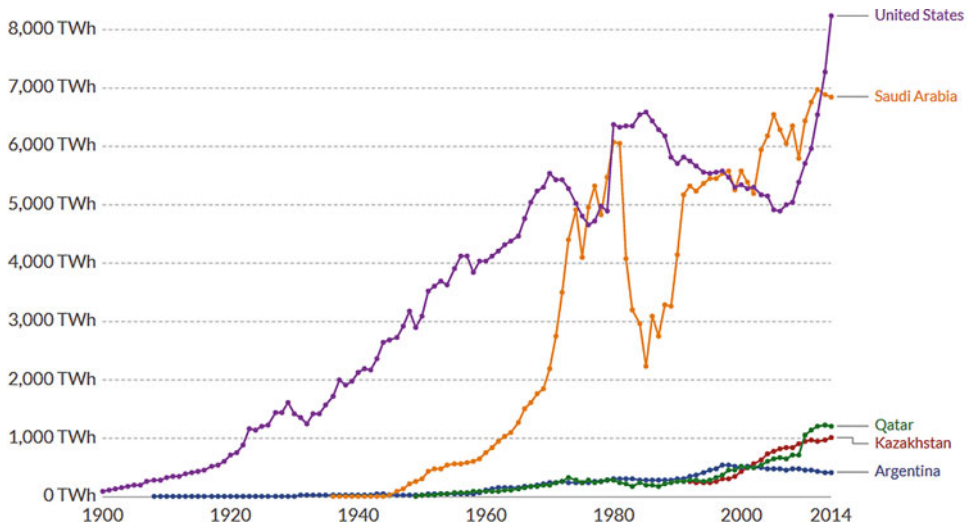

Fig. 1 Oil production by country, terawatt-hours (TWh)

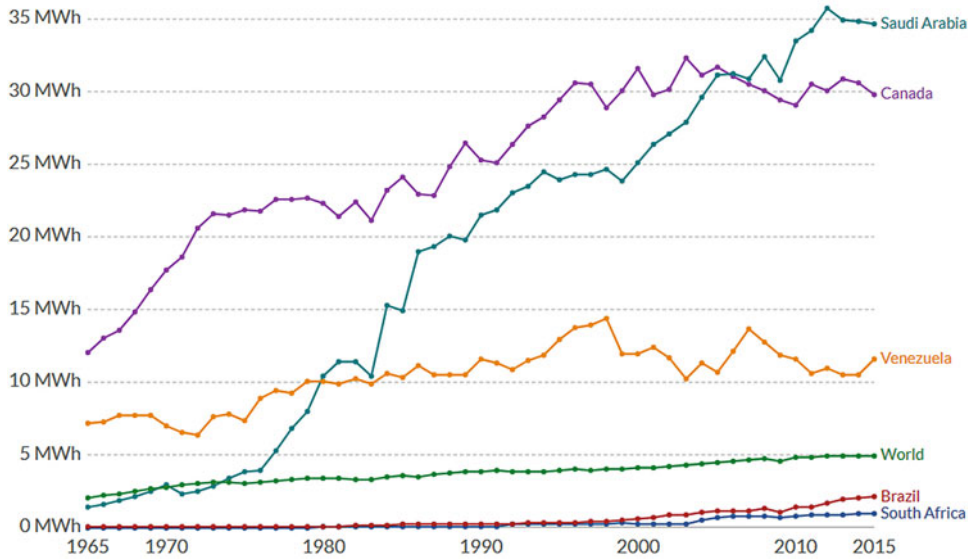

Fig. 2 Natural gas consumption per capita, megawatt-hours per year

based on the continuous development in its generating devices with decreasing their cost. The main disadvantages of generating energy using solar power are its high capital costs and required area for PV cells (Mosly and Makki 2018). Meanwhile, the decrease in its cost reaches up to 50% in only 4 years between 2010 and 2014 (Ferreira et al. 2018).

2.2.2 Wind Energy

Wind power was the first renewable energy resource for the whole world. Exploring the historical ages in the Netherlands and other parts of the world, we will find a significant role in wind power. Wind power still has the biggest portion of energy production to save the world from carbon emissions. Its advantages make countries invest growing up worldwide. The first power plant for renewable electricity production was registered to wind power (Singh and Parida 2013). Many countries that have the potential of harvesting onshore and offshore wind installed wind turbines to be used for a step forward toward sustainability (Mosly and Makki 2018). Saudi Arabia has one of the biggest potentials to generate energy using wind power. It has three sea fronts, the length of which is about 3,400 km (Kaplan 2015). On the other hand, it has heights in several parts and regions that ensure a very suitable amount of renewable energy based on wind turbines.

2.2.3 Geothermal Energy

Geothermal energy is based on the thermal layer in lower ground level and it is an uncommon source of renewable energy. It is a sustainable source that can be used also in heating and cooling. Geothermal energy neither needs a huge area for construction nor sophisticated maintenance procedures (Herez et al. 2017). Those two reasons make it the least environmental impact among other renewable energy resources (Shortall et al. 2015). Saudi Arabia is one of the few Arabian countries that can generate energy using geothermal technology. The western coast (Al-Lith) coast is rich in both hydrothermal and geothermal potentials. It has volcanic centers and high heat generating granites. The heat flow value is more than 80 mW/m^2 across the Al-Lith coast. Also, the thermal waters are chloride-rich (Lashin et al. 2014).

2.2.4 Hydro Energy

Hydropower as a renewable energy resource is considered a continuous, clean, and constant resource. Worldwide, it is placed as the largest renewable source and plays a significant role in electricity generation (Kanit and Wongwises 2015). It is a very cheap and easily available resource. When compared to other renewable technologies, it has some social and environmental impacts as observed in the high dam in Upper Egypt and nowadays during the construction of Ethiopian high dam on the Nile River. Egypt lost many Pharaonic temples during the construction of its high dam. On the other hand, Noba society was changed and most of their homes were destroyed as an impact of this dam. Nowadays, and after five decades Egypt is searching for the disadvantages of constructing the high dam and negative impacts on its ecology, society, and heritage.

Saudi Arabia is not mentioned in the World Small Hydropower Development Report (WSHPDR) 2013. Saudi Arabia, in particular, did not installed hydropower Fig. 3 (United Nations Industrial Development Organization 2016). Asir province has many dams for rain harvesting. Unfortunately, the investment for generating energy from hydropower in Asir is not considered yet. However, it has a higher ratio of rainfall all over the Arabian Peninsula.

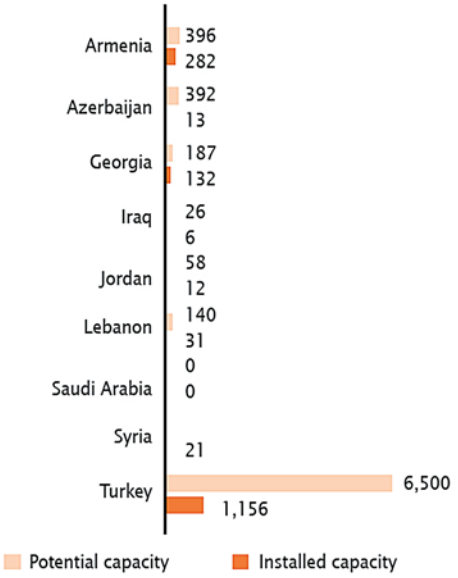

Fig. 3 Small hydro power SHP capacities in Western Asia. Mega Watt (MW)

2.2.5 Biomass Energy

Biomass energy is growing year after year. It is a useful source of renewable energy that reaches 10% of the total main energy source in 2009 worldwide (Algarny et al. 2017). It consists of carbon, nitrogen, hydrogen, and oxygen. The name of it is given to the substance as a result of the photosynthesis process, where the energy from the sun converts water and carbon dioxide into an organic substance (Mosly and Makki 2018). It decomposes biological wastes that protect the environment to get rid of it (i.e., domestic, forest, or organic waste). Saudi Arabia has a big potential to generate electricity from biomass energy. It has more than 15 million tons of solid waste which they need to get rid of it. The daily rate of solid waste is at the level of 1.5 to 1.8 kg per person. Biomass energy from solid waste can be described as a magic process for the kingdom. Big cities such as Riyadh, Jeddah, and Dammam generates more than 6 million tons of solid waste annually. Many other processes such as recycling, reuse, and energy recovery took place to get rid of solid wastes, however, they are not sufficient yet. (Algarny et al. 2017). As mentioned, Saudi authorities have signed for generating energy from waste by 300 million US dollars (C. I. A. 2011). It is planned to decompose up to 180 tons of waste per day.

2.2.6 Wave Energy

The motion of the sea waves is the source of this type of renewable energy. Saudi Arabia has 3,400 km of seashore. Most of them are on the red sea, which means that it has a big potential for generating energy from wave energy. Also, the western bank of Saudi Arabia is rich in renewable energy resources such as biomass, wave, solar, and geothermal energy. The amount of generated energy depends on many conditions such as wave height, period, and seasonal variation (Mosly and Makki 2018). Wave energy is a part of wind as shown in Fig. 4 (Ulazia et al. 2017). It is a new renewable energy source that is considered by many countries but not in Saudi Arabia. More studies and device enhancements can push this type forward to decrease the required area for installing its devices (Brundin 2018).

2.3 Asir Province

Asir location is in the southern west of Saudi Arabia. It has an area of 81,000 km^2. It has around 6.8% of Saudi Arabia's population with a total number of 1,913,392 (Jaber 2018). Abha is its capital. It is located on a high eminence, which receives the highest ratio of rainfall all over the Arabian Peninsula. It has the highest hill in Saudi Arabia. The average annual rainfall ranges from 300 mm (12 in.) to 500 mm (20 in.), which means it has the biggest potential for hydropower. Asir is a region of more natural vegetation than any other part of Saudi Arabia. Asir is home to many farmers, who mainly grow wheat and fruit trees. Recently, an expansion in the irrigated land has greatly increased the agricultural productivity of the province, which means more organic wastes and bigger potential of generating energy from solid wastes.

2.3.1 Public Transportation in Asir

The rugged terrain of the Asir region due to its geological formation, which is full of mountains and plateaus, minimized the solutions of public transportation in Asir (Aljoufie 2016). Unfortunately, the private car is the only means of transportation with a very few number of taxi drivers. On the other hand, the greatest advantage is the infrastructure in Asir such as roads and streets that connect Asir cities and with the rest of the kingdom.

3 Methodology Steps for Achieving Energy Efficiency Performance and Urban Connectivity in Saudi Arabia

This paper aims to prove the development of energy efficiency by studying the implementation of one sustainable device which is a solar water heater for domestic use. On the other hand, the paper will present the advantages of using sustainable transportation for oil consumption and for urban connectivity.

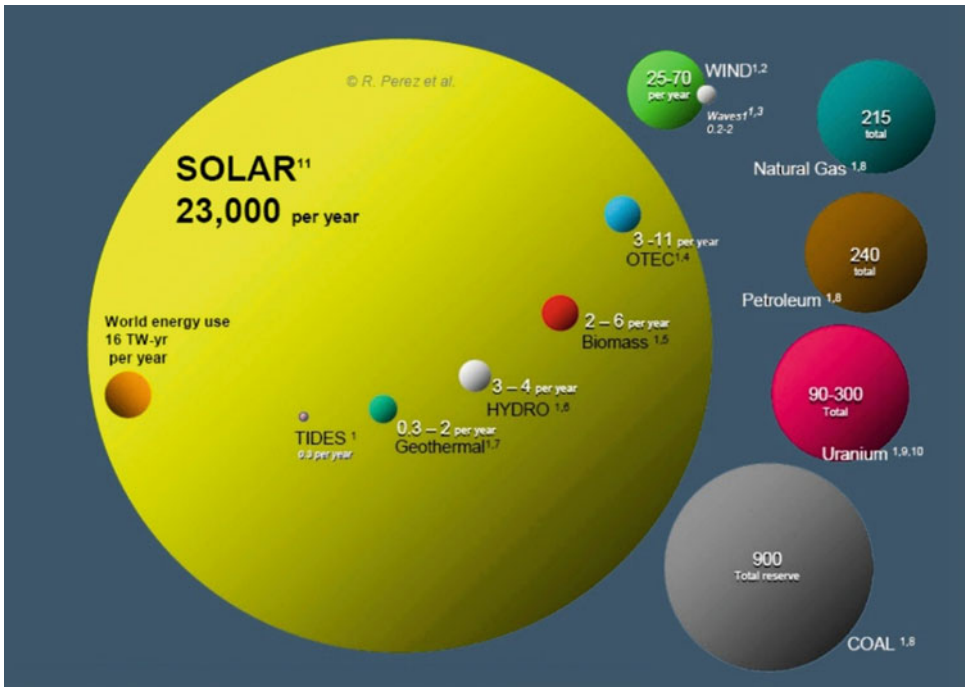

Fig. 4 Amounts of energy available on earth. Comparing finite and renewable energy resources by Terawatt/year

3.1 Electric Water Heater Consumption

A water heater that is used to heat water in all buildings. The research is focused on studying water heaters in homes for family daily needs. Electric water heaters used to work and consume electricity for 3 h per day to heat water. May the newer versions be more efficient and run half the time. A typical water heater consumes around 4 kilowatts (Calculator 2019). In Saudi Arabia, each housing unit has a minimum of two bathrooms and one kitchen. It means that each small apartment has three units of water heaters. Bigger apartments may exceed 5 units of electrical water heaters. Villas and big houses that have more than one floor may contain 8 heaters. This paper will assume each housing unit has (3.5 water heater units). The next step is to calculate the number of electricity needs for each typical electric water heater per year. Then to calculate the amount of fuel needed to generate this electricity.

- 1 water heater = 4000 W/day = 4 KWh/day.
- 1 water heater = 4 × 365 = 1,460 KWh/year.
- 1 housing unit = 3.5 × 1460 = 5110 KWh/year.
- 1 kWh = 3412 Btu (Bluejay 2017).
- Let us convert fuel to electricity, considering that some energy will be lost due to the inefficiency of the generating process. We refer to this inefficiency by using the temperature rate, which is the actual amount of fuel required to produce 1 kWh. For example, if the temperature rate is 8000 Btu, then the efficiency is 3412 ÷ 8400 = 40.6%. Here are the efficiencies for different kinds of fuels (usually for turning a steam turbine) (Bluejay 2017).
- Coal: 33.6%.
- Petroleum: 25.5–33.3%.
- Natural Gas: 29.4–44.8%.
- On the other hand, the amount of oil (residential fuel) needed to generate one kilowatt of electricity. It takes 0.0016 barrels to make one kWh. This includes the inefficiency of the conversion process (Bluejay 2017).
- Conclusion: One typical housing apartment that has 3.5 typical water heaters for bathrooms and kitchen will consume the following:
- Petroleum 0.0016 × 5110 = 8.176 barrels/year.

3.2 Saudi Arabia and Asir Demography

The Saudi Arabia population is 33,979,611 (Worldometers 2019) Fig. 5 (Worldometers 2019) and the growth rate located between 2 and 3%, Fig. 6 (Worldometers 2019). Householder number in Saudi Arabia is 5.46 million, of which 35.9% were immigrants, with about 1.96 million households. Meanwhile, the number of Saudi households is 3.5 million which is equivalent to 64.1% (Salam 2014). Based on the above data we can conclude the average number of family members in Saudi Arabia, which is as the follows:

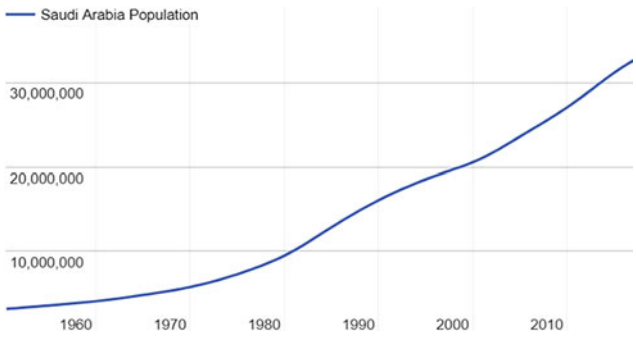

Fig. 5 Saudi Arabia population (1950–2019)

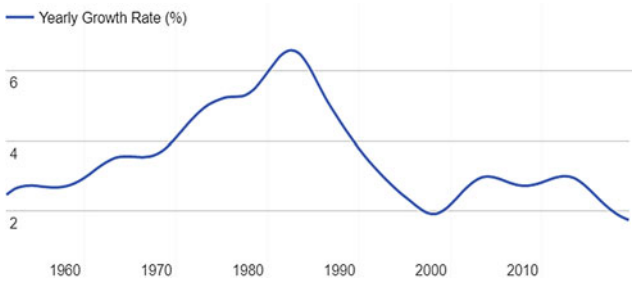

Fig. 6 Saudi Arabia yearly population growth

- Population/no. of householders
- 33979611/5460000 = 6.2 person per family.

As per Table 1 (Government 2017), Asir's population in 2016 was 2211875 and the population of Saudi Arabia in the same year was (32,552,336), meanwhile, it is (33,979,611) in 2019. With a very simple equation we can conclude the Asir population in 2019:

- (33979611/32552336) × 2211875 = 2,308,856.

With an average number of family members (6.2) we can calculate the householders in Asir:

- 2,308,856/6.2 = 372,396 householders in Asir.

3.3 Solar Water Heater for Energy Efficiency Performance in Asir

Solar water heating (SWH) is a sustainable device that heats the water using sunlight thermal load using a solar thermal collector as shown in Fig. 7 (Barbhuiya 2013). They are widely installed for residential and some industrial applications. It has more components than a typical electrical heater, which makes its installation price higher than the electrical one (Khudhayer et al. 2018).

SWH has an electric boiler in case of the absence of solar radiation. A comparison between solar water heaters to a typical electric one has been done and gets the conclusion of 56.1% as an estimating saving of energy (Powersaving.co.za 2010).

As per the last calculations of householders in Asir, and the annual consumption of each unit, we can get the total energy consumption in Asir for heating water as the following:

- No. of householders × Householder consumption for typical electrical heater.
- 372,396 × 8.176 = 3,044,709.696 barrels/year.

Installing a solar water heater in all Asir residential units will save the following:

- Energy for typical electrical devices × Saving value.
- 3,044,709.696 × 0.561 = 1,708,082 barrels/year.
- Saving electricity = No. of barrels/0.0016 (amount of barrel needed for each KWh).
- 1,708,082/.0016 = 1,067,551,250 KWh/year.
- More than one million megawatts per year.
- The price of an oil barrel is 60 US dollars = 225 SR that is according to the global market day price while typing this paper (markets.businessinsider.com 2019). It means that the Saudi government can save per year:
- No. of saved barrels × barrel's price
- 1,708,082 × 225 = 384,318,450 SR/year.

Table 1 Saudi Arabia population growth rate/Asir

Administrative area	Total			Non – Saudi			Saudi		
	Total	Females	Males	Total	Females	Males	Total	Females	Males
Asir	2,211,875	1,001,739	1,210,136	461,744	116,559	345,185	1,750,131	885,180	864,951

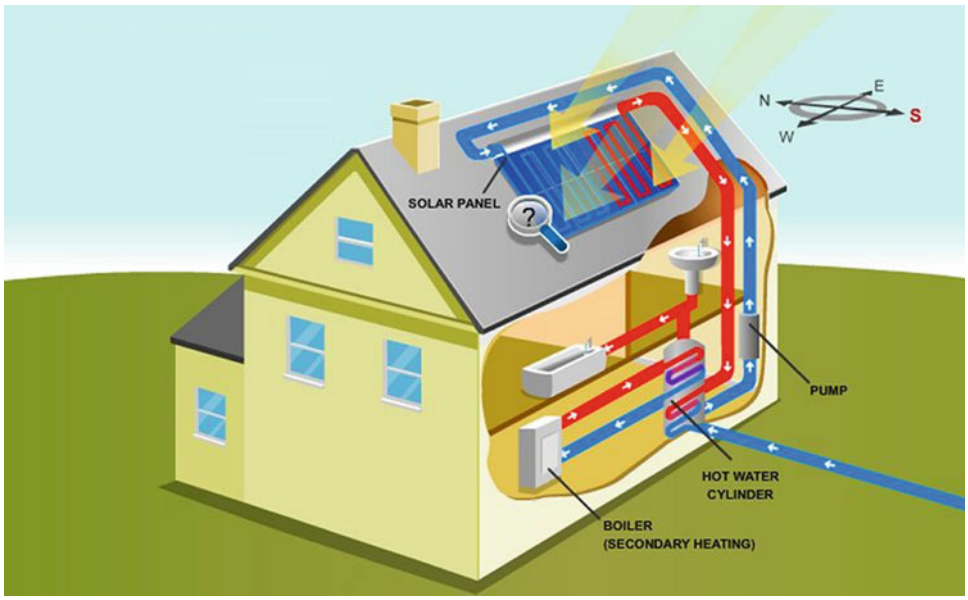

Fig. 7 Solar water heater. It is important that the surface the panels are mounted on southern west-facing facades. This lets panels absorb maximum daylight hours

The government can help each householder to install solar heating devices from its saving in the first year by

- Saved money per year/no. of householders.
- 384,318,450/372,396 = 1,032.02 SR.

This amount can be a donation for each householder besides the reduction of the electricity bill.

3.4 Solar Water Heater for Energy Efficiency Performance in All Saudi Arabia

We can estimate the impact of applying solar water heaters in all of Saudi Arabia. We need to get the ratio of Asir province inside the whole country. Back to Table 1, Asir population is 2,211,875 meanwhile Saudi Arabia's is 32,552,336 in 2016 (Government 2017).

- Asir ratio = 2,211,875/32,552,336 = 0.068 = 6.8%.

The calculation of saved barrel for the whole country if the government applies solar heaters to all provinces is the following:

- No. of saved barrel in Asir/Asir ratio = 1,708,082/0.068 = 25,173,975 barrel/year.
- According to monthly production numbers from S&P Global Platts, Saudi Arabia produced 3.8 billion barrels per year of oil and condensate in 2018 (Wald 2019). The amount of saved barrels is around the whole oil production of Saudi Arabia for 2.5 days.
- Total saving money per year as per oil price today = 25,173,975 × 60 $ = 1,508,278,519 $ = 5,656,044,448 SR.

3.5 Sustainable Transportation

Asir province is suffering from a lack of public transportation unless very few numbers of taxi drivers. A few efforts by some organizations such as universities can provide buses as a means of transportation for only female students. The private car is the only means to move someone from one place to another. Private car affects the environment and the economy in Saudi Arabia negatively in different ways such as pollution, carbon emissions, and losing the main exported pillar in Saudi's economy which is the oil production. The first step for applying sustainable means of transportation is creating a full transportation plan for Asir to connect its cities and to connect Asir by the rest of Saudi Arabia provinces. Old means of transportation are responsible for 20 to 25% of world energy consumption and carbon emissions (Jeon et al. 2014). Sustainable means of transportation are trolleybus, tramlines, zero-emission buses, zero-emission vehicles and fuel cell hybrid bus fleet. They all use electric energy or hybrid fuel such as nitrogen. This paper will study the impact of installing one type of sustainable public transportation and zero-emission vehicles on energy efficiency and urban connectivity.

3.5.1 Installing Zero-Emission Buses and Fuel Cell Hybrid Bus Fleet

The zero-emission buses are the future and to extend the fully electric solution to the core part of the urban bus.

Hybrid buses produce only water vapor: no smog-forming nitrogen oxides as shown in Figs. 8 and 9 (Cte.tv 2018). Both types can maneuver freely without any cable link like a trolleybus. Also, they do not need infrastructure. All these advantages put the zero-emission and fuel cell hybrid buses as the best solution in Asir province to have sustainable transportation connecting each city district and connecting cities with each other (Aboneama 2015).

3.5.2 Zero-Emission Vehicles

Electric cars have the same advantages as combustion engine cars, but they avoid all negative impacts on the environment and economy. They run and get the required energy from installed batteries inside the car. They produce less harmful impacts on the environment as shown in Fig. 10 (Voelcker 2016). They produce zero carbon emissions. On the other hand, there is another type of hydrogen car that uses hydrogen as their fuel (Gable. 2008). Policy-makers can encourage people to buy this kind of car in Saudi Arabia by reducing all taxes and customs to the level of zero and provide stations for car charging or alternative fuel supply. Nevertheless, Saudi Arabian people need to change the culture of buying big four-wheel drive cars which is an essential issue for a sustainable life.

3.6 Apply Public Sustainable Transportation on High-Occupied Buildings and Organizations

Educational buildings such as King Khalid University (KKU) in Abha is a good sample to start apply using sustainable transportation tool as a shuttle bus for students and staff, Fig. 11. KKU has 59,495 students and 6,014 employers in total 65,509 (Admin 2019). Grainger is one of the KKU locations, which is the biggest operated one. The location has around 12,000 official parking spaces (calculated from the project layout by the researcher), and more than 2,000 around the site. As illustrated in Fig. 11, the parking spaces are more than the triple area of the whole buildings. The students and staff are complaining each day of lack of car parking spaces (al-madina.com 2014). There is no public transportation for this project. This is the case study of this paper. As per car parking available spaces in and around this project, it is estimated that more than 15

Fig. 8 Hybrid bus

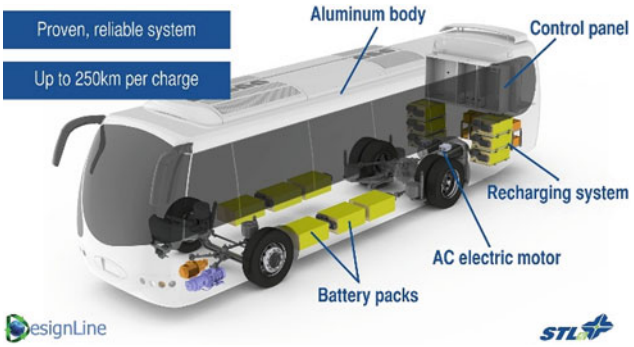

Fig. 9 Electric bus

Fig. 10 Zero-emission electric car

Fig. 11 King Khalid University "by the researcher using Goggle earth"

thousand cars visit this project every day. The research will calculate the impact of applying sustainable transportation on only one big public project such as KKU. The following items are the case study assumptions:

- Each car will travel only 50 km in everyday KKU journey back and forth.
- All cars are fuel-efficient cars that consume only 8 L per 100 km (www.together-eu.org 2012).
- Only 60% of the university users will use sustainable public transportation, and the rest 40% will keep using their private cars.
- The study period is only 9 months per year including summer courses, and 3 months per year the university is fully closed (which is not the actual case).
- There are 22 studying days per month.
- More than 15,000 private cars are coming to this location every day, and around 5,000 auto-stop cars.
- There is no calculation for auto-stop journeys; however, public transportation will end auto-stop transportation.
- There is no calculation of visitors who will use zero-emission vehicles.
- Car fuel consumption/day = running km/efficiency = 4 L fuel per day.
- Car consumption/year = 4 × 22 × 9 = 792 L.
- No. of visitor's private cars who will use public transportation = 15,000 × 60% = 9000 Cars.
- Saved fuel amount per year = 9000 × 792 = 7,128,000 L of fuel/year.

To transform this amount to the number of oil barrels which is the pillar of Saudi's economy, we need to know the amount of fuel produced by each barrel.

- In simple words, every 159 L barrel of Crude oil produces the following (Cah 2015):
- 73 L Petrol,
- 36 L Diesel,
- 20 L Jet fuel and heavy fuel oil,
- 6 L Propene,
- 34 L of other products (Butane, Asphalt, and Sulfur),
- The amount of barrels saved by using public transportation = 7,128,000/(73 + 36) = 65,394 barrels per year = 65,394 × 60 = 3,923,670 $.

Conclusion

Only one location such as King Khalid University if half of its visitors will use sustainable public transportation that can save Saudi's economy up to 4 million US dollars per year and more than 7 million liters of fuel. Also, it can save Asir ecology from 41,400 metric tons of CO_2 because a typical passenger vehicle can produce more than 4.6 metric tons of carbon dioxide per year (U. S.-E. P. A. 2015). We need to calculate the value of applying a fully sustainable public transportation plan inside Asir cities and to connect those cities. Imagine there is a tramline between Abha and Khamis Mushait cities. Asir will be an icon for the whole of Saudi Arabia's provinces.

3.6.1 Social Impact of Public Transportation

Public transportation has many benefits more than fuel and energy saving. The research will discuss neither the reduction of air pollution nor the impact on traffic. The greatest advantage of having public transportation is social connectivity. It is related to bus stations and buses themselves. The bus station is a connection point for neighbors to meet each other and discuss social life waiting for their bus as shown in Fig. 12 (Broward.org 2019). On the other hand, many shops, commercial activities, food sellers, and kiosks are available near each bus station. All these features of social life are missed in Asir and all Saudi Arabia provinces because people use only private cars.

Inside the bus itself, there is another type of social connectivity. The bus station provides social connectivity between neighbors, but the bus vehicle provides connectivity between district neighbors. Let us study an example of an old man who takes the bus from station (A) that will communicate with a student who always sits on the back seat from the station (B) and leaves it for him. Families start to communicate based on bus meetings. Saudi vision for 2030 focuses on social aspects that need all efforts to can achieve.

4 Results and Findings

This paper proved that every province in Saudi Arabia has an excellent opportunity to reach the level of energy efficiency and urban connectivity with little effort. They are not using most of their potential for generating energy from renewable

Fig. 12 Neighborhood bus station and social connectivity

resources. Sustainable devices are not considered in Saudi's law for building permits. On the other hand, there are many items to achieve urban connectivity that are not considered.

Asir has the potential to be the first sustainable province in the Middle East. It has the best weather and rainfall in the Arabian Peninsula. Asir needs real planning that considers sustainable means of transportation, energy consumption, etc., solar energy devices such as solar water heaters should be applied to all sectors. It will save energy and environmentally friendly. Asir has a big opportunity with Saudi's vision 2030. Regional transportation planning using sustainable tools is the only way to develop and enhance social living in Asir. As discussed in King Khalid University, the impact of using shuttle buses will save fuel consumption and avoid heat island problems from a huge area of parking lots covered by asphalt. On the other hand, the social influences for the whole society will be positively great.

5 Discussion and Analysis

Applying sustainable devices that depend on renewable energy resources will improve energy efficiency performance for the whole country. This paper proved the benefits of using one sustainable device, which is a water solar heater on energy consumption for the whole country. There are several other devices such as LED street lights and others to improve energy efficiency performance for the whole country. Generating energy from renewable resources and installing sustainable means of transportation in a full transportation plan will play a major role in the 2030 vision of Saudi Arabia. To overcome all obstacles, politicians should define short, 5-year stages in future planning. Increase in people's awareness of using renewable energy resources and moving toward using transportation instead of their private cars need a long-term plan and some governmental investment. The excitement of using zero-emission vehicles as transportation tools and intimidation of electricity bills and parking tariffs may help in people's awareness. Transforming Asir to the sustainable province in Saudi Arabia is a magnificent solution and guide-way for many countries and the rest of the Middle East that have typical challenges. Asir is the best model to start in Saudi Arabia. It has many potentials for sustainability development and urban connectivity.

6 Conclusion and Recommendations

- Saudi's vision should implement roles and laws for using sustainable devices with low energy consumption.
- The location of new cities and urban development should consider the location of renewable energy and potable water resources.
- Decision-makers should consider and generate energy from all available types of renewable energy resources. The development in all resources is running fast and the demand increases year and after.
- Sustainable transportation is a mandatory item for all of Saudi's cities.
- Transforming Asir into a sustainable province to use renewable energy devices and sustainable means of transportation should go through coordination between private and public sectors under the supervision of governmental authorities. They should perform practical experiments and gathering information from other countries and cities that apply sustainable development.
- People's awareness is the keyword of energy efficiency and a sustainable way of living. All studies of solar water heaters have been done based on 77°, which is quite enough for residential use. If the householder raises it to 90° the whole theory will change and the saving will be less.
- The installation process should be done through its rules. The absence of one item such as thermal isolation of hot water pipes will lead to the whole system failure. It will lead to the opposite result with people's awareness.
- Using zero-emission vehicles and hybrid buses needs a full maintenance background. In some cases, they bought the vehicles without knowing how to maintain them. It leads to destroying people's awareness of sustainability.

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Smart Cities: Efficient, Sustainable and Digitized Living

It is now an irrefutable reality that the world's population will increase and even double in the next 20–30 years. As we approach the final part in this volume, it is has become clear that smart cities are one way to accommodate this trend by making available solutions for mobility, sustainable energy, space utilization and paving the way to efficient, eco-friendly and digitized living. Smart technology and e-governance programs creating a direct link between public administrators and citizens is one approach to making cities more energy efficient, inclusive and adaptive.Accordingly, in the chapter ``Toward a Smart and Sustainable Campus Future Vision, Opportunities, and Challenges'', the authors present a framework to elucidate how the Internet of Things can be used to bring a smart and innovative university campus to life to improve the delivery and efficiency of daily activities with consideration of the social and environmental interactions. This framework provides guidelines for not only a smart but also a sustainable campus with improved educational activities and better student life experience. Other approaches include a shift toward low-carbon economy sectors, promotion of sustainable transport, promotion of labor mobility and investment in education and life-long learning and more, some of which are taken in "Applying Sustainable Principles to Create New Urban Areas and Developing Existing Cities in 2030 Vision of Saudi Arabia". In his chapter, the author explores sustainable determinants to creating new urban areas and developing existing cities in Saudi Arabia. In particular, after the presentation of the problems in Saudi Arabia cities and its goals for the 2030 vision, illustrates several available approaches for the consolidation of using sustainable tools and many other applicable criteria to push forward its new urban areas and old cities toward better performance.Moreover, this part of the book showcases valuable planning approaches and case studies. Often not given enough attention for the roles they play in shaping and transforming a city, rivers must be accounted for land use plans. With lessons to be learned from cities that plan for and learn from their rivers, the chapter on "Sustainable Urban form and Dynamics of Rivers in the Context of Faridpur City, Bangladesh" looks into a rudimental relation between spatial configuration and river network of Faridpur, Bangladesh. By examining the location of the river, the role of the river network in the formation of the city's spatial structure and predicting future development is identified. The author uses Space Syntax software to simulate the city's road network and identify the spatial and functional core, road integrations, determination of the choice of people of the city corresponding to its past and present. A syntactic analysis by Depthmap software was applied as a tool to correlate issues of accessibility, choice, and connectivity to the town is undertaken and followed by suggestions for the future expansion of road networks. Correspondingly, components of the natural landscape, such as rivers, are sought to reconcile cities with their wadis. Titled "Study the intervention on Wadi Al Harrach to eliminate pollution using urban solutions and sustainable development``, this chapter in the book highlights Wadi El Harrach as an essential component of the natural landscape of the city of Algiers, so the visualization shows that it belongs to the future. The authors activate the study of Oued El Harrach to eliminate pollution and integrate it into the urban image of the Algerian city. As they arrive at the context of their research, a non-pleasing general impression of the emerging landscape arises and they finally identify the most important issues and propose a set of methods and recommendations in the field of sustainability in order to put a definitive end to this phenomenon. As global issues surrounding sustainability and environmentalism are discussed in this volume, solutions are offered in hopes of contributing to and promoting a better quality of urban living, reducing ecological damage and creating healthier surroundings. In the chapter 'Reviewing Whole Building Design Sustainability Challenges: Perspectives on Net Zero Energy and Rainwater Harvesting``, the author critically

examines the architectural designer's response to Whole Building Design sustainability challenges, evidence of challenges through case studies on Net Zero energy and rainwater harvesting. In a review of studies on the core ideology of design sustainability for buildings and guideline principles adopted for green architectural design, the author also determines the extent of issues of environmental and social well-being impacting architectural sustainability and presents two case studies of LEED platinum-certified buildings.

Reviewing Whole Building Design Sustainability Challenges: Perspectives on Net Zero Energy and Rainwater Harvesting

Stephen T. F. Poon

Abstract

The principles of net zero energy and rainwater harvesting are increasingly adopted in designing architecture which adheres to whole building design (WBD) principles. This paper will critically examine evidence of WBD ecological and social well-being benefits. The research asks if green building measures are beneficial beyond preservation of non-renewable resources and costs savings and whether social well-being is reflected in sustainability indices such as LEED® and net zero energy ratings. Evidence from the literature suggest that sustainable buildings may lead to better living in principle, but some studies find efficiency in green buildings do not help mitigate environmental degradation, and some have failed to create social impact. Methodology involves case studies of two LEED® Platinum-certified buildings to understand how net zero energy and rainwater harvesting play key ecological and social roles driving green building initiatives based on WBD. The conclusion will recommend ways to implement WBD more effectively for future green building projects.

Keywords

Sustainability • Green building • Whole building design • Net zero energy • Rainwater harvesting

1 Introduction

In the spirit of global discussions surrounding sustainability and environmentalism, broad issues have surfaced within the field of architectural design which involves a host of experts in architectural design, urban planning, construction development, environmental design and industrial management and other fields. Sustainability advocates and green building experts are drawn heavily into these dialogues and battles, being urged to produce "green"-certified solutions for spatial efficiency of infrastructures and landscapes and cost-sustainable benefits, promoting a better quality of urban living through creating healthier surroundings; enabling more equitable distribution and access to social spaces; and at the same time, look for ways to reduce ecological damages consequent to urbanisation and population growth (USGBC 2003; Bruntland Report 1987; Edwards and Naboni 2013; Ghaffarian Hoseini et al. 2013).

This paper provides a critical review of architectural sustainability literature on quantitative and qualitative impacts of green buildings on urban society and ecological preservation. It is acknowledged that despite the substantial investments incurred, few architectural design scholars have attempted to clarify perceptions towards sustainability by framing discussions around green buildings' social and environmental contributions in the use of renewable resources such as energy and water (Bruntland Report 1987; Wheeler and Beatley 2014). Case study methodology approach will be utilised, through an analysis of two LEED® Platinum green architecture applying *Whole Building Design* (WBD) principles, namely, the Heifer International Headquarters and The David & Lucile Packard Foundation. Discussions and recommendations are offered in conclusion.

1.1 Statement of the Problem

As urban development necessitates built and transport infrastructures, environmental management problems including pollution, emissions from transportation and unbalanced land use produce negative effects on the economy, leading to urban poverty, a lower quality of human health and most of all, the survivability of Earth's

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ecosystems (Bruntland Report 1987; Ries et al. 2007; Portney 2013; Haughton and Hunter 2004). Furthermore, the rapid growth of urban infrastructures to accommodate population growth is correlated to an increase in urban demands for developers to *demonstrate* sustainability through balanced use of renewable and non-renewable resources in constructing buildings, against cost savings, maintenance and energy consumption (Ghaffarian Hoseini et al. 2013; Ries et al. 2007; International Energy Agency 2019; World Green Building Council 2018; Williams et al. 2001). Inevitably, the problem of sustainability comes with hard issues of costs to design, construct and maintain, and related utility usage costs which, in the case of commercial properties, affect real estate values and the economic costs of tenanting those buildings (Edwards and Naboni 2013; Kibert 2016; O'Brien 2014; World Green Building Council 2018).

1.2 Significance of Research

Global awareness on sustainable living grew out of the simple wish to improve environmental features that sustain society's health and well-being, provide access to all, while stimulating and benefiting economic growth in densely populated city areas, a new paradigm essentially known as "smart urban growth" (Portney 2013: pp. 123–150).

"Smart" in the sense that buildings recognised for achieving universal sustainability standards aim to nurture occupants' long-term well-being, meeting users' social needs to enjoy healthier surroundings, strengthen human and cultural connections, while mitigating environmental impacts through methods, systems and technologies of construction, development, operations and maintenance which conserves time, energy, space and costs (Kibert 2016; Portney 2013; Haughton and Hunter 2004).

Whether for residential, industrial or commercial purposes, existing or new buildings are now directly implicated in considering design approaches which integrates solutions to the problems causes by ecological and climate change conditions to be mitigated (Santamouris and Kolokotsa 2016; Edwards and Naboni 2013; Wheeler and Beatley 2014; Ghaffarian Hoseini et al. 2013; Williams et al. 2001). However, most studies show growth as measured for quantitative (efficiency, cost savings) rather than qualitative (social impact, health and well-being) outcomes. It is undeniable that architects and designers shape the quality of living and environment indirectly through buildings, landscape and interior design planning, yet ostensibly, the imbalance of stakeholder participation derived from a lesser number of architects and designers being directly implicated in issue discussions related to conservation (Kibert 2016; Williams et al. 2001). The momentum towards assessing their contributions took a turn in the last three decades.

This paper aims to understand the pertinent issues through qualitative case study descriptive methods. By doing so, the researcher hopes to contribute towards encouraging architectural design scholars and researchers to understanding the concepts and approaches of sustainability in architectural design as a reflection of the inter-linkages between human, surroundings and natural systems.

1.3 Research Objectives and Hypothetical Questions

The main objective of this paper is to review significant theoretical perspectives of the architectural design community's literature on sustainability, and to bring a more intense awareness on the issues of human-nature sustainable living challenges, such as wastage, resource optimisation with regards energy and water, and the beneficial impacts of green design choices on the social well-being of occupants and users. Another objective is to determine the extent of natural resource preservation possible in the process of developing and constructing green building systems. In an early review of studies on interlinks between architectural design and sustainability, the researcher asks.

- *How far has construction industry adopted green building design principles in practice?*
- *How impactful is green building design principles among industries' practitioners?*
- *How do sustainable strategies such as Net Zero Energy and rainwater harvesting reduce resource use?*

Towards understanding current sustainability challenges to architectural design, the literature undertakes a critical review of the fundamental theories, principles and philosophies of sustainable building design methodologies.

2 Literature Review

Sustainable environmental design undoubtedly influences urban lifestyles and quality of human health and living, in accordance with United Nations' World Commission on Environment and Development's report, *Our Common Future* (Bruntland Report 1987). The blueprint laid the ground principles for sustainability, saying that a sustainable form of development must aim to "[meet] the needs and aspiration of the present without compromising the ability of future generations to meet their own needs" (Bruntland Report 1987: p. 49).

To discuss this complex issue from architectural, economic, social, ecological and sustainable design perspectives, one of the recognised conceptual frameworks guiding

global sustainable development strategies, the *Whole Building Design* (WBD) will be reviewed, defined and further examined in the next section on sustainable design ideology.

2.1 Defining Whole Building Design

According to National Institute of Building Sciences' Whole Building Design Guide, a green building achieves the classification of being a "high-performance whole building" by maximising its design to be successfully "cost-effective over its entire lifecycle, at the same time, is safe secure, accessible, flexible, aesthetic, productive and sustainable" (Whole Building Design Guide 2019). Additionally, a green building must demonstrate effective application of design foremost for cost-effectiveness. Due to their role as direct contributors to environmental damage, especially in the emission of greenhouse gases, the primary source of global warming and climate change, the structural form has to demonstrate its smart design capacity in lowering, reducing or mitigating environmental impact, resource wastage and carbon footprint (Whole Building Design Guide 2019).

Another objective of green buildings is to enhance or improve the quality of life of occupants and users. Environmental design principles are holistically integrated through adopting passive techniques and technologies which enable smart design to be leveraged through material choice, operational systems using renewable sources for ventilation, day-lighting, heat gain or heat loss, spatial optimisation and climate-based solutions (Whole Building Design Guide 2019). Lastly, green buildings incorporate design thinking processes through stakeholders' collaborative, participative methods to seek solutions, reflecting the social construction of architecture as a key indicator of its long-term sustainable performance (Whole Building Design Guide 2019). In short, *a well-designed whole building is designed to meet its users' needs and goals and orientated towards meeting environmental conservation ends.*

2.2 Ecological Issues and Architectural Sustainability

Natural resources are rapidly succumbing to human demands for infrastructural expansion to accommodate living needs. While the usage of natural resources is unavoidable, irresponsible culling of resources aggravates efforts to sustain them for future generations.

Deterioration of resources and disruption to natural ecosystem food chains have escalated in the past thirty years, with scientific evidence pointing to worsening climate change conditions brought about by land use disparities which are affecting more ecosystems and along with it, the well-being of global populations (Williams et al. 2001: pp. 84–96).

A bleak future scenario was described in the Brundtland Report (1987: p. 35) in such terms:

> Little time is available for corrective action. We [may even be] close to transgressing critical thresholds. While scientists continue to … debate [the] causes and effects, in many cases we already know enough to warrant action. This is true [in regions facing threats such as] desertification, deforestation, toxic wastes, and acidification; it is true globally for such threats as climate change, ozone depletion, and species loss. The risks [have increased] faster than … our abilities to manage them.

In addressing such pressing conditions, sustainability advocates seem to be fighting an uphill battle to deliver results of green performance; while at the same time, the thirst for energy, water and non-renewable resources such as fuel and nature-derived building materials have not subsided (Williams et al. 2001: pp. 46–53).

Often-cited are examples of urbanisation impact upon large forested areas in once-pristine regions. Forest management authorities, for instance, find that the economic incentives for land use conversion clash with sustaining of indigenous lifestyles (Bettinger et al. 2017; Siry et al. 2015). Thus, problems of resource exploitation lie at the heart of forest management to ensure logging processes and timber production adhere to strict certification and stewardship requirements such as indices provided under the *Leadership in Energy and Environmental Design* or LEED® guidelines of the United States Green Building Council (USGBC 2003).

For industries, climate change adaptation including low-carbon and low-energy alternatives is crucial in the era of "new energy realities" (Blue Planet Prize Laureates 2012: pp. 17–18, 77–81). Preservation and restoration of habitat biodiversity, the other important elements of sustainability, were often neglected and taken for granted, yet today, built sectors have started to embrace its holistic philosophy by demonstrating the benefits of ecological biodiversity in the planning and design of health-giving spaces which support living ecosystems, e.g. residential landscaping, forested tracts, nature parks and urban lakesides (McLennan 2004).

Another issue is the over-justified notion of preservation to measure performance of sustainable buildings (Todd 2016), particularly ways to minimise usage of non-renewable resources. On this, there are sharp disagreements between classically trained economists seeking empirical model and data validation to show environmental and social well-being compromised or affected by unsustainable development (Williams et al. 2001: pp. 1–5), and environmentalists seeking justice through policy changes "here and now" for over-stressed ecological systems and populations suffering various harmful effects of unsustainable development (Illge and Schwarze 2006).

Field theories from both economic and environmental disciplines provide a breadth of literature and studies on the empirical testability of urban design quality, but the dichotomies of functional performance versus social benefits and aesthetic values of urban design provoke ongoing debates in academia and industry (Todd 2016; Illge and Schwarze 2006; Dovey and Pafka 2016). In between these arguments are questions of equitable spatial uses in terms of economic viability, environmental impact and cultural diversity, but how these affect the broader social environment, remain unanswered (Pearce and Barbier 2000). Attitudinal contrasts arise from "which end of the yardstick" from where one might view sustainability. While adopting green building designs may satisfy health and well-being indices and reflect positively on architectural and construction firms, some scholars believe green practices are ineffective in the long term due to lack of proper industrial knowledge of performance assessments and policymaking for what makes green design choices and techniques sustainable.

Scholars discussing green building advantages and disadvantages argue that among these difficulties, chief is the voluntary nature of standards and certification processes (Edwards and Naboni 2013; International Energy Agency 2019; O'Brien, 2014). As disclosure of relevant information isn't fully regulated in every country, the onus is on urban planners, construction engineers and architectural designers to demonstrate consistent proof that the environmental benefits of green buildings outweigh sustainability platitudes, not merely for the sake of developing codes, labels and rating systems (Illge and Schwarze 2006; Whole Building Design Guide 2016; Wu 2014).

Some researchers believe the concept of ecological preservation and architectural sustainability should be approached as a medium-term, risk-calculated, balanced and pragmatic demonstration of *stewardship of both renewable and non-renewable sources* (Pearce and Barbier 2000: pp. 263–268). Non-renewable materials derived from natural environments such as minerals, coals and oil should be assessed carefully for suitability as a long-term economic asset in construction, obtained and used with care; but renewable sources such as sunlight, energy, water, fish and forest timber must be harnessed and effectively integrated into architectural design of buildings and facilities for its many benefits (Wheeler and Beatley 2014: pp. 255–256).

While mindful of the usage of non-renewable resources such as timber and other forestry products, other green design advocates also believe these "admirable and challenging endeavours" are ill-defined outcomes, producing an unresolvable, dual conflict of objectives: that of resource preservation while ensuring no further decline in environmental quality (Bettinger et al. 2017: p. 201). Nevertheless, these two pillars of sustainable practice serve as crucial leverage to achieve a successful foundation for eco-architectural design.

2.3 Social Well-Being and Architectural Sustainability

From the previous century, leading modernist architect Wright (1943: p. 344) took his famed organic architectural design ideology to the limits of aesthetic living, declaring that architects must instinctively avoid building for the sake of commercial vanity, or in mere lip service of political ambitions. To Wright, the hallmarks of organic architecture reflect nature by providing spaces for human conduct to be expressed in society.

In demonstrating architecture's social benefits through the twenty-first century, a less-studied knowledge area for contemporary researchers is to understand the relationships between aesthetic enjoyment, ecological biodiversity, social enablement and health benefits of planned urban landscapes (Wright 1943). However, inasmuch as conceptual models suggest that sustainability increases social interaction and improves perceptions of quality of buildings, the surroundings and neighbourhood, there have also arisen concerns among architects about design's ignorance of building science in the construction, operation and management of green buildings (Wu 2014: p. 58): "… they [propose] too much glass, they are over-ventilated, they are leaky to air … they rely on gimmicks and fads rather than physics."

The agility of industry response is also affected by the industrial inheritance philosophy. Unyielding traditions learned and passed down as generational knowledge of architects, designers, engineers and related professions is hard to obviate (Siry et al. 2015; McLennan 2004: pp. 86–87). Construction industry studies show that in the process of developing best practices, material and technological selection are often the biggest pain points, as capital outlays for green building innovation systems do not accord with economic engineering's desired outcomes (Illge and Schwarze 2006; Pearce and Barbier 2000). Where once pride of workmanship implied the use of "The Best Quality Materials", today it must demonstrate awareness of "The Greenest Design" instead (Lowe 2010). Where stiff construction market competition, financial constraints and realities of fluctuating economic cycles make it hard to proposition costly green design concepts, older building owners caught in rapid urbanisation could find it less efficient to adopt practices such as energy-saving or green waste management systems and technologies. Nevertheless, the Sustainable Construction movement posits that sustainable architecture and built designs are crucial factors behind smart growth (Kibert 2016; Ries et al. 2007). Along with a shift of orientation towards human health, sustainable construction

must monitor the use of scarce or rare materials that are harvested or removed from sites, destroying vegetation or biodiversity of forested tracts.

Architecture and urban design critics Dovey and Pafka (2016) use qualitative design thinking tools to map spatial knowledge under *socio-spatial* frameworks of sustainability dynamics, complementing data findings from empirical assessment of urban designs. Mapping classical ground theories by *New Urbanism* scholars such as Christopher Alexander, Gordon Cullen, Kevin Lynch and Jane Jacobs, they offer insightful evidence of the social and communal benefits of aesthetical grids such as walkways, squares and informal clusters of spaces arranged into "open villages". Other researchers recommend a balance between *quantitative* tools to gather data from cost–benefit assessments and *qualitative* scales and techniques to identify where sustainability may be established through measuring variables such as productivity, absenteeism and user safety awareness (Ries et al. 2007).

In summary, understanding the interlocking factors which affect the socio-spatial planning and economic decision to construct green buildings as part of urban development are salient from the developers' point of view, as managing and measuring performance in the long run *must not* defeat the accrued advantages of positive image and well-being benefits (Whole Building Design Guide 2019; Dovey and Pafka 2016; McLennan 2004).

The following sections examine two important criteria for green building assessments: Net Zero Energy and Rainwater Harvesting.

2.4 Role of Energy Reduction as Sustainability Solutions

Statistics on energy security from the Efficient World Scenario published by France-based intergovernmental policy adviser The International Energy Agency (2019) shows that mitigation of climate change must prioritise sustainability principles as a strategic thrust for future built environments such as workplaces, the latter being responsible for over 40% of current energy consumption and the same amount is discharged as carbon dioxide emissions.

A review by Ghaffarian Hoseini et al. (2013) found that renewable energy systems such as thermal cooling and solar (photovoltaic) energy can be practical and sensible resolutions in reducing carbon emissions of green buildings. However, findings from the authors point to an *integrated approach* combining renewable systems with conventional *heating, ventilation and air-conditioning* (HVAC) systems may enable building owners to respond better in longer term considerations of costs, maintenance and operational factors.

Similarly, Konstantinou and Prieto (2018) suggest a *combination* application of passive and active techniques for energy consumption management such as solar power harnessing, bioclimatic designs and heating systems for the overall reduction of energy consumption demand, as both types of measures would also help achieve the architect's "design ambition".

Researchers studying perceptions of green architectural design benefits have also given extensive framing to show architect and construction practitioners' slow and gradual response to urban heat island mitigation solutions. For instance, Voss et al. (2011) question impediments such as local industries' readiness and acceptance towards passive thermal cooling systems which affects the perceptions of net zero energy advocacy as either an expense or an investment by the end consumers (e.g. homebuyer or property owner), as installation of technologies that save energy and optimise renewables such as photovoltaic systems to cull solar energy may not be high on their consideration list.

2.5 Net Zero Building as Sustainability Solution

According to the World Green Building Council's recent Net Zero Carbon Buildings Commitment Challenge, the construction and developer sectors have the greatest potential for significant reduction of greenhouse gas emissions versus other industrial sectors (World Green Building Council 2018). Research acknowledges that sustainable building construction comes with disaggregated risks, including costs of buying efficient equipment, material manufacture, energy consumption for design decisions (e.g. whether to build car-parks or garages above- or underground), etc. These factors raise concerns about tracking and publicly reporting the building's long-term performance such as carbon footprint, resource consumption and emissions. Some studies show that construction sector has yet to yield to transparent accounting practices, for instance, in reporting of energy and water usage, or information on material usage (Kibert 2016: p. xv).

Long run energy consumption of commercial infrastructures should be properly addressed. Haughter and Hunter (2004: p.105) found that energy usage of artificially lighted modern offices takes up 30% of UK's energy supply, pointing to inefficient systems that could be avoided if passive day-lighting through sun-orientation, solar heating panels, draught-proofing and wall insulation were built into the design ethos to start with.

Net zero energy solutions for interior spaces have been studied for tropical architectural designs within model township developments in Asian countries, particularly the use of bioclimatic designs such as solar shading, glazed fenestrations, vestibules, natural ventilation and insulating materials, combined with conventional lighting and air-conditioning systems to assure thermal comfort in

reduced energy-dependent surroundings (Lenoir 2013; ERIA Research Project 2017).

2.6 Rainwater Harvesting as Sustainability Solution

Rainwater storage is a method for recycling a renewable source. Rainwater harvesting ensures continued supply for consumption, long-run reduction of water bills and mitigating the impact of water runoff on soil erosion.

Literature shows plenty of evidence of water conservation benefits. Young (2013: pp. 177–188) acknowledges the conservation heritage movement in the UK in writing about the sociocultural impact of plants from a horticulturist's perspective, offering descriptive narratives in discussing the carbon mitigation and rainwater absorption capabilities of trees; hence, the value of trees as conservation agents makes them important for sustainability practices in counteracting greenhouse gas emissions and air pollutants.

Rainwater harvesting help conserve water use especially in areas with extreme aridity, or where consumption demands burden the environment's natural ability to replenish supplies (Haughton and Hunter 2004: pp. 209–210). *Passive* water conservation methods involve barrels or tanks connected to downspouts for reuse of rainwater from vegetated catchment basins; green roofs for storm-water management; and *Active*, where captured rainwater is collected via distribution systems attached to pumps, to discharge grey-water for landscape irrigation, sidewalk washing and flushing of toilets. Active methods also incorporate filtering and treatment technologies to enable reuse of potable water for evaporative cooling for power plants (Sustainability Certification 2013; WBDG 2018). WBDG (2018) calls for equal consideration of energy use to be monitored in pumping, supply, sewerage, treatment, transportation and storage of potable water for recycled use.

Overall, literature review conclusively shows there to be decidedly an earnest strive among industry stakeholders, business sectors and environmental agencies to drive the ambitious global green building agenda forward, underscoring that investments into sustainable urban design innovations require vision and courage in making positive change through equitable, sustainable growth, balanced with ecological preservation strategies and social responsibility.

3 Research Methods

Through a summary review of literature, two factors are found to interplay crucially in green building construction and development: Firstly, the practical *efficiency* of designed systems such as rainwater harvesting, and secondly, the *cost-efficiency* of resource consumption such as energy and materials, which compounds into operational savings.

A third will be considered in this research, namely, the challenges of implementing *whole building design* (WBD) principles which harmonises both ecological and sociological functions and involves stakeholder participation, enabling sustainable urban development and smart growth.

LEED®-certified buildings have been shown to improved efficiency as features for improved cost savings. Such shifts are becoming increasingly tangible today. As studies suggest, the commercial valuation of green buildings has a less-romanticised sheen, incorporating more pragmatic considerations of construction costs as well as leveraging on competitive gains such as real estate tax incentives for responsible material usage, disposal and recycling, renewable energy consumption for built environments and cost-saving designs (O'Brien 2014).

Urban sustainability design in qualitative case methodology, conceived as a multidisciplinary field, enables research to draw out real-life complexities that influence local decision-making, affecting business owners, employees, taxpayers, residents, social advocates and environmental stakeholders alike. To analyse how far WBD principles have been successfully applied, two case study examples of green building implementation are discussed.

4 Analysis and Interpretation of Case Study

Case studies detail approaches based on harnessing ecological and social benefits of sustainable architectural designs. Both projects exemplify astute efforts in conceptualising, constructing and maintenance of green building and their facilities, allowing insights on functional and conducive design for users, pragmatic in its means and ecological in its ends.

4.1 Heifer International Headquarters, Arkansas

This is a reclaimed brownfield project borne out of an industrial rail-yard, located within walking distance of a new light-rail transit transport hub in Little Rock, Arkansas (Fig. 1). Principle architect Rowland et al. (2008) explained that the building, headquarters to an American non-profit charitable organisation that alleviates Third World hunger and poverty, have shown exemplary resource stewardship, enabling building owner Heifer International (2018) to demonstrate its "gifting" philosophy of energy conservation and water conservation measures.

Designing process began from collaborative brainstorming between the client directors and external consultants who

Fig. 1 Heifer International Headquarters in Little Rock, Arkansas. BNIM (2006). Heifer International Headquarters. Retrieved from: https://www.bnim.com/project/heifer-international-headquarters

were responsible for researching its form, seeking construction suppliers and designing the four-storey building envelope to achieve goals of net zero energy optimisation, user comfort and improved productivity (Rowland et al. 2008; De Sousa and Testaguzza 2013).

Water conservation became a foremost strategy; through retention, recovery and recycling methods that involved rainwater harvesting to reuse for cooling towers, waterless urinals, low-flow lavatories and collected condensation from ventilation unit, a 65% reduction of potable water was achieved (Rowland et al. 2008; De Sousa and Testaguzza 2013). Floor planning maximised views of river and sunlight streams in on all open offices and gathering spaces, including overhanging balconies which screened a restored wetland wrapping three sides of the building (Journal of The American Institute of Architects 2009).

On top of earning an *American Institute of Architect* (AIA) Honor Award, gaining USGBC LEED® Platinum certification shows the building's capacity for sustainable, functional performance through excellent scorecard ratings under all categories including Site Sustainability, Energy and Atmosphere, Water Efficiency, Indoor Air Quality, Design Innovation, as well as creditable scores for its Material and Resource use (General Services Administration 2009: pp. 77–79; Journal of The American Institute of Architects 2009).

Among its achievements, the building was awarded a site sustainability rating of 12/14, through usage of 97% for recycled building materials to offset costs of demolition, and the choice of redeveloping a brownfield site. Energy optimisation was gained via north–south daylight orientation, ensuring that floor areas were within 30 ft. (9 m), while thermal comfort was maintained via an *underfloor air delivery* system (UFAD) with less pressure compared to overhead ventilation systems which mixes warm ambient air at the ceiling with ventilated air streams.

4.2 The David and Lucile Packard Foundation Headquarters, California

Actions before, during and after construction development are crucial to assess how much materials selection and building processes contribute in mitigating negative environmental impacts such as wastage minimisation, energy consumption and control of pollution during construction. The David and Lucile Packard Foundation implements net zero energy by offsetting 100% of the building's energy needs through solar roof electricity production (Fig. 2). It recycles 95% of construction materials from pre-existing buildings to minimise waste, while wood features such as red cedar and eucalyptus are sourced from *Forest Stewardship Council* (FSC), certified sources, within 500-mile radius from site.

Sunshade and control of glare were achieved through overhanging roofs, indoor and outdoor blinds and trees, with outdoor courtyard doubling as informal meeting spaces, surrounded by a Californian-inspired landscape incorporating native plants, ensuring landscape heritage is preserved from using 90% Californian species, with native pollinators, birds and insects drawn to the plantings and rain-permeable paving forming part of its green landscaping. The interior work environment has open ventilation fenestrations and avoids VOC-infused paint materials that have potentially health-harming emissions.

Water use is reduced by 40% involving strategies such as green roofing and vegetated gutters for rainwater collection,

Fig. 2 The David & Lucile Packard Foundation Headquarters. American Institute of Architects (n.d.). Retrieved from: https://www.aiatopten.org/node/403

as well as a 20,000-gallon water storage facility for irrigation and toilet flushing. Stored water further generates energy for passive thermal comfort use. These are key characteristics of resource conservation strategies that have earned the Foundation both Net Zero Energy Building™ award and LEED® Platinum certification (The David & Lucile Foundation n.d.; The American Institutes of Architects 2012; The Packard Foundation 2012).

5 Discussion of the Study

The Heifer International Headquarters in Little Rock, Arkansas and The David and Lucile Packard Foundation Headquarters in California are elaborate initiatives to measure the impact of green buildings involving systems of assessments through quantitative and qualitative data under the LEED® certification programme. As a recognised green building index, LEED® provides a set of evaluation guidelines developed to articulate building sustainability (Whole Building Design Guide 2016).

These assessment indices have improved architectural design and industrial understanding about the scale of environmental impacts from material manufacture, transport, pre-construction processes, energy and water conservation and efficiency management systems, as well as providing nature-supportive landscaping design, but at the same time, they pinpoint the impossibly wide range of other non-tangible assessable factors that must be integrated into ecologically responsible designs, which WBD principles may not currently encompass.

These include perceptions of institutional image and aesthetic improvements of surroundings, and relationships to improved user well-being and productivity, indoor environmental quality, occupants' safety from hazards, equal access and inclusiveness of design for all users.

There are many ways for architectural designers to implement sustainability into built designs, but ecological impact stands as the key source of inspiration to challenge practitioners to develop better systems and solutions that work within defined parameters of urban sustainability policy requirements it (Titheridge et al. 2001; Hinrichsen 1987). Hypothetically, it is suggested from findings that *green buildings are enablers for smart urban growth and sustainable development when efficiency and social impact conjoin*.

The processes *before, during and after* construction should demonstrate vital design planning intelligence, including details such as orientation to sunlight and geographical location, climatic variability, non-renewable resource usage, replanting in deforested areas. Initial stages of design planning and development must include factors of emissions during construction, chemical or fume discharge from transportation vehicles and recycling of material packaging wastes (Bruntland Report 1987: p. VI. No. 105).

Despite scientific research and development investments into sustainable architecture, green buildings have been called the antithesis of sustainable urban development, with unrealistic ideologies and benchmarks assumptions projected as achievable goals to be targeted. Findings suggest that architectural design on its own may not solve many existing problems of energy efficiency or non-renewable material conservation (Kibert 2016; Haughton and Hunter 2004; Rowland et al. 2008). Furthermore, changes to urban planning and environmental management policies directly affect economic decisions for the adoption of green building principles (Williams et al. 2001; General Services Administration 2009).

Case studies imply WBD principles as smart strategies of achieving sustainability by preserving renewable resources, but these efforts mean little without effective stakeholder involvement, governance, monitoring and reporting before, during and after its construction.

As Hinrichsen (1987: p. 8) notes, the governance of natural resources is impossible since air, water and soil cannot specifically be quantified in national or business accounting, hence, a key impediment to the "marriage of economics and ecology" seem to be the "fragmentation of responsibility" up and down the chain of policymakers in the pursuit of sustainable development.

6 Conclusion

Thus, architects, designers, urban spatial planners and authorities must work together to overcome the compartmentalisation of conflicting responsibilities, with efforts to change unyielding systems through brainstorming and dialogue exchanges.

Questions raised in answering them, this paper showed how sustainability is possible in facing resources demands and limitations, but in the final argument, the holistic management of green buildings must go beyond tokenism and lip service. Whole building design principles are proven to lessen ecological burden that comes with urban development but there is a tussle between perceptions of costliness versus ecological and social benefits that green buildings proport to offer (O'Brien 2014).

To address the cost issues, a joint social responsibility agenda is necessary among construction sector, developers, architects, designers, urban planners and environmental authorities, to emphasise productivity increase, social well-being and long-run savings by educating stakeholders the on underlying soundness of green architectural design. Additionally, there should be room for stronger construction and developer sector transparency in monitoring and

reporting sustainability adoption, implementation and performance measurement; overall adherence must be benchmarked against recognised sustainability models to attain improved conservation ratings.

This study has put a more intense focus on institutional social responsibility agenda which underscores all actions which directly impact building users and the environment. Aside from essential industrial sector stewardship and environmentalism education, green building performance should be monitored for long-run negative environmental impacts as well.

Integration of smart urban resource conservation strategies including net zero energy solutions, daylight optimising design, rainwater harvesting systems, as well as other pragmatic ways of reducing users' carbon footprint from transportation and travel while ensuring occupants' thermal and spatial comfort through blending ecological elements, continue to make up key indices of sustainable design solutions that give consumers, the construction industry and architectural practitioners to foster greater green architecture uptake for buildings of the future.

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Applying Sustainable Principles to Create New Urban Areas and Developing Existing Cities in 2030 Vision of Saudi Arabia

Wael A. Aboneama

Abstract

This paper attempts to explore sustainable determinants to create new urban areas and developing existing cities in Saudi Arabia. They are looking to enhance their economic resources and social needs by 2030. They announced their vision for the next 15 years based on specific dimensions; social, economic, and urbanization. Saudi Arabia has plenty of challenges and obstacles that face sustainable development. Meanwhile, it has many potentials to play a leading role during the implementation of the 2030 vision. Most of its land is desert and suffers from a lack of potable water resources. Also, it has severe weather conditions. On the other hand, it has one of the most stable economies in the world which is based mainly on petroleum production. It is the second-largest oil producer. It has a big potential for generating renewable energy from solar energy and wind power. In 2030 vision, Saudi Arabia is looking to create new urban areas to support its economy and develop existing cities. NEOM is the largest project of its 2030 vision with approximately budget of 500 billion US dollars. Sustainability is not an option for its vision. It should be the keyword for any development in this country, as a result of its challenges and potentials. Saudi Arabia should work through a strategy which aims to keep environmental, social and economic needs as the main target for creating new urban areas and developing existing cities.

Keywords

Sustainable principals • New urban areas • Developing existing cities • 2030 Vision of Saudi Arabia

1 Introduction

Saudi Arabia does not suffer from a lack of resources, on the contrary, it has plenty of them. The problem is that they do not exploit or use their resources for upcoming generations and towards a better sustainable lifestyle. Decision-makers in Saudi Arabia now believe that oil resources play a far less significant role in the economy than before twenty-first century, and oil resources will not be the main energy resource than has historically been the case (Kinninmont, 2017). Each one of the three pillars of sustainability which are environment, economy, and society needs applicable strategies to develop Saudi Arabia's cities towards a sustainable lifestyle. That was the reason for the 2030 vision of Saudi Arabia. They are planning to create new urban areas for economic and social reasons, as the big portion of their investments will go towards those new cities.

Saudi Arabia now has two kinds of cities; existing cities, and new cities. 2030 vision looks for new areas of investment and enables the growth of creating new cities and provinces such as NEOM for new technologies (Kinninmont, 2017). On the other hand, Saudi Arabia has unique religious tourism that does not exist in any other country in the world for pilgrims to Makkah and Madinah Fig. 1 (Statista, 2017). Sustainability is the core philosophy of Saudi Arabia vision. There are several aspects such as transportation, CO_2 emissions, freshwater resources, and generating renewable energy those resist the development of Saudi Cities.

Urbanization was a characteristic of Saudi Arabia showing a rise in percentage living in urban area from 46% in 1974 to 81% in 2004: variations from one administrative area to another; increase in the number of cities; the east–

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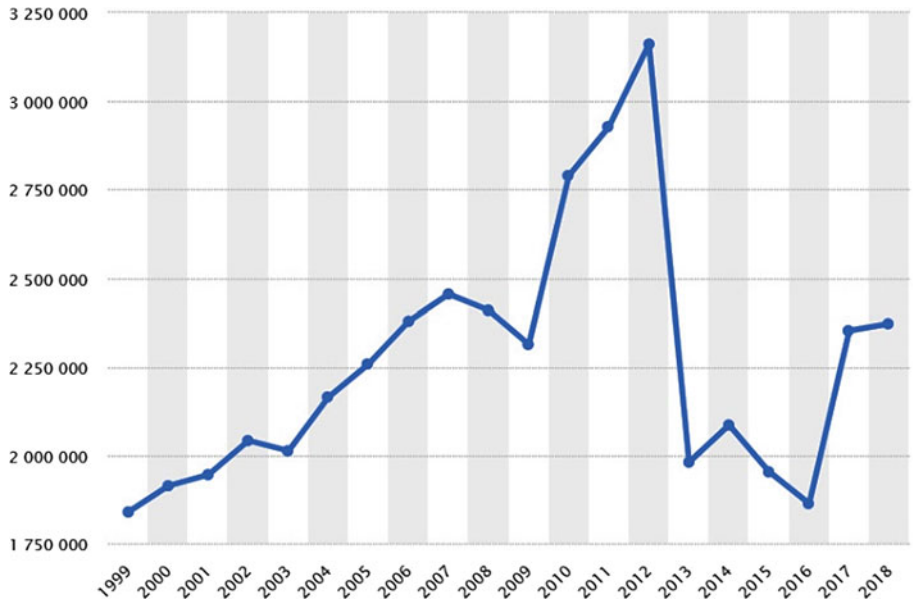


Fig. 1 Illustrates the number of pilgrims to Makkah in hajj season

west corridor of urban growth and differential growth rates. Residential mobility in the Kingdom during the last three decades were, majorly, long distant movements related to buying and building a home, increase in family size or capability to afford a better dwelling apart (Salam, 2014).

Sustainability is focusing on protecting the environment for future generation through decreasing CO_2 emissions and exploring all potential resources to get freshwater for human and agriculture use. Besides, creating sustainable multiple resources of economic income. Finally, it considers the social culture and habits to strengthen the relationship between society and their lands.

2 Literature Review

2.1 Transportation in Saudi Arabia

Transportation is a key component of the service sector in every economy and indeed is the engine for economic development. It is one of the most important issues for sustainable design because of its emissions (Personnel et al., n. d.). Road traffic accidents are the major danger for people that record the highest cause of death in Saudi Arabia (Dahim, 2018). Saudi Arabia is one of the top twenty fossil fuel CO_2 emitting countries by total emissions (Rahman & Al-Ahmadi, 2010) Fig. 4 (Henriques, 2016). The demand for gasoline and other transportation fuels has been increasing progressively over the past decades and is expected to increase more and more in the future. The local consumption of oil products has increased at an average rate of 24% over the last 20 years (Rahman & Al-Ahmadi, 2010). Unfortunately, a private car is the main transportation tool in Saudi Arabia until now Fig. 2 (Mohammed, 2016). Even big cities that have means of public transportation Fig. 3 (saudiarabiaofw.com, 2016), the private car is the main tool. Saudi Arabian and other Gulf cities are described as dependent on the private vehicle and currently, they try to overcome the obstacles of planning an effective and sustainable public transport system (Aljoufie, 2016). Riyadh, Jeddah, Makkah, Madinah, and Dammam are the only cities that have public transportation Fig. 5 (Authority, 2016). On the other hand, Saudi Arabian culture is to buy big cars with high engine performance which are the highest consumption engines in the world. Transportation plans and infrastructure are fundamentals for sustainable city development and creating new urban areas in Saudi Arabia.

Transport of goods inside Saudi Arabia is not much better. It depends only on heavy trucks which affect negatively the environment by their emissions. There are no railways for the transportation of goods between big ports

Fig. 2 Illustrates the normal view of Saudi Arabia streets and the main transportation tool

Fig. 3 Illustrates the main type of public transportation used in big cities

and the rest of the country. However, there is a plan to connect big cities in the future by railways Fig. 6 (Saudi_Arabia, 2019).

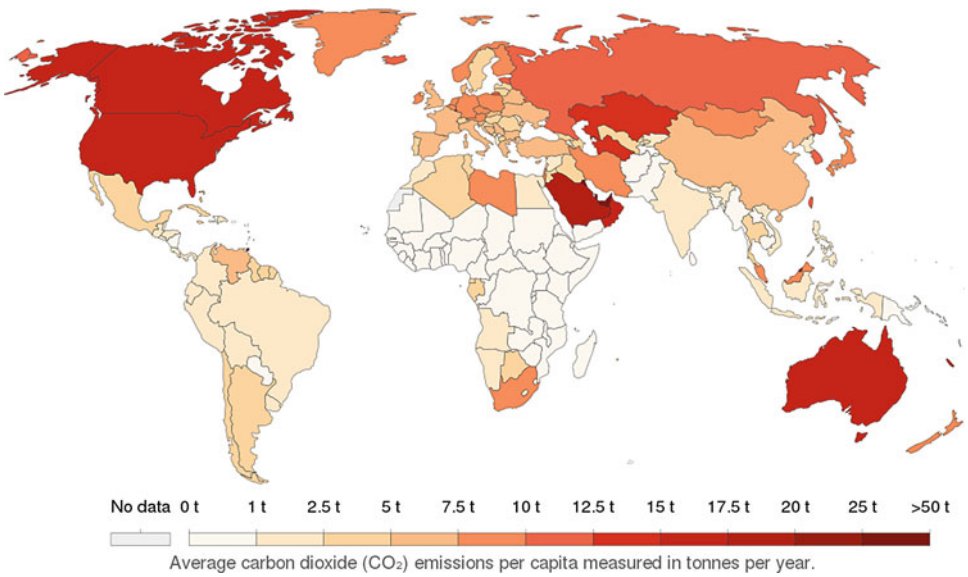
2.2 Freshwater Resources in Saudi Arabia

Saudi Arabia has 95% of its land as a desert. The rainfall range is at its minimum level. It suffers from a shortage of freshwater resources. On the other hand, it has about 2446 km of seashores (Salam, 2014). Economic and population growth imposes an ascending risen for freshwater. Freshwater resources are too limited. About 50% of drinking water comes from desalination of seawater, 40% from non-renewable groundwater extraction, and 10% from surface water, especially in mountainous areas in the southwest of the country. Desalinating plants provide householders with 30% of their demand. Saudi Arabia's consumption of desalinated water has 26% of the total in the world (Al-Zahrani & Baig, 2011). All these facts about water resource scarcity and increasing demand impose the scenario of new cities' location to be near freshwater resources. Figure 7 (Al-saud, 2010) represents the location of each type of freshwater resources. Unfortunately, NEOM city location does not consider this item which impinges the biggest challenge of Saudi's environment and one of the NEOM pillars which is sustainability.

2.3 Energy Resources in Saudi Arabia

Saudi Arabia has the biggest stock of fossil oil and the second producer of it. In the seventies, one liter of potable water in Saudi Arabia was more expensive than one liter of gasoline (Mosly & Makki, 2018). That was the reason for the delay in thinking about renewable energy resources. The richness of oil reservoirs and production led to the overuse and shape of people's culture of carelessness about CO_2 emissions Fig. 4. The main source of electricity production is fossil fuel Fig. 8 (Adminstration, 2019). The petroleum sector provides Saudi Arabia with 87% of its budget, and it acquires 90% of export earnings, and 42% of Saudi's GDP (CIA, 2011). That is the reason in which Saudi Arabia subsidizes strongly all energy products, and it is one of the cheapest countries in the world for energy. The result is the overuse of oil and natural gas resources Fig. 9 (Adminstration, 2019). If the consumption rate remains as it is up to 2030, it is predicted Saudi Arabia will consume all its production (Mosly & Makki, 2018) Fig. 10 (Adminstration, 2019). Unfortunately, there are neither laws nor roles for renewable energy technologies (RETs) usage in Saudi Arabia. Fortunately, Saudi's decision-makers designed a

Fig. 4 Illustrates CO2 emissions per capita by country 2016



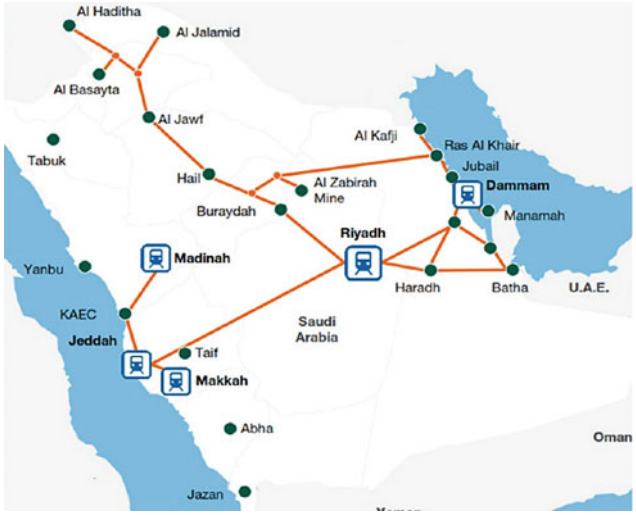


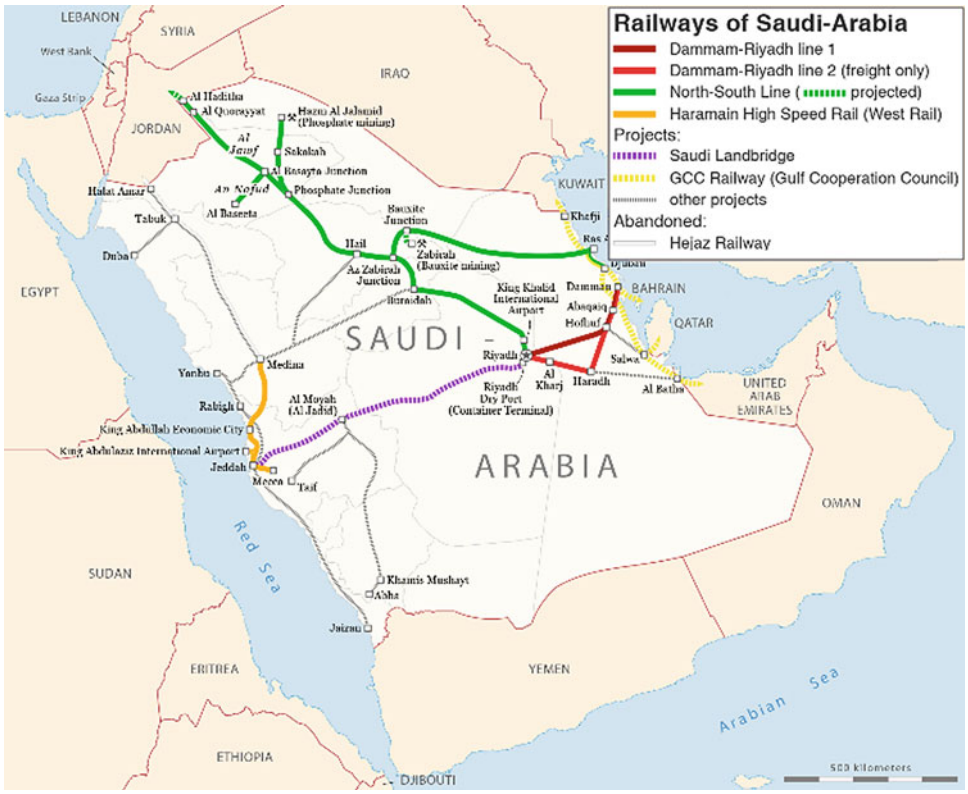
Fig. 5 Illustrates cities with the availability of public transportation inside Saudi Arabia

good plan to adopt RETs on a wide scale. Saudi Arabia's vision 2030 opens fields for renewable energy to be one of the pillars to control the use of fossil fuel and CO_2 emissions.

2.4 City Planning in Saudi Arabia

Climate conditions and huge desert areas impose big challenges on Saudi Arabia cities. The weather in Saudi Arabia is extremely hot and dry with big differences in temperature ranging from −11 C° to 51.1 C° (Susilawati & Al Surf, 2011). On the other hand, urbanization in Saudi Arabia is running very fast. In only two decades (1970–1990), people moved from rural areas to cities. In the past, rural areas were triple urban cities, but now this ratio had reversed. The population growth is at the highest rate of 3.2% between 1974 and 2010 (Susilawati & Al Surf, 2011). The parameters of the planning and development of Saudi cities do not fulfill the conditions

Fig. 6 Illustrates railway existing and vision in Saudi Arabia



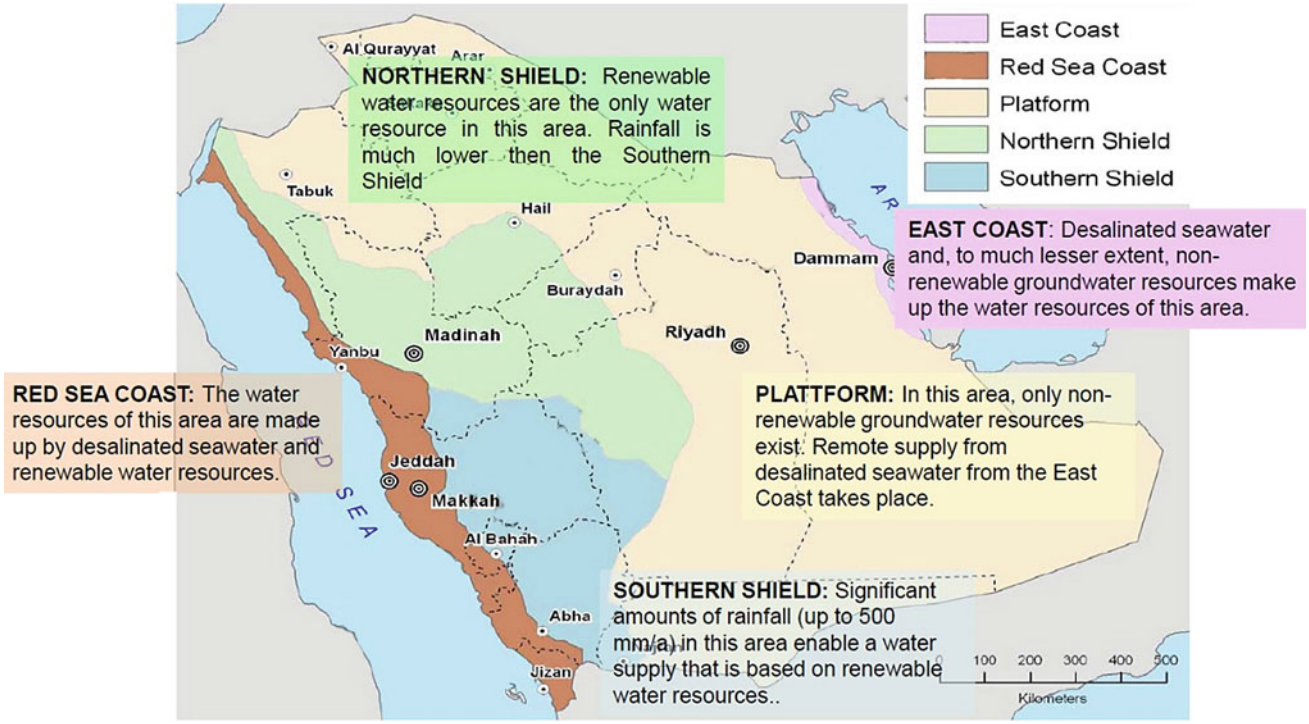
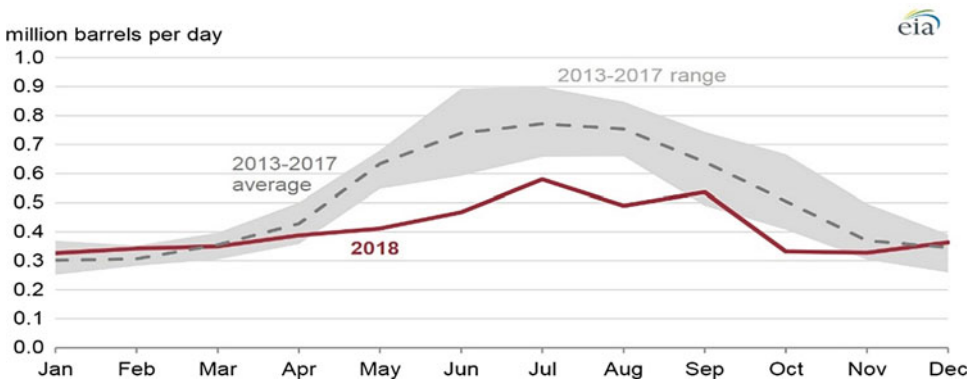


Fig. 7 Illustrates Major freshwater sources in saudi provinces

Fig. 8 Illustrates Saudi Arabia direct use of crude oil for electric generation (2013–2017)



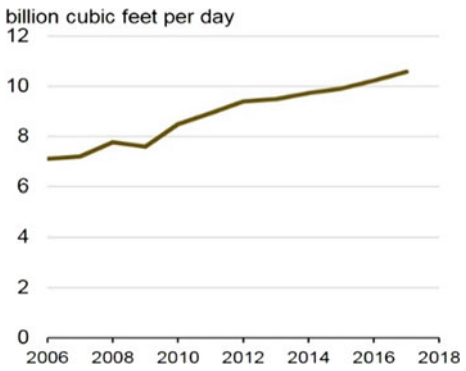


Fig. 9 Illustrates Saudi Arabia natural gas consumption

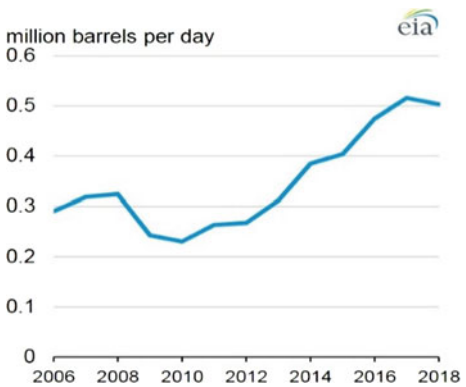


Fig. 10 Illustrates Saudi Arabia fuel oil consumption

for sustainability. Some of the issues that threaten sustainability are in the following list (Al-shihri, 2013):

- The harsh climate and lack of appropriate infrastructure.
- Pedestrian connections between neighborhoods are not considered.
- Green spaces are not considered in built-up areas.
- Lack of green building concept which is the reason for high energy consumption.
- Lack of public awareness about the importance of sustainable development. Also, Saudi people should reduce their use of energy and electricity consumption and should believe in natural resources preservation.
- Disregarding architectural heritage for dry and hot weather conditions.
- Disregarding of pedestrian connections inside neighborhoods which makes the private car is the only tool for moving short distances such as going to Masjid to pray five times per day Fig. 11 (Pour Rahimian, Ibrahim, Goulding, & Ali, 2012).

2.5 2030 Vision of Saudi Arabia

As discussed before, the main challenge for Saudi Arabia's plan is the dependence on fossil oil production. The vision 2030 tries to reduce it and to create several resources for its economy (Salman, Abdulaziz, & Saud, 2016). The vision concentrates on sustainability to play a major role in city development and creating new urban areas such as NEOM city. One of the biggest challenges in Saudi Arabia that it has a very high ratio in energy consumption per capita Fig. 12 (Mears & Wentz, 2016). That is the reason for considering to generate energy from renewable resources and searching for sustainable resources of freshwater. The vision mentioned transportation as one of the major subjects to be enhanced and moves towards sustainability.

NEOM is the biggest project of the 2030 vision with an estimated cost of 500 billion US dollars. They aim to finish its first stage by 2025. The main goal is to find new products for exportation income which are not oil products. The new city economy will depend on different types of industries and manufacturing, not oil production and its exports. The entertainment which is cinemas and concerts took place in the 2030 vision, however, it impinges with people's culture and the religious value of its lands. Saudi Arabia hasn't released a masterplan yet for what it will look like. It aims to run without fossil fuels like Burlington and Vermont in the United States, which does not come close to the planned size of NEOM (Garfield, 2018).

2.6 he General Environmental Law

The preparation for the environmental target was established two decades before. The 9th plan (2010–2014) has many environmental objectives (Al-shihri, 2013). The objectives of environmental law in Saudi Arabia and its rules can be described in the following (Ministry of Economy & Planning, 2001):

- Protect the environment and Saudi's ecology from pollution.
- Protect natural resources for upcoming generations and sustainably use them.
- Setup environmental and sustainable planning and thinking in all industrial, agricultural, architectural, and other areas.
- Raise public awareness about the importance of sustainable development. Also, Saudi people should reduce their

Fig. 11 Illustrates a sample of Saudi neighborhood and green areas ration. The circles are around locations of Masjid

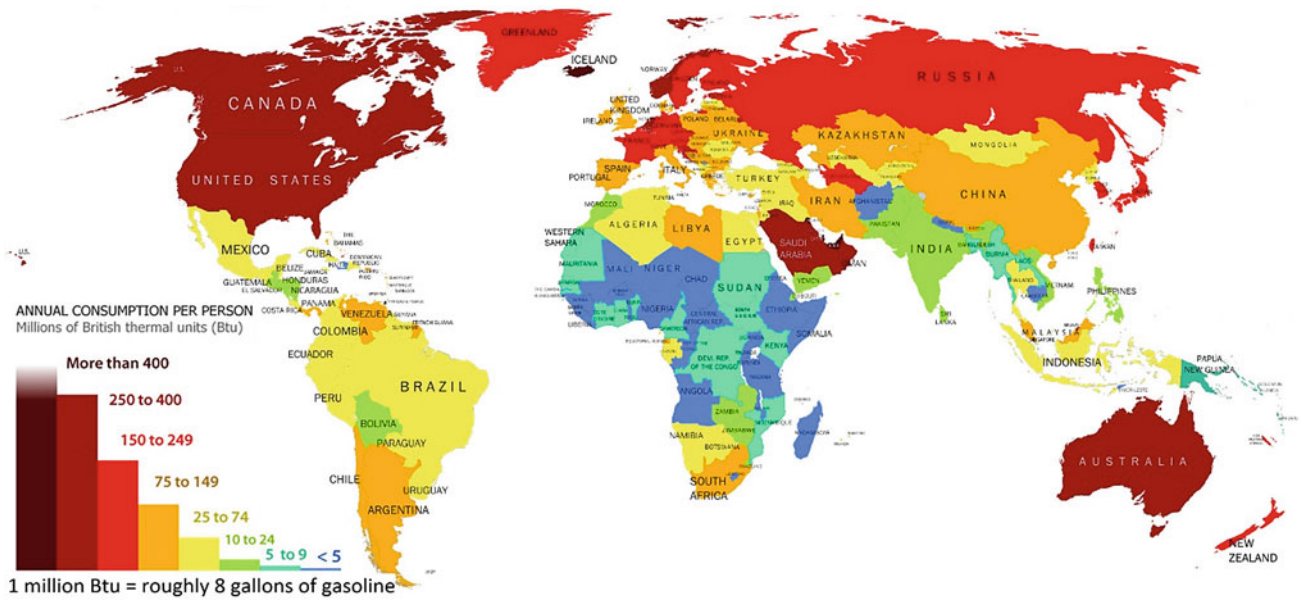


Fig. 12 Illustrates energy consumption per person by country

use of energy and electricity consumption and should believe in natural resources preservation.

- Create environmental and sustainable studies for any project and plan.
- Setup the awareness of creating and publishing reports on the results of environmental and sustainable studies.
- All studies and rules should be compatible with environmental standards.
- Make sure that environmental laws and sustainable standards are strictly applied.
- Setup strict actions to deal with any contraventions of environmental laws or sustainability standards.

3 Methodology Steps for Applying Sustainable Principles on Existing and New Cities in Saudi Arabia

3.1 Sustainable Transportation Strategies

Setup a full transportation plan based on using sustainable means of transportation is the first step towards a sustainable city. The government should eliminate combustion engine vehicles because it has a bad impact on the environment. They produce more than a quarter of the world's carbon emissions (Jeon, Asce, Amekudzi, & Asce, 2014). The plan should include attracting people to zero-emission vehicles. Saudi 2030 vision should consider the following strategies for its sustainable transportation plan:

- Facilitate importing electric and zero-emission cars and facilitate the operation of those vehicles by installing their energy supply stations all over the Saud's cities.
- Increase taxes and customs on fuel combustion cars and make the increasing ascendant with the size of the car engine and its fuel consumption.
- Encourage the distribution of economic sources among Saudi's cities to eliminate centralization. It will decrease traffic problems in big cities and facilitate the transportation plan.
- Set up a sustainable transportation plan in all Saudi's cities.
- Connect between big ports such as Jeddah and all other cities by railway network to decrease the role of heavy trucks and their CO_2 emissions.
- Enlarge the role of trains between holy cities and religious rites places for Hajj to avoid using buses for pilgrims transportation Fig. 13 (Gamal, 2017). One line is not enough at all. A full transportation study with a multi-lines operation to avoid using buses. The study should consider moving around two millions of people from one place to another in only two hours. They should facilitate the investments of constructing more than 10 lines or less and buy more vehicles to achieve the goal.
- Use zero-emission buses instead of diesel engines inside holy cities like Makkah and Al-Madinah Fig. 14 (www.almowaten.net, 2017).
- Develop a network transportation plan and shutter buses for high-density buildings such as universities and governmental buildings.

Fig. 13 Illustrates the first train used in Hajj and the number of pilgrims

Fig. 14 Illustrates the number of buses used in Hajj moving people from Arafa to Muzdalefa

- Encourage and facilitate electric charging points all over the kingdom and service centers for electric vehicles.
- Increase the awareness of sustainable transportation tool and the harmful impact of CO_2 emissions on the environment and economy.
- Increase the awareness of people to use public transportation to reduce road traffic accidents which are the first and major cause of death in Saudi Arabia (Dahim, 2018) and to reduce CO_2 emissions.

The strategy includes all Saudi Arabia cities. The government should install sustainable means of transportation in all existing cities and new urban areas. Hereby some examples of those means:

- The trolleybus is an old sustainable public transportation tool that does not produce any emissions. The advantage of these tools that it has the flexibility to maneuver in the street like a normal bus.
- Zero-emission buses and Fuel Cell Hybrid Bus are the future of public transportation. They are used successfully in all eco-cities in the world.
- Tramlines are used inside the cities and to connect between them. For example, Abha and Khamis Mushait cities are very close. The distance between them is around 30 km. They can install a tramline to connect between them. Also, big cities like Riyadh or Jeddah tram lines could be used to reduce traffic problems with zero CO_2 emissions.
- The monorail is a public transportation railway and could be installed inside heavy traffic places. It is a magic solution inside old and big cities to solve traffic problems sustainably.
- Zero-emission cars and busses are vehicles that don't produce carbon and other toxic emissions. Saudi Arabia's government should encourage people to buy zero-emission vehicles and facilitate the operation of them by installing their energy stations around the kingdom.

3.2 Sustainable Freshwater Resources

As discussed before, Saudi Arabia has one of the smallest averages of rainfall and it does not have rivers. Freshwater is one of the biggest problems facing Saudi Arabia people and decision-makers (Al-Omran, Al-Barakah, Altuquq, Aly, & Nadeem, 2015). Desalination plants and wastewater reclamation projects produce CO_2 emissions and consume a big amount of produced crude oil. Asir province has a very good average of rainfall that equals 278 mm. Asir is the only part of the Arabian peninsula that depends on rainfall harvesting for human use and irrigation. For example, Abha's dam for collecting rainfall water is one of the biggest sustainable projects in Asir Fig. 15 (Photos, 2017). Saudi Arabia receives about 8 billion m3 /year of surface runoff water during rainstorms (Guizani, 2016).

Fig. 15 Illustrates the Abha dam in Asir province

The studies explored that several cities in Saudi Arabia, particularly in Asir province, can collect and store a significant volume of potable water from rainwater, exceeding 7.5 m3/100 m2 per year (Guizani, 2016). Also, the cost of one cubic meter of harvested rainwater is cheaper than a cubic meter of water produced desalinated water from renewable energy-driven desalination plants, (Guizani, 2016). Nevertheless, harvesting rainwater can preserve cities and rural areas from the harmful impact of floods and reducing greenhouse gas emissions. The following Saudi cities can harvest rain from installing rooftop rainwater collecting systems and it is cheaper, reduce carbon emissions, and economically feasible for Saudi's economy; Hail, Jeddah, Taif, Abha, Khamis Mushait, Tabuk, and Riyadh, while it is not recommended in the holy cities of Makkah, Medina, and Buraidah (Guizani, 2016).

Saudi Arabia needs many projects like King Abdul-Aziz City for Science and Technology (KACST) which expects to finish the infrastructure of three solar power projects by the end of 2019. The national initiative for water desalination using solar energy, which includes building a desalination plant with a production capacity of 30,000 cubic meters per day, and a 10-megawatt solar power plant Fig. 16 (Argaam, 2018).

The following strategies are for creating new urban areas and developing existing cities towards sustainability:

- Creating new cities in the region that have a high average of precipitation Fig. 17 (Amin, Mahmoud, & Alazba, 2016) illustrates the average rainfall. One of the observations that NEOM city which has a huge part of 2030 vision investments is located in the least part of rainfall average in Saudi Arabia.

Fig. 16 Illustrates desalination plant in Saudi Arabia

- Creating sustainable freshwater resources for existing cities such as water desalination using solar energy.
- Increase people awareness of rainfall harvesting and water saving.
- Facilitate the types of equipment and implementation of rainfall harvesting and water saving.

3.3 Renewable Energy Resources in Saudi Arabia

Saudi Arabia depends on fossil fuel for energy generation and it is one of the highest countries for energy consumption per capita Fig. 12 (Mears & Wentz, 2016). The solution to this problem is focused on generating energy from renewable resources. Wind power, solar energy, and hydro energy in Asir are available resources all over the year for energy generation to reduce carbon-emitting and pollution. Saudi's authorities should present a full study plan for the whole country and generating energy from renewable resources potentials to be a guide-map for the location of new urban areas in the 2030 vision.

3.4 Strategies for Architecture Design and City Planning in Saudi Arabia

- Considering pedestrian lanes inside the neighborhood for social connectivity.
- Considering weather conditions for buildings height and street width for new urban areas and developing existing cities.
- Mention all sustainable aspects as rules inside 2030 vision, not just recommendations.
- Considering Saudi's culture and lifestyle from the history of architecture of the whole islamic countries and the Arabian peninsula Fig. 18 (Hazaa, 2012).
- Avoid the importing of some architectural features and styles from other cultures that do not match Saudi's culture.
- Considering the value of the internal courtyard of islamic architecture and its sustainable role for energy consumption and social life Fig. 19 (Saleh, 2018).
- Considering passive design techniques Fig. 19 in governmental laws and rules for building design.
- Considering the native landscape for hot weather countries to avoid importing some features of open space areas from cold weather and foresty environment.

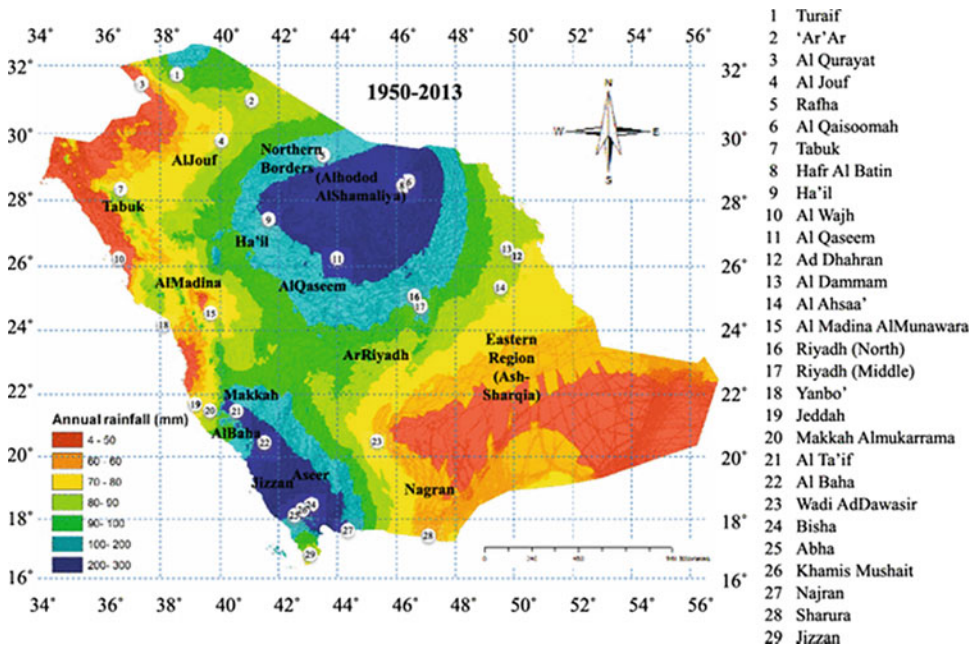


Fig. 17 Illustrates the annual rainfall in Saudi Arabia

Fig. 18 Illustrates sketches for hot weather and Islamic culture. By: Rasem Badran

Fig. 19 Illustrates Wekalet Al-Ghory, Cairo. By: Mohammed Saleh

- Considering building materials, colors, and facades finish in building law to match environmental conditions and eliminating the reproduction of western styles that match their ecology and culture.

4 Results and Findings

Saudi Arabia's goal to set up a plan for its future under the umbrella of 2030 vision is a wonderful step towards a sustainable lifestyle. Energy supply, freshwater resources, and designs for Saudi's cities are the main keywords for this vision. The location and resources of Saudi Arabia have a solution for all environmental challenges that are facing decision-makers. In 2006, the 8th 5 years plan has started to consider some aspects of sustainable vision. There are some rules and environmental laws which are not enough to drive the 2030 vision. Generating energy from renewable resources and guiding the investments towards researches for desalination water using solar energy are mandatory in the next few years. Unfortunately, the building and construction rules are still behind the sustainable vision. In 2019, they announced more rules for building designs that only focus on setbacks and heights without concerns for passive design techniques.

5 Discussion and Analysis

In the following the SWOT analysis for using renewable energy strategies, sustainable freshwater resources, and applying sustainable principles for creating and developing existing cities in Saudi Arabia (IRENA–International Renewable Energy Agency, 2014).

Strengths

- The high potential for renewable energy resources mainly with solar radiation and wind speed.
- Desert areas are available to build renewable energy projects. There is no need to harm green areas.
- Availability for regional electricity transfer.
- Environmental and governmental incentives exist.
- Thousands kilometers seasides on the Red Sea and Arabian Gulf.
- Long term of daily hours of sunshine, hot, and the minimum level of cloudy weather all over the year which is perfect for desalination water using solar energy.

Weaknesses

- Subsidization of the fuel that comes from fossil fuel is a huge obstacle that confronts renewable energy resources.
- There are no laws or rules for using solar devices in residential, public streets, and industrial sectors.
- Renewable energy resources and awareness have not been incorporated into the educational system.
- Lack of knowledge in government agencies to deal with renewable energy-related issues.
- Quality assurance systems are not sufficiently prepared for RET standardization, testing, accreditation, and certification.
- Lack of efficiency in desalination water using solar energy.
- There are no obligations for architects and planners to produce their designs using a sustainable methodology.
- People awareness with all the disadvantages of non-sustainable buildings.

Threats

- Fossil oil international prices reduction and its impact on the competitiveness of renewable energy.
- A sudden change of policy at the national level, which will affect the attraction of investments.
- The weakness of human, financial, and investment capacities.
- Using all seasides for urban development.
- People admiration with glass buildings and non-sustainable materials for hot weather.

Opportunities

- Decreasing prices of renewable energy technologies could add recognized capacities each year.
- Using lighting systems in streets, advertising, and remote areas powered by solar devices and photovoltaic cells.
- For the short term: focus on low technology applications and equipment in promoting local manufacturing market, civil and electrical components in large-scale projects.
- For the long term: focus on R&D applications and link them with market needs.
- Most local investors are willing to enter into a partnership with international investors.
- Saudi Arabia 2030 vision is the strongest opportunity to guide all construction industry starting from first sketches to achieve eco-city philosophy in all Saudi's cities.

6 Conclusion and Recommendations

This paper attempts to explore sustainable determinants to create new urban areas and developing existing cities in Saudi Arabia. The following.

- Facilitate importing electric and zero-emission cars. The government can encourage people to buy them by decreasing all taxes and customs on them. On the other hand, Increase taxes and customs on fuel combustion cars and make the increasing ascendant with the size of car engines.
- Encourage the distribution of economic sources among Saudi's cities to eliminate centralization. It will decrease traffic problems in big cities and facilitate the transportation plan.
- Set up sustainable transportation plan in all Saudi's cities using all means of sustainable transportation.
- Connect between big ports such as Jeddah and all other cities by railway to decrease the role of heavy trucks and their CO_2 emissions.
- Enlarge the role of trains between holy cities and religious rites places for Hajj to avoid using buses for pilgrims transportation. One line is not enough at all. A full transportation study with a multi-lines operation to avoid using buses. The study should consider moving around two millions of people from one place to another in only 2 h. They should facilitate the investments of constructing more than 10 lines or less and buy more vehicles to achieve the goal.
- Use zero-emission buses instead of diesel engines inside holy cities like Makkah and Al-Madinah.

- Develop a network transportation plan and shutter buses for high-density buildings such as universities and governmental buildings.
- Encourage and facilitate electric charging points all over the kingdom and service centers for electric vehicles.
- Increase the awareness of sustainable transportation tool and the harmful impact of CO_2 emissions on the environment and economy.
- Increase the awareness of people to use public transportation to reduce road traffic.
- Creating new cities in the region that have a high average of precipitation.
- One of the observations that NEOM city which has a huge part of 2030 vision investments is located in the least part of rainfall average in Saudi Arabia which is against vision's objectives.
- Creating sustainable freshwater resources for existing cities such as water desalination using solar energy.
- Increase people awareness of rainfall harvesting and water saving.
- Facilitate the types of equipment and implementation of rainfall harvesting and water saving.
- Considering pedestrian lanes inside the neighborhood for social connectivity.
- Considering weather conditions for buildings height and street width for new urban areas and developing existing cities.
- Mention all sustainable aspects as rules inside 2030 vision, not just recommendations.
- Considering Saudi's culture and lifestyle from the history of architecture of the whole Islamic countries and the Arabian peninsula.
- Considering the value of the internal courtyard of Islamic architecture and its sustainable role for energy consumption and social life.
- Considering passive design techniques in governmental law and rules for building design.
- Considering the native landscape for hot weather countries to avoid importing some features of open space areas from cold weather and foresty environment.
- Considering building materials, colors, and facades finish in building law to match environmental conditions and to avoid the reproduction of western features that match their ecology and culture.

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Toward a Smart and Sustainable Campus: Future Vision, Opportunities, and Challenges

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Abstract

The Internet of Things (IoT) is a buzzing technology nowadays. It is believed to have the potential for revolutionizing today's world. Several projects and publications addressed the use of IoT in various applications such as smart cities, smart homes, wearables, smart grids, connected vehicles, and health care. However, few works addressed the potential of using IoT in educational institutions. The technological revolution along with several changes through the past era, including the COVID-19 global pandemic, have made it indispensable to employ innovative learning methods, also, the students will be looking forward to existing in the environment of a smart campus. This study presents a framework to elucidate how IoT can be used to bring a smart and innovative university campus to life in order to improve the efficiency of delivering the daily educational activities. In the context of sustainable development, the social and environmental interactions should be considered to provide a sustainable campus. Also, challenges are investigated and research opportunities are highlighted. This framework can be put in practice in guiding universities to adopt novel visions to improve the performance of their educational activities and student life experience by properly adopting and deploying IoT technologies. These concepts are elaborated based on the case of the innovative campus of the Egypt-Japan University of Science and Technology, which is located in New Borg Elarab, Alexandria, Egypt.

Keywords

Smart cities • Smart university • Smart campus • Internet of things • Industry 4.0 • Sustainability • E-JUST

1 Introduction

The Internet of Things (IoT) is a trending technology that enables objects to sense, capture data, compute, and communicate with each other via the Internet. This will lead to a seamless coordination between everyday things in our homes, offices, schools, hospitals, banks, stores, etc. The concept of a connected world has risen in the late 1980s with the emergence of ubiquitous computing but it was not possible to realize due to the technological limitations (Weiser 1993). About a decade later, in 1999, Kevin Ashton, a brand manager with Procter & Gamble, suggested the term "Internet of Things" with an idea to use passive RFID tags to transmit a small amount of static, pre-programmed information by a network-connected reader. The objective is to enable the products to communicate their type and location in order to support inventory management decisions across different facilities (Ashton 2009). The past 15 years have witnessed marvelous advances in the area of Information and Communication Technology (ICT); the most significant technologies that enable IoT applications include wireless sensing technology, machine-to-machine cellular connectivity, cloud computing, global Internet connectivity and speed and big data analytics (IoT and the campus of things 2016).

Since the emergence of the concepts of IoT, hundreds of works addressed the potential of implementing IoT in various fields. The main applications that have received high attention during the few past years are smart homes

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(Stojkoska and Trivodaliev 2017), wearable devices for health monitoring (Metcalf et al. 2016) and for sports (Anzaldo 2015), smart cities (Talari et al. 2017), smart grids (Reka and Dragicevic 2018), connected cars (Swan 2015), industrial applications Trappey et al. 2017), supply chain (Ben-Daya et al. 2017), smart warehouses (Mostafa et al. 2019), and smart farming (Talavera et al. 2017). IoT is a main block of what is known as Industry 4.0 (Majeed and Rupasinghe 2017). Industry 4.0 is concerned with the intelligently automated or smart factory in which labor, machines, products, and customers can be connected with the objective of maximizing value across the whole value chain through autonomous knowledge and information sharing (Karre et al. 2017).

For universities, the IoT can be utilized to provide new student services and improve the current ones with better student life experience and better learning and research environment. However, relatively few works addressed the smart campus so far, that is why it still needs more research and perspectives on it.

The scope of this paper is the examination of the concept of "smart campus" and their implementation. Owoc and Marciniak (2013) defined a smart campus as "a business organization that integrates providing educational services with information systems in order to manage and improve the processes, based on five elements: people, environment, buildings, governance, and knowledge grid". Coccoli et al. (2014) argued that education and knowledge sharing are the basic elements, but they also highlighted communication, transportation, and governance as supporting elements of a smart campus.

The paper is organized as follows; Sect. 2 gives a review of the previous research on smart campus. Section 3 discusses the concepts of smart city and smart university and how they can be linked to each other. Section 4 illustrated the elements and applications of a smart campus. Some real-world cases of implementing smart campus features are overviewed in Sect. 5. Section 6 addresses the case of Egypt-Japan University of Science and Technology (E-JUST) as a model of smart campus development in the Middle East. Finally conclusions are given in Sect. 7.

2 Review of Literature

One of the earliest works that addressed the topic of smart campus was the paper by Tan and Wang (2010) proposed using IoT technology in managing campus facilities. In their architecture they have deployed RFID tags and sensors in the campus buildings to monitor the elevators and HVAC systems. The system collects data and senses the environmental changes. Each building has a data acquisition manager that uses Wi-Fi to transmit data to a control system that processes the data and can make some decisions such as turning off some air conditioners or sending specific configure information. Nie (2013) discussed the difference between smart campus and digital campus; according to him, he argued that a smart campus uses a higher level of information systems in education, and it evolves based the digital campus development. He proposed a smart campus application framework that combines IoT with cloud computing platform to integrate teaching management, school management system, office system, finance management system, and library system. Adamko et al. (2014) proposed an architecture for smart campus in which data is captured from several sources, such as built-in sensors and user- or application-generated data from the library information system, and the local education system. Extensible Messaging and Presence Protocol (XMPP) was chosen as a communication protocol. The architecture includes a smart campus central component that provides an interface between data sources, database, and the web services layer.

Liu et al. (2014) divided the overall platform architecture of the smart campus into three types: perception network platform that is based on IoT, service support platform that is based on cloud computing, and intelligent application platform that is centered on users. A similar system was presented by Ji et al. (2014) for a cloud-based smart vehicle parking system; the proposed system has three layers; a sensor layer, a communication layer, and an application layer. They implemented that system in a university campus with three tiers: Cloud tier, OSGI tier, and mobile app tier. When the driver is geographically close to the campus, a request is sent automatically through the mobile application to the parking web server that searches for free parking lots. Based on the specific preferences on the user profile, the server finds the "best" parking space for the user. Then, Directions are sent to the driver along with a detailed map via the Google maps application. Atif et al. (2015) have proposed a ubiquitous learning framework that can achieve multi-modal u-learning in the smart campus. They specified an autonomic ecosystem that has advanced learning capabilities, e.g., self-organization and self-adaptation. Liu et al. (2017) built a cloud-based campus platform that utilizes mobile edge computing with three innovative applications; a semantic information analysis application, an augmented reality mobile application, and a smart class application. Wang et al. (2017) presented a smart campus framework based on IoT and machine learning techniques to provide an environment-friendly campus with better functionality, security, and safety. This is performed through monitoring and controlling energy usage in rooms and buildings. Rao et al. (2018) developed IoT-based campus platform; the IoT devices monitor and control the mechanical and electrical systems inside the campus. The various devices are controlled by a single admin and are connected to the cloud

server. This platform can support several functions such as lighting system, parking, automation, gardening, pollution control, noise monitoring, library, and cafeteria.

Bellagente et al. (2015) used the IoT approach to design flexible energy management system architecture in order to manage the electrical generators and loads at the campus grid of University of Brescia in Italy. They used sensors to collect meteorological data and share them among several users. Sharing this data allows the system to improve energy management services in addition to other services, such as surveillance system, preventive maintenance, and emergency management system. A similar approach was addressed by Bates and Friday (2017) who presented a case study of Lancaster University and how to use IoT infrastructure to create what they called a "campus scale living laboratory" that promotes environmental sustainability and energy savings by integrating the following data sources: energy monitoring system, building management system, wind turbine, local meteorological data, and campus timetabling and room booking. Bi et al. (2017) addressed the Shenyang Jianzhu University smart campus project in China. According to them, a smart campus system integrates the position information of Geographic Information System (GIS), IoT and multimedia data in order to realize the mutual linkage. The proposed design implements several functions such as location, campus information system function, 3D video monitoring, infrastructure management system based on GIS technology, and measurement function. Hentschel et al. (2016) developed a sensor network approach that uses commodity single board computers and operates campus-wide. They suggested using super sensors hosted on Raspberry Pi devices, ad hoc networking and sensor fusion, and machine learning techniques. The basic idea is to integrate sensors within the campus fabric, such as sound sensors in libraries, sensors on walkways for footfalls, and temperature sensors inside the rooms. An initial prototype was deployed in one department at the University of Glasgow, and it could enable versatile data collection and processing with the capability of reacting.

Chang (2011) proposed a system for attendance recording inside the classrooms by attaching RFID tags to students ID cards; the system reads the cards and displays the actual attendance automatically inside the classroom at the beginning of each class which helps in saving teacher's time to record the attendance and share the information with the academic office. Wang (2013) adopted IoT concepts to manage computer labs and realize energy saving by decreasing the number of idle power-on computers and turning on air conditioners only at preset temperature levels. Bakken et al. (2016) addressed the approaches of smart university and smart classrooms; they especially discussed the potential benefits of using IoT technology for educating students with various types of disabilities. Sari et al. (2017) addressed three applications for a smart campus; smart education, smart room, and smart parking.

3 Smart City and Smart University Concept

The past few years witnessed a massive evolution of smartphones and mobile applications markets whose economic and social aspects have dramatically changed the style of our daily lives. By 2020 we will see the development of integrated and networked Megacities, and by 2025, more than sixty percent of the world population is estimated to be living in urban communities (Vermesan et al. 2013). This would have an influence on the lifestyles and mobility of the residents with the expansion of cities borders and infrastructure development. By 2023, it is expected that there will be around thirty megacities worldwide with 55% of them in rising economies such as China, Russia, India, and Latin America. The main features of smart cities are smart economy, smart energy, smart buildings, smart mobility, smart planning, smart ICT, smart citizen, and smart governance (Vermesan et al. 2013). The research on smart cities has started two decades ago, has become an ideal platform for the research on IoT. In this context, the main applications in smart cities include traffic congestion, smart lighting, smart parking, intelligent transportation systems, structural health, noise urban maps, and waste management. To realize such applications, various types of sensors will be used; biometrics also can be integrated with cameras at selected locations around the city. To enable smart cities to affect the everyday lives of the citizens, it is necessary to understand human needs and lifestyles and their interaction with technology (Bates and Friday 2017).

A university campus can be seen as a mini-representation of a city; since the campus is comprised of buildings, laboratories, theater, library, sports center, shops, and maybe residences. With a large number of users; students, professors, employees, and visitors and a large amount of energy consumed daily in a campus, there exists high potential in using IoT and other advanced technology to transform the traditional campus into a smart one. In that sense the same main features of smart cities can be used as baseline for planning and designing a smart campus. According to Mattoni et al. (2016), the same challenges that face smart cities are applicable to a smart campus, such as energy costs, connectivity, parking, and crowd. Hence, models for smart cities can be adapted to fit a smart university campus.

4 Elements of the Smart Campus

A smart campus allows the users to actively share knowledge and ideas and to participate in the campus activities. From Mattoni et al. (2016), Alghamdi and shetty (2016), the main elements for smart campus can be categorized as follows:

- **Economy**: A main challenge in smart campus is the economic aspect and the initial investment. Hence, actions for endorsing the development of smart campus should be planned and revenue management models should be studied. Consequently, university governance can support innovation and encourage the creation of a sustainable smart campus.
- **Educational**: Since the main function of a university campus is delivering education to students, then educational and academic aspects are key elements of a smart campus.
- **Energy**: Actions should be planned in order to improve energy generation, distribution, and consumption within the campus. This is done through employing technology and also by raising awareness about sustainable and efficient energy usage.
- **Environment**: Actions should be planned in order to improve air quality, optimizing resource utilization, and developing an efficient waste management system.
- **Mobility**: Public and private transportation from, to and inside the campus should be optimized, environment-friendly transportation can be considered.
- **Society**: A university is not a standalone organization, it is a part of a bigger society and interacts dynamically with this society, and then designing the smart campus should take into consideration not only the inner social bonds between the users, but also the interactions with the outer society.

Since IoT is a main block in smart campus, it is necessary to examine the potential applications of IoT in a smart campus. Table 1 gives a brief description of the elements of a smart campus and the potential areas of applications in which IoT can be utilized.

5 Cases of Smart Campus Implementation

Many universities around the world have already started to implement smart campus design elements and applications, in this section some of these implementation cases are overviewed and illustrated.

5.1 The Technical University of Denmark (DTU), Copenhagen

In this university, the campus can be seen as a "living lab". Its structure enables the students, professors, and admin staff to co-built the environment to test new technologies. Several projects were implemented in the campus such as "Smart Avenue" that uses Wi-Fi tracking and positioning technologies for traffic control and monitoring in the main street on campus. Another project is "Smart Library" to control lighting and heating and provide dynamic workspaces for the students. The "Skylab" project works as an innovation hub where students can find information, facilities, and technical support for their innovative ideas. Figure 1 shows some of the projects in DTU smart campus.

Table 1 Elements and applications of a smart campus

Element	Applications					
Economy	Buildings	ICT infrastructure	Business processes	Transactions	Data privacy	Automation
Educational	Learning environment	Classrooms	Library	Assessment system	Attendance system	Documentation
Energy	Power grid	HVAC	Energy consumption	Charging stations	Maintenance	Load management
Environment	Water management	Waste management	Emissions	Lighting	Noise	Gardening
Mobility	Location services	Parking	Transportation	Electric vehicles	Connectivity	GIS
Society	Social activities	Safety	Special needs services	Health and fitness	Housing	Sports activities

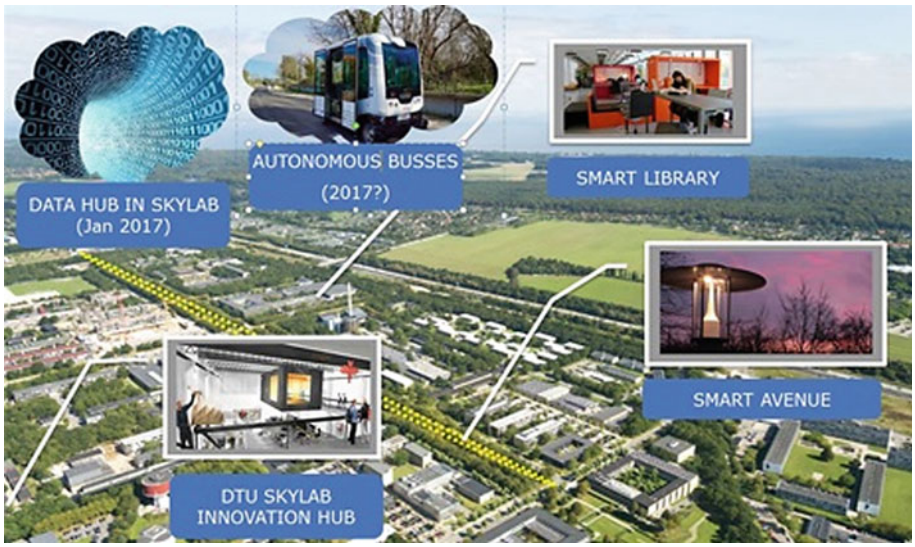

Fig. 1 DTU smart campus applications (smartcampus.dtu.dk DTU Smart Campus 2018)

Fig. 2 A student uses Snap2It application in CMU campus (cmu.edu, 2015)

5.2 Carnegie Mellon University, Pittsburgh

In 2016, Google has announced its plans to adopt Pittsburgh's Carnegie Mellon University (CMU) to turn it into a testing ground for digital innovation and IoT solutions. The plan is to outfit thousands of everyday items with inexpensive sensors to collect data and enable interaction in the campus through various applications in what they call "IoT App Store". For example, one of the implemented applications is "Snab2It" shown in Fig. 2, Snab2It is an application that connects users with printers and projectors by taking a photo from a smartphone to a system that accesses shared applications.

5.3 University of Glasgow, Scotland

The University of Glasgow has allocated £800 million investment to transform their campus into a smart one. With new land added to the campus, the university board decided to design the new extension in a smart and innovative way. Their strategy focuses on a human-centered approach to understand users' needs and problems. The plan is to embed new technology into campus daily life such as IoT, data science, and networks. The main applications are on-site demonstration park, research collaboration and co-creation, contract research, and student projects (gla.ac.uk, Kerr 2017).

5.4 Nanyang Technological University (NTU)—Singapore

On January 2018, the president of NTU announced his vision to transform NTU into a smart campus to support

Fig. 3 Students in NTU with their smart passes (todayonline.com, Ming 2018)

better learning and living experiences and sustainable environment. The applications include distributing personalized smart passes with embedded identity chips that can be used for payments and several services (Fig. 3). Other initiatives included deploying 22 fully electric shuttles and 40 autonomous buses with smart bus stops in addition to e-scooters and e-bicycles, robot cleaners and tray-returners in the cafeteria, shelving robots, painting robots, promoting eco-friendly buildings through energy reduction and efficient waste management (enewsletter.ntu.edu.sg, Smart campus for the future 2018).

6 E-JUST as a Model Smart Campus in the Middle East

E-JUST is an Egyptian governmental university established in partnership between the governments of Egypt and Japan in New Borg Elarab City, Alexandria, Egypt. The university is supported by Japan International Cooperation Agency (JICA) and a consortium of 15 Japanese leading universities. E-JUST is expected to be a symbol of Japanese international development programs and a top class Center of Excellence for higher education and research in the Middle East. JICA provides advanced research and educational equipment which contributes to the development of the higher education and research sector in Egypt, the Middle East, and Africa with a focus on science and engineering areas. JICA has also provided academic and technical support to support the education and research infrastructure of E-JUST, including the establishment of engineering undergraduate and postgraduate schools and faculties, university administration capacity-building, and research guidance.

By getting the support of JICA for the both hardware and software components, E-JUST is going to apply the most advanced smart campus solutions in Egypt to improve the quality and performance of the services, to engage university members more effectively and actively, to reduce costs and resource consumption, to introduce higher security level, and to protect environment. Full integration of smart imaging, smart broadcast and communication, smart building management and access control, and environmental monitoring can realize the above concepts. But among them, the Japanese side encourages the introduction of Japanese level lab safety standard and environmental protection policy by getting help of the smart technology; this is important for E-JUST to be a leading model in the Middle East.

JICA has signed a grant agreement with the Egyptian Government to provide a 27 million USD grant aid for the Project for Procurement of Education and Research Equipment for E-JUST. By utilizing this Grant Aid support scheme and other budget sources, the following advanced ICT tools for safe operation of research and educational labs, and environmental protection will be introduced. Some of the ICT applications used in E-JUST smart campus are given below:

Fig. 4 Toxic and flammable gas monitoring system

6.1 Smart Internet-Enabled Real-Time Laboratory Air Quality Monitoring

Gas sensors provide information on air quality. Continuous monitoring of air quality has prime importance in particular labs with toxic chemicals, organic solvents, and high-pressure gas cylinders. Thanks to the rapid development of sensor technology and Internet connectivity, it will be possible to introduce Internet-Enabled Real-Time Gas Sensors in E-JUST labs, such as carbon monoxide and other reactant sensors in chemical reaction/materials science research labs, nitrogen oxide sensors in combustion engine labs, and hydrogen sulfide and methane sensors in a sewage treatment station. To realize maximum safety conditions, the output of the sensors must be monitored in a centralized monitoring station 24 × 7, and also be indicated at the entrance of the lab so that students can confirm clean air conditions before entering the lab. Figure 4 shows the installed toxic and flammable gas monitoring system that uses sensor technology to detect many key toxic and flammable gases in the lab. It can monitor points up to 100 feet (30 m) away.

6.2 Smart Airflow Sensors and Monitoring

Airflow conditions in specific labs or facilities must be also important for lab safety and environmental protection. Airflow rate in fume foods and ducts from labs with chemical exhaust have to be continuously monitored to avoid air pollution. Also, labs with pressurized or de-pressurized conditions, such as clean rooms, have to be monitored for protection of the equipment inside the lab or to prevent environmental pollution caused by hazardous materials.

Fig. 5 Toxic gas management system

Systematic and continuous monitoring of the airflow conditions at the centralized station by using smart sensors enables quick analysis and prompt action in case of problems. Figure 5 shows the integrated toxic gas management system; airflow and leakage monitoring, automatic valve control, and emergency detoxification units.

6.3 Smart Access and Control of Harmful and Dangerous Materials

Excess amount of chemicals, high-pressure gases, flammable compounds, and any other dangerous materials need to be stored in designated areas with specially designed air ventilation and fire-fighting systems, explosion proof partitions, or other necessary safety measures. Smart key system enables to control the access to the harmful compounds and dangerous materials easily. The smart key system must provide necessary information of registered members including affiliation, position, knowledge level, and experience to avoid any dangers caused by misuse of dangerous materials. Individual material, such as a bottle of chemicals must have identical barcode or smart tags and registered on a university wide common database system for proper control of the total amount of dangerous materials. Figure 6 shows these systems.

6.4 Smart Lab Waste Management

Laboratory liquid waste needs to be classified into several different categories, such as organic, inorganic, halogen, or heavy metal-containing liquid,. Those wastes need to be stored in plastic containers until being transferred to chemical treatment companies outside of the campus. To minimize possible danger caused by exposure to chemicals, and unexpected reaction inside of the containers, proper management of the waste liquid, and registration of the container contents on a database are important. For smooth treatment of the containers, using smart tags or barcode registration system would be very useful. Figure 7 shows the storage system of lab liquid waste.

(a) Barcoded Chemical Storage (b) Access control panel

Fig. 6 Intelligent control of access to harmful compounds

Fig. 7 Storage of lab liquid waste

6.5 Smart Lab Sewage Management

Lab sewage lines should be separated from life sewage lines for environmental protection and the lab sewage must be transferred to the specially designed lab sewage treatment plant before releasing it to the city sewage lines. Internet-enabled pH and BOD sensors will be installed in the sewage reservoir tank of each section or building to monitor the quality of lab sewage. In case of anomaly value detection, the centralized monitoring station has to direct all of the labs to stop the research work until the origin of the problem is found and the problem is solved.

6.6 Sustainable Smart Campus Safety Management

The above-mentioned IoT-enabled technology is very useful for getting necessary information, but it can't realize ideal lab safety conditions automatically. Establishment of an organization with necessary capacity and authority to take appropriate action at the right place and time has prime importance. Also, the organization, office for safety management/environmental protection have to provide safety education service, risk assessment and consultation service, and preparation of incident and accident reports, analysis and management of database of the reports for realization of ideal safety and environmental protection in labs. By getting help of JICA and Japanese supporting universities for the both hardware and software components, the most advanced safe and eco-friendly campus environment is going to be realized in this region. Other technologies will also be adopted such as Wi-Fi coverage, electric buses, energy management and control system, renewable energy generation station based on solar Photovoltaic system, water reuse system, and smart IDs. In such smart and sustainable campus, students will have a unique experience by being exposed to the combination smartness, safety, and sustainability which will have a significant impact on the future development of industry and academia in the Africa and the Middle East. Figure 8 shows the features of E-JUST smart campus.

7 Conclusions

IoT technology can play a key role in campus design, planning, and management. With the accurate, reliable, and real-time data provided by IoT applications, better decisions can be made to shift toward a smart campus. A smart campus provides a vast amount of benefits in various directions, in the same time there are challenges that face its implementation.

7.1 Benefits

- Monitoring energy efficiency in the campus by improving energy generation and consumption.
- Evaluating system behavior in real time to provide a sustainable ecosystem.
- Enabling the user-system interaction.
- Facilitating daily time-consuming such as parking, facilities reservation, menu selection, and laundry facility availability.

7.2 Challenges

- Data access and privacy rules should be controlled to avoid hacks and sabotage.
- Advanced ICT mechanisms are required for data exchange; this will incur costs for hardware and software requirements.

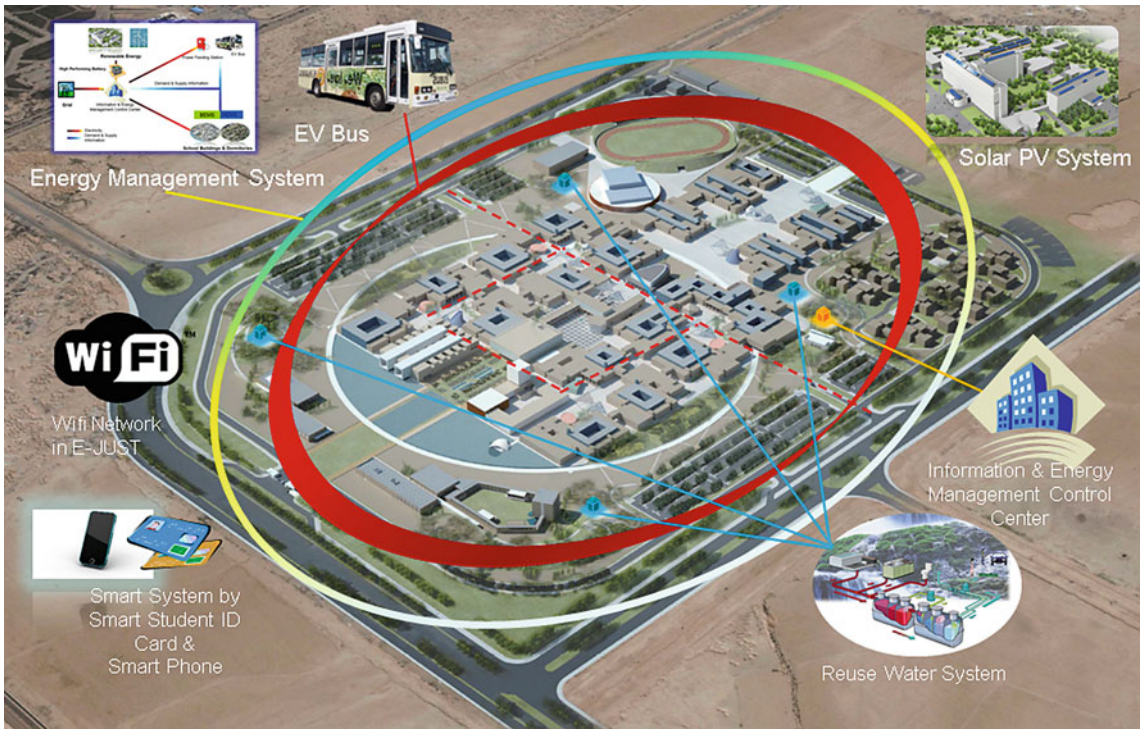

Fig. 8 E-JUST smart and sustainable campus

- It is necessary to have scalable and secure management protocols that ensure the verification and authentication of sensors and trust domains of new devices.
- There may be some restrictions on data usage and exchange that differ between countries according to their laws and regulations.
- User data information exchange can be anonymous or may need some control over the data distribution.

E-JUST new campus in New Bog Elarab will be a role model for IoT implementation and smart campus realization in the Middle East.

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Sustainable Urban Form and Dynamics of Rivers in the Context of Faridpur City, Bangladesh

Asif Ibney Basit Turza

Abstract

Faridpur, a south-central district in Bangladesh with an ancient yet colorful history, is always mentioned as a significant urban area in Bangladesh. As Bangladesh is going through a rapid urbanization process, Faridpur is reforming and developing to keep pace with this vibrant urban development of other cities in the country. Once known as a riverine city, Faridpur is now shifting its development trend from river-based transportation to alternative road connections. With the aim to look into a rudimental relation between spatial configuration and river network of Faridpur, this paper examines the location of the rivers, as central axis or peripheral edge. The study attempts to identify the role of river network in the formation of the city's spatial structure and to predict the future development of Faridpur city. This paper demonstrates the spatial character of the functional core of this spontaneous city corresponding to its past and present. Simulation of the city's road network is conducted by space syntax to identify the spatial and functional core, road integrations, determination of choice of people through configuration analysis. The dynamics of the river were then correlated with the spatial configuration for foreseeing the role of the river to predict the further extension of Faridpur city. This paper concluded with a general recommendation on future expansion of the road network of Faridpur for sustainable development.

Keywords

Sustainability • Urban form • River dynamics • Morphology • Space syntax

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1 Introduction

Faridpur city is situated in the south-central part of Bangladesh. It is also an integral part of the Dhaka division. Faridpuýr city is organized by its parallel position to the Kumar Nodh and bounded by the Padma River to its northeast side. Historically, the town was recognized as Fathabad. Another quite popular name was "Haveli Mahal Fathabad." Though the city is renowned for its ancient history and colonial architecture, it was merely tagged as a suburban area.

In 2014, the government of Bangladesh started the construction of a multipurpose road-rail bridge across the Padma River. This megastructure is going to initiate a connection between the southwestern part and northeast part of the country. The bridge will bring a massive howling to the surrounding area and encourage rapid urbanization in Faridpur city. Faridpur city is now emerging as one of the potential areas for industrial development, including other facilities. Because of this momentum, this urban area has currently been experiencing rapid urban growth in recent years.

2 Literature Review

2.1 A Brief History of Faridpur

Faridpur city was named after the famous Sufi ascetic Farid-al-din Masud Ganj-i-shakar, popularly known as Sheikh Farid and Baba Farid. Initially, the city was founded near a stream, generally known as the dead Padma. The dead Padma has shifted around 20 miles away from the current location of the Padma River. The first mention of Faridpur city was recorded in the time of 1415–1433. About its origin history, Reza stated that "*Famous Mughal emperor Akbar established a mint in Fatehabad during his reign in the early 15th century. Until 1538 Fatehabad was*

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https://doi.org/10.1007/978-3-030-63567-1_21

recognized as the famous mint town of Bengal. In the book Ain I Akbari, it was mentioned as Haweli Mahal during the reign of Emperor Akbar in the Mughal Empire" (Reza 2012, p. 24).

The Portuguese cartographer, Joao de Barros in his journey, crossed this land and mentioned it as Fatiabas (see Fig. 1). The Dutch map by Van den Brock also identified this place as Fathur. In bengali literature, this city has its unique spot, Daulat Uzir Bahram Khan, in his great adaption of Layla and Majnun indicate this place. In 1664, 16th October, Bengal subahdar Shaista Khan mentioned this city when he was traveling to Dhaka from Delhi. In Bengal literature, Faridpur was identified as one of the developed urban areas as it was the administrative center of many crucial mughal authorities, including governors, generals, jagirdars, and civil servants.

In 1721, the mughal empire created a new partition in Bengal and divided it into 13 large divisions, which eventually shifted the power of Government in the province of Bengal. In 1765, the british seized Bengal, and it was the beginning of the british era in Bengal providence. In 1793 separate officers were authorized under a unified judicial system, and it helped them to pull the magisterial authority together.

In 1860 the city was renamed as Faridpur to pay tribute to twelfth-century Sufi saint Shah Farid Uddin. Previously Faridpur was also acclaimed as Greater Faridpur as it consisted of large areas, including separate districts like Rajbari, Shariatpur, and Gaoplaganj. It was also a part of East Bengal and Assam providence in the rule of the British era in 1905–1912. In the British period, Faridpur was one of the main terminals connecting Calcutta with Goalanda. It was also a vital river port where many ships departed for Assam and Burma in that period. Faridpur witnessed a colossal war and suffered a lot in the liberation war of 1971 that happened between East and West Pakistan. After the independence of Bangladesh, it appeared as one of the 18 subdivisions of Bangladesh. Later in 1984, the government of Bangladesh divided the old subdivision system and created five individual districts. In recent years, a proposal was announced for making it the Faridpur division.

The first part of the literature is focused on indicating the historical significance of Faridpur to establish reasons for taking this city as a model. If a development is in collision with its authentic features, it needs to be identified and protected from unsustainable development by predicting its future growth.

2.2 History of Urban Settlements in Faridpur Town

The history of settlements in Faridpur town is obscure. In the middle age era, the Portuguese traders started coming into this area. The zamindari system also had begun in this timeline, and trading business flourished at that time. Chalkbazar area became the main central hub for business when mughals conquered the area around 1666 AD. Niltuli road became the main central road by connecting many religious areas like Goalchamot, Khabaspur, and Ambikapur.

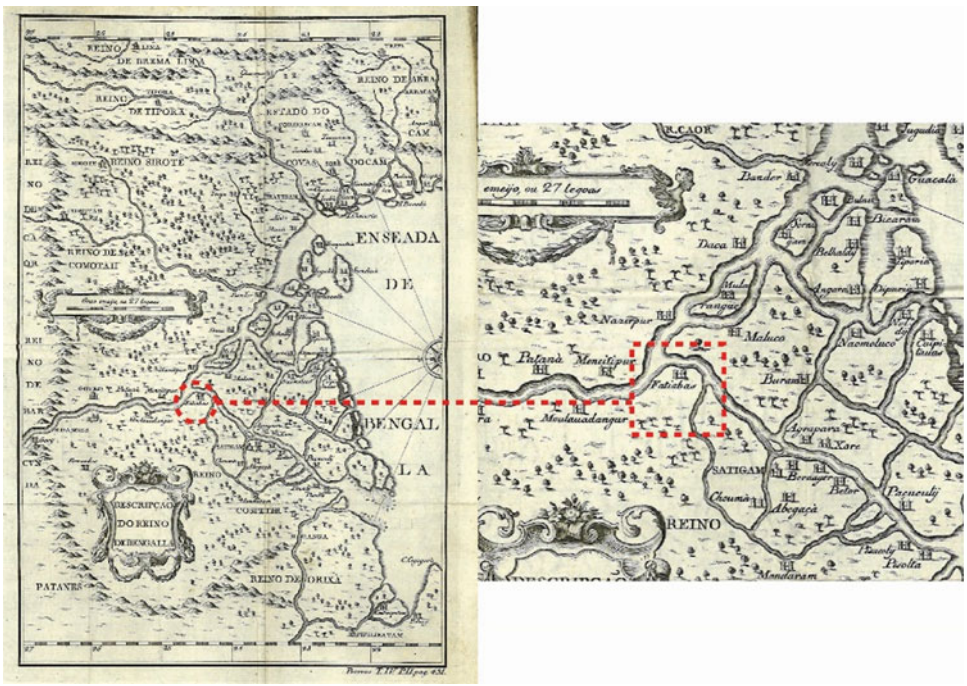

Fig. 1 Map of Bengal in the sixteenth century, created by João de Barros mentioning Fatiabaz [Faridpur]

The British influence became prominent in 1760 AD. For a directional change of the mighty Padma River, a new delta area emerged, and the city began to expand on the east side. In 1853 AD, the municipality of Faridpur was established, and a rail-line plan was proposed to facilitate the business in this area. In 1895 the Asam–Bengal rail-line started to expand to the Goyalanda–Kolkata rail-line, and later the extension of this rail-line signified a massive development of this area. Various significant structures like Faridpur Zilla school [1840], Faridpur court-house [1889], Hitoshi high school [1889], Ishan Institute [1891], Faridpur rail-station [1916], and Rajendra college [1918] were built in this period of time.

During the Pakistan period, there was no significant development. After independence, the whole urbanization process was increased. The entire structure of the city began to reform, and new road construction started to accelerate. After the bridge on Kumar Nodh, the west side of the city expanded for industrial and administrative purposes. But the main residential area always developed around the central city. This city grows spontaneously as a demand of public necessities. Furthermore, the urbanization process began to accelerate after 2014 and now on the verge of enormous development.

2.3 Origins and Developments of Rivers, Canals in Faridpur City

All the rivers entered in Bangladesh can be divided into two sources. One is Mahananda–Tista–Jamuna, and others are Ganga–Padma. Both of these rivers cross the Faripur city while going to the south and later end at the Bay of Bengal.

It has a riverine border with Ganga and Brahmaputra in the east, Arial Khan and Noyavangani Rivers in the south, Gorai on the southwest side. There are many canals and waterways like Kumar Nodh, Choto Kumar, Vubenashwar, Loyar Kumar, Mora Padma, Bil Padma, Noya vanga, Shoilodah, Bierut, Mandar tola, etc. which passed through the Faridpur city. Among all the rivers, Padma Rivers and Kumar Nodh are most significant because of their location. These rivers changed their courses slightly with time but became the primary connection between Faridpur and other cities of Bangladesh.

Kumar Nodh once played a very vital role in the formation of the city but currently is under threat because of the city's unplanned urban settlements and lack of focus on its edge. After independence, a massive unplanned development around the country was in full throttle. But the development of Faridpur remains steady because there was no direct road connection. Ferry vehicle Ghats, locally known as Paturiya Ghat, remains the main connection port between Faridpur and the north part of Bengal. But in recent years, a mega project of creating a bridge over the Padma River is undertaken. For that reason, it is now predictable that the process of industrialization and settlements will increase in the upcoming days.

2.4 A Brief Review of Depth Map and Space Syntax

Space syntax is a combination of some theories and techniques to analyze the spatial relation between spaces. Bill Hiller and Julienne Hanson developed it in early 1980. Hiller stated that "Space syntax theory describes and measures the configurational properties of urban space" (Hillier and Hanson 1984, p. 4). The fundamental idea was to divide the spaces into components and later analyze them with choices to develop necessary maps to identify the integration and connectivity. These variables will help to determine how the accessibility works in the street segment in a particular spatial system.

The main hierarchy point of the depth map is the segments of the street between intersections. When a plan is given as an input, it generates this from the end line; then it designs an axial by following the pattern. In the recent year, a newly developed algorithm used which works with road center data. Every depth map typically allows three types of distance between each segment following their neighbors. Hiller explained the process as, "Metric, that is the distance in meters between the center of a segment and the center of a neighboring segment; topological, assigning a value of 1 if there is a change of direction between a segment and a neighboring segment, and 0 if not; and geometric—assigning the degree of the angular change of direction between a section and a neighbor, thus straight connected square measure 0-valued and a line could be a sequence of 0-valued connections, so the linear structure of cities is captured. It then uses these three concepts of distance to calculate two kinds of measure: syntactic integration, or mathematical closeness" (Hillier 2009, p. 3).

With this space syntax software, there are few variables we are going to analyze, and those findings will help us to predict the outcome. Some terminologies which are often used in the paper like accessibilities, permeability, the intelligibility of functional core, and connectivity are explained here for basic understanding. Accessibilities usually indicate a spatial characteristic. Accessibilities show us the significant link between land use patterns and transportations. It also emphasized the performance of the road network, which is estimated by the infrastructure-based method.

Hansen stated that "accessibility is dependent on the spatial distributions of the destinations (centers of opportunities) relative to a given location, the magnitudes, quality, and character of the activities found at the destinations, the efficiency of the transportation system, and the characteristics of the traveler" (Hansen 2009, p. 386).

Permeability is another essential aspect of urban design. It was stated that "Only places which are accessible to people can offer them the choice. The extent to which an environment allows people a choice of access through it, from place to place, is, therefore, a key measure of its responsiveness. We have called this quality permeability" (Bently et al. 1985, p. 12). So it is understandable that this quality used to measure people's responsiveness in a specific context. Connectivity shows us the number of spaces that connected with the origin space. A functional core is mainly the city's central commercial and development zone. Usually, the operational center determines the future development of the town. It also shares the largest population of a city. By understanding the functional core of the city, it provides a basis to predict the sustainable development of a city.

3 Aim of the Study

This study determines the impact of the river network on the formation of the Faridpur city's spatial structure corresponding to its past and present. With the aim to establish guidelines for future expansion of urban areas, this paper examines the dynamics of the river for predicting further sustainable development of Faridpur city.

4 Methodology

This paper follows a descriptive and simulation-based method. Relevant literature and past maps were reviewed to understand the origin of the city. From a recent GSI map collected from a secondary source (Urban Development Directorate Office), the current road network is derived. Then a physical survey was conducted to reexamine the spatial organization concerning the derived map. Syntactic analysis by depth map software analysis was applied as a tool to find out the most integrated roads of the city and to correlate the attributes such as accessibility, choice, the intelligibility of functional core, and connectivity to the town. Then values of choice, integration, and control of riverside roads and central roads were compared to find out the trend of the city's expansion. Based on the analysis, a general recommendation is suggested concerning the future expansion of road networks.

4.1 Identification of Functional Core of Faridpur City and Coherent Relation with the River

Various historical maps and literature were collected from different timelines to understand the origin of the city. The first map of Faridpur was created by a Portuguese cartographer, Joao de Barros (see Figs. 1 and 2). He mentioned this place as Faiabas and drew it beside a river, currently known as Padma (see Fig. 2). It shows us that the city was first founded near a vast river which connected Faridpur with other parts of the country in that period.

Later from the literature study, we found that the city flourished on the southwest part, including Goalchamot, Khabaspur, and Ambikapur area in british period. A vast delta on the northeast side emerged afterward, and the city was developed on both sides of the river. After the independence, another map of Faridpur city was constructed by Faridpur municipality. From that map, it is visible that the city was small in size, and all the main buildings were concentrated in the center of the city (see Fig. 3). The road networks began to flourish from the center, which was eventually beside the Kumar Nodh. Various small bridges over the Kumar Nodh connected the two parts of the city and began to facilitate the expansion of the city.

If we observe the spatial pattern of the city, it is visible that in recent times the city expanded on both northeast and southwest parts (see Fig. 4), which eventually connected by various bridges over the Kumar Nodh. Later various roads had constructed on both sides of the Kumar Nodh (see Fig. 4). Though the main central market roads were situated alongside the river, all the other public amenities like hospitals, schools, administrative buildings were later constructed concerning the city's central road, known as Mujib sarak. All the secondary and tertiary streets are also connected with this central road (see Fig. 5).

After the first simulation, an axial map for the Faridpur city was assembled using the street data collected from GIS software. The axial map does the syntactical analysis, and the calculation follows the method defined by Hiller and Hanson. There are two separate values for integration, global integration, and local integration. N = global integration and R = 3 for local integration. This axial map is used as the base map for calculating the other variables including choice, connectivity, and integration.

Choice defines the degree of likeness of an axial line. It also indicates a street segment if it moved through all the shortest paths to all spaces in the whole system, within a preset distance, usually calculated in radius from each of its segments. Arguably in the language of space syntax, these values indicate the car traffic flow of streets. Axial analysis needs to be done to determine the degree of choice. In Figs. 6 and 7, the hotter color indicates the more choice here,

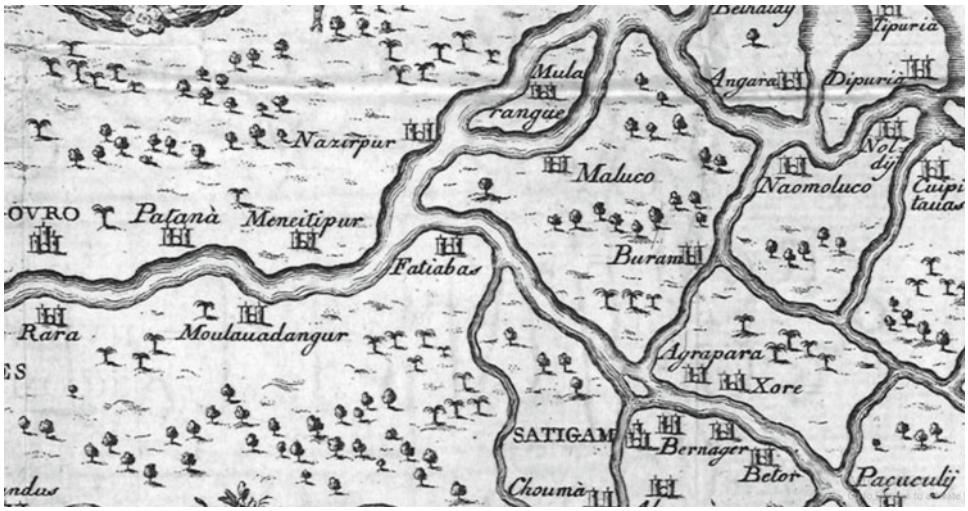

Fig. 2 Map of João de Barros mentioning Fatiabas [sixteenth century]

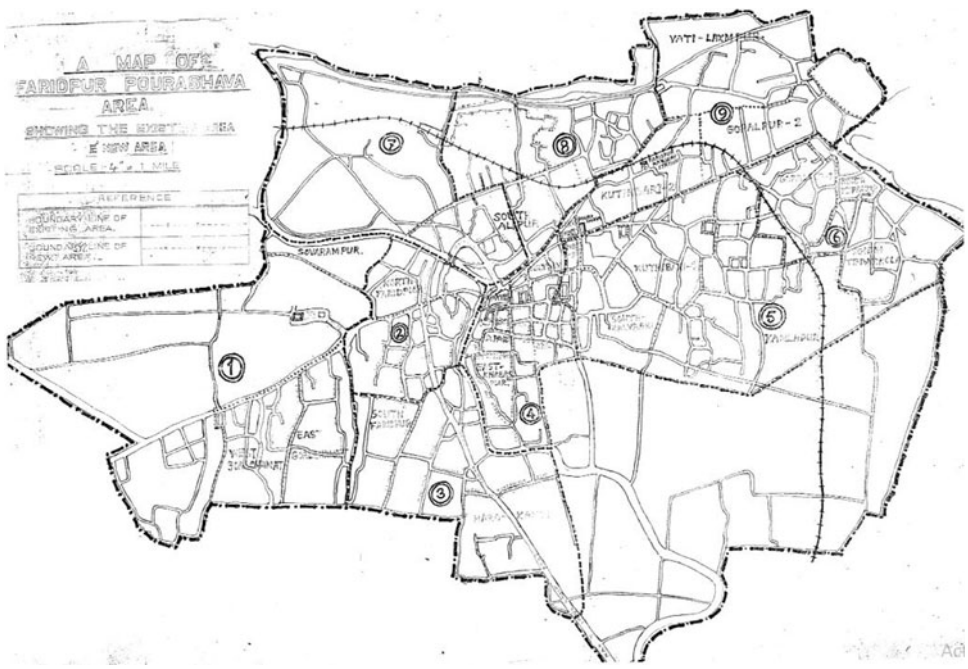

Fig. 3 Map of Faridpur municipal [1990]

and both figures indicated that the roads near the central axis have more choice values colors than the streets alongside the river.

Control calculates the level of choice every space represents compared to its closest neighbors as space to move. Each area has its value, which is identified as K here with its immediate neighbor. For that reason, each space gives its next neighbor the value of 1/k, and then all the values are summed for every receiving area to provide the proper amount of control of that specific space. If the value is greater than one will indicate that it has strong control, and if the value is less than one then the control of the spaces will be weak. In Fig. 8, It is visible that the central axis roads are showing more control than the riverside roads by warmer color because of their direct connection with the value of choices.

5 Connectivity

Connectivity measures the number of spaces immediately connecting spaces of origin. Connectivity ensures us how urban people frequently use spaces and why they are so much

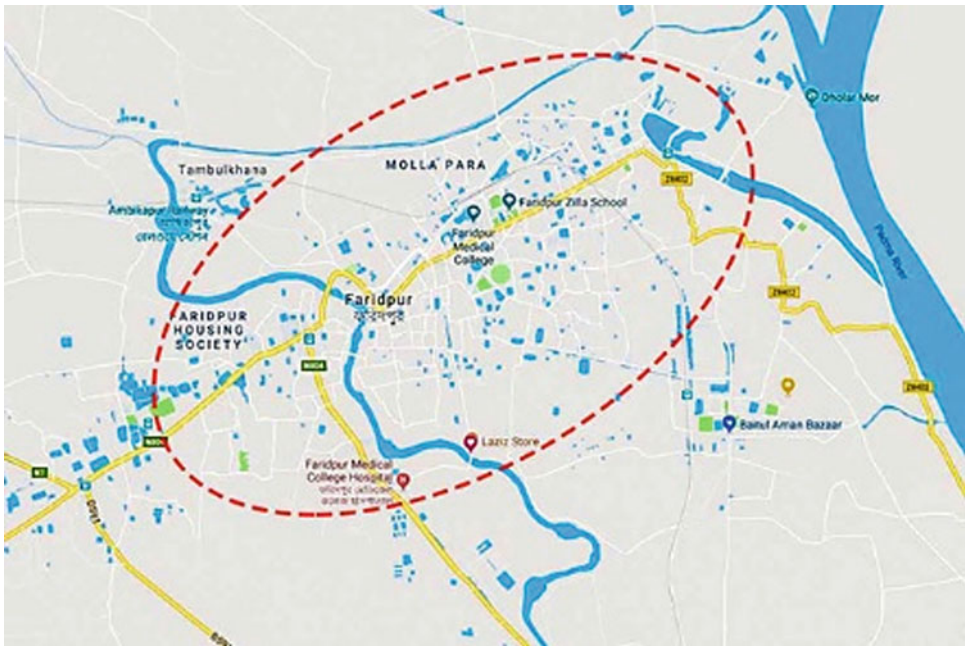

Fig. 4 Recent settlements of the city [2018]

Fig. 5 Road layouts of the city [2018]

integrated with the whole urban transportation. In Fig. 9, we can see that every road produces a different color type indicating their connectivity. As we know, warmer color indicates more connectivity, so it is understandable by checking their color and specific values that the central roads are more connected among all the other roads of Faridpur city.

6 Global Integration

In space, syntax integration indicates the basic turn one needs to do to reach one point of a street segment to all the other possible street segments accessible in that network

Fig. 6 Choice axial line R = n [global choice]

Fig. 7 Choice axial line R = 3 [local choice]

and, most importantly, by using the shortest path. When the number of turns needed to reach all possible parts appeared in the graph is calculated, then it can be declared that the measurement integration radius was "N". At the initial stage, only one turn was needed for the first intersecting segment. The second stage will need two more rolls. Thus the process will go on. The "most integrated" street is leveled as its performance determines how many turns it required to reach another road. The fewest turn will be leveled as most integrated. The hotter color represents more integration. In the aspect of Faridpur city, we can clearly understand the impact of the central road for integration (see Fig. 10).

7 Local Integration

In the local case, integration can also be done. For radius 3, three turns are needed to count from the departing street segment. In theory, integration calculates the complexity to reach one point to another point. Arguably it can be called that it measures the pedestrian choice of a street, how much popular this street is. In Fig. 11, it can be observed that the main road is still more integrated the way instead of alongside the river.

7.1 Comparative Analysis of Various Roads

From the axial map, it is visible that the central path and the southwestern road, which is also connected with the main road, is frequently used for transportation. To find out the most frequently used roads, another method is used. Two of the significant location's roads are selected, one is the roads which pass through the central axis of the city (see Fig. 12), and another is the roads near the river (see Fig. 15). Later two secondary areas are identified for each primary area. For the central axis selected area, The red zone marked area is considered as the 1st area (see Fig. 13), and the dark red area (see Fig. 14) is regarded as the 2nd area. With the help of the depth map, a table is created for each sector with their numerical values of connectivity, integration, and choice at each specific point marked in Figs. 13 and 14.

From Tables 1 and 2, from the drawing point number 01–07 it is visible that all the roads connectivity is more than 15, and from drawing point number 8–12 it is more than 26 which indicate their high connectivity, their average integration value is 0.70, which also suggests that all these roads are highly preferable and frequently used by the users, they are also very well integrated with the whole road network.

Again, from the axial road diagram, it is visible that roads along with the river have a low choice and lower integration. For further confirmation, two areas along with the river are selected (see Fig. 15) and marked with blue color. A table is created for each sector with its numerical value of connectivity, integration, and choice at each specific point (see Figs. 16 and 17).

From Tables 3 and 4, from the drawing number 13–24, it is visible that all the road connectivity is less than 5. Roads' average integration value is less than 0.35, which indicates that all these roads are not preferable and moderately used by the users. These roads are also not well integrated with the whole road network.

Fig. 8 control axial analysis of city

Fig. 9 Connectivity axial analysis of city

8 Discussion

From the analysis of the axial map of road analysis of Faridpur city, A clear scenario can be depicted that with the recent development of infrastructure, the city's functional core expands around the central road and its secondary roads. The analysis also indicates that the central road of Faridpur city and a southwest road connecting the main Bazar are now being the most frequently used roads for transportation movement. From the choice and integration maps, it is observed that roads alongside the river are not well integrated with the central part of the city anymore, resulting in a decrease of frequent uses.

Fig. 10 Global integration of city [R = n]

Fig. 11 Local integration of city [R = 3]

Fig. 12 The selected area along with the main road

While comparing the road network of the above-mentioned areas, it is found that the roads which pass through the central axis have connectivity value of more than 15, while the roads near the river have connectivity value less than 5. It indicates the central road acts as the functional core of the cities. Furthermore, in comparison with the integration value of the central road, which is 0.70, the riverside roads have 0.35 integration value, which proves riverside roads are less integrated with the overall road network of Faridpur city. Though the choice varies for characteristics of the individual, most of the roads near the central axis have higher choice values than the roads alongside the river.

So, it is merely understood that, though the city was initially founded alongside the river, later with the formation of new road layout, the functional core of Faridpur city is shifted to the central part of the city. It can also be predicted that, in future, the expansion of the city will be concentrated around the central road and later can infuse unplanned development, while the riverside road network will remain less integrated with the functional core of the city.

Fig. 13 Area 1 along with central axis of the city

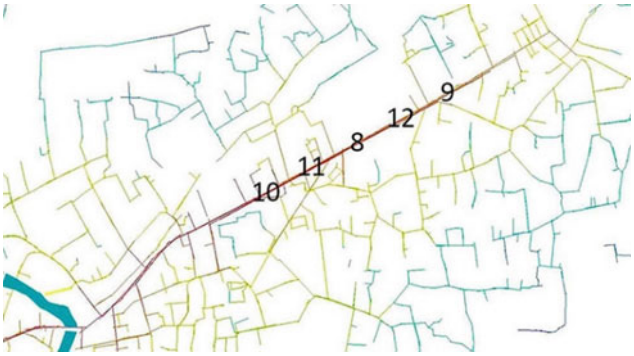

Fig. 14 Area 2 along with the main road

Table 1 Numerical values of area 1 selected points

Drawing number	Ref. number	Choice	Connectivity	Integration value [HH]	Integration value [p value]
1	1450	184783	4	0.73239744	0.73239744
2	1397	2587598	7	0.76426035	0.76426035
3	1669	62570	16	0.70525992	0.70525992
4	1259	1025005	8	0.75938827	0.75938827
5	1366	963308	16	0.7429446	0.7429446
6	1735	911842	16	0.71169865	0.71169865
7	1794	1841307	21	0.71573466	0.71573466

Table 2 Numerical values of area 2 selected points

Drawing number	Ref. number	Choice	Connectivity	Integration value [HH]	Integration value [p value]
8	770	942014	35	0.73468137	0.73468137
9	290	252229	29	0.69909787	0.69909787
10	560	249888	27	0.72481161	0.72481161
11	561	246250	26	0.72362429	0.72362429
12	344	84780	30	0.69935155	0.69935155

9 Conclusion and Recommendation

The main focus was to explore a relationship between the old road network of Faridpur, which was evolved along the riverside and the current road network of the expanded city in terms of spatial configuration. With the method of space syntax, it also tried to identify the functional core and the most frequently used roads concerning its rivers location. Though the city development was started from the riverside, with the new road layout development, a new pattern of development has begun to develop. This new development is neglecting the potency of the riverside area while focusing all the development alongside the central road. To sustain the morphology of the city, the city needs an integrated road network layout between the central road and the riverside roads. Further study is required to explore the opportunities of this integrated road layout for future planning to achieve sustainable development.

Based on the literature review and spatial analysis, as the city was initially founded near the river, to sustain the city's morphology, the impact of the river should not be neglected. Though we found that the connectivity and integration of the riverside road are low, we need to rethink the road layout of Faridpur city. In terms of planning and development, the road network should be redesigned in such a way that it will improve the connection between the riverside road network and the central core, thus improve the integration value of the riverside road network. It also needs to be evaluated on how the new road network will affect the overall connectivity and integration. New connections between the central road and riverside roads can be established to improve the current situation regarding the riverside road. However,

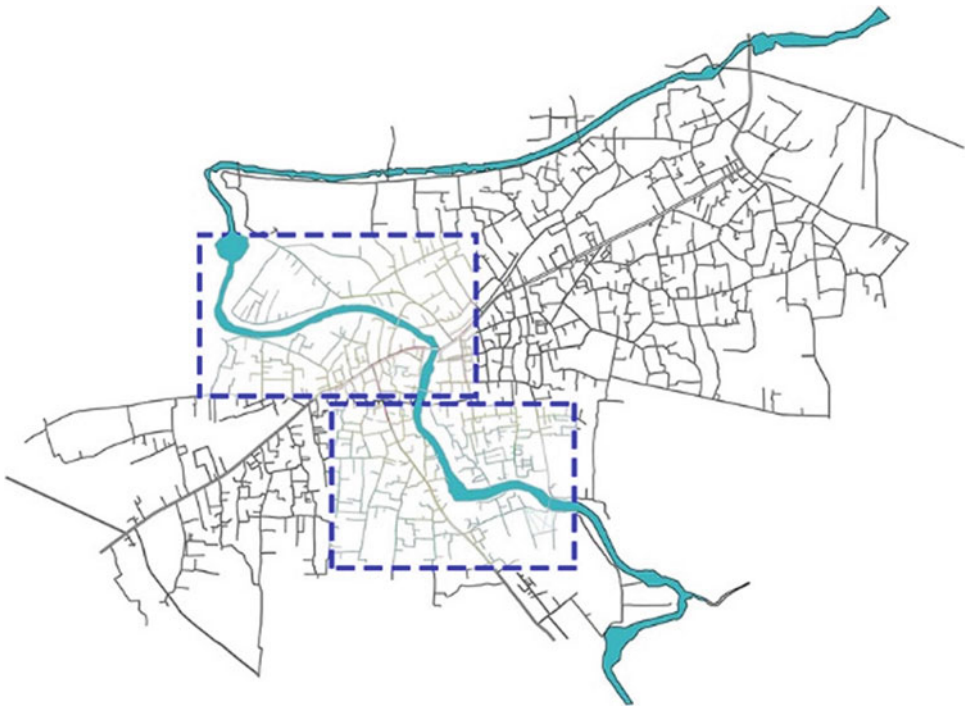

Fig. 15 The selected area along with the river

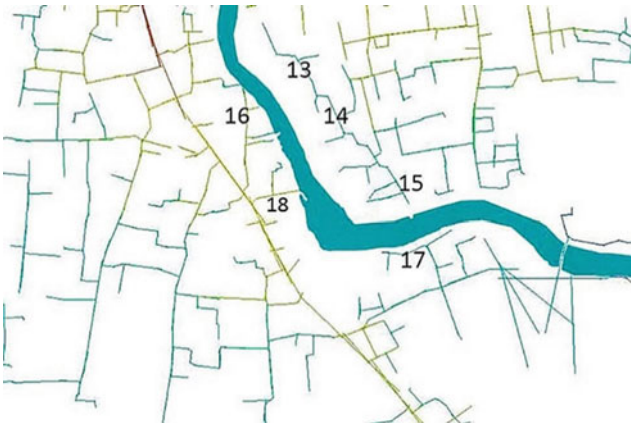

Fig. 16 Area 3 along with the main road

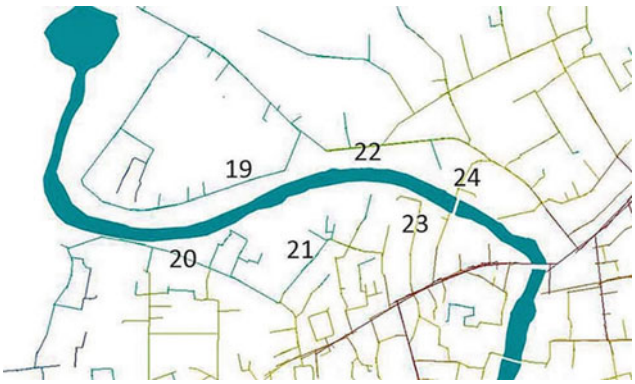

Fig. 17 Area 4 along with the main road

Table 3 Numerical values of area 3 selected points

Drawing number	Ref. number	Choice	Connectivity	Integration value [HH]	Integration value [p value]
13	1429	19528	3	0.34740701	0.34740701
14	1384	58065	4	0.39455238	0.39455238
15	1319	29262	4	0.37852827	0.37852827
16	1559	49028	5	0.52281082	0.52281082
17	1218	14646	2	0.33662447	0.33662447
18	1532	43858	3	0.55868149	0.55868149

Table ±4 Numerical values of area 4 selected points

Drawing number	Ref. number	Choice	Connectivity	Integration value [HH]	Integration value [p value]
19	2028	75748	3	0.40882364	0.40882364
20	2063	259845	5	0.46099877	0.46099877
21	1902	34118	3	0.41926795	0.41926795
22	1695	248563	8	0.4999679	0.4999679
23	1766	14646	2	0.59718466	0.59718466
24	1627	179480	3	0.61160225	0.61160225

while taking this type of decision in planning and development, further extensive research is needed to ensure the sustainable development of Faridpur city.

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Study the Intervention on Oued El Harrach to Eliminate Pollution Using Urban Solutions and Sustainable Development

Saouane Med Boudiaf and Zeghichi Sarra

Abstract

Pollution is the main concern of the world today, especially the Arab countries, and Algeria is one of the countries affected by this phenomenon of all kinds Algeria suffers, Oued El Harrach has caused it to distort the urban fabric and the health of the individual due to having caused it to distort the urban fabric and the health of the individual due to waste in the city of Algiers, which suffers from air, land, and sea pollution due to Oued El Harrach, which divides the capital from the east by 18 km. Algeria, which is home to several river cities, has embarked on this reconquest of these natural landscape components and seeks to reconcile its cities with their wadis. The movement is reversed. If the urban shores of port wastelands give rise to large-scale projects, the desire to revive these little ignored rivers, to bring them to light, and to re-qualify them in their urban crossing is becoming increasingly necessary, in this way Oued El Harrach with the hydraulic and landscaping project. Where is seen Oued El Harrach is increasingly perceived as an essential component of the landscape, so it is conceptualized and belongs to the future. The problem raised in this research is the perception of Oued El Harrach in the Algerian landscape. In this sense, the wadi is seeing from a particular angle: of its integration into the city and its contribution to the enhancement of the image of the capital and the restitution of the imaginary and the collective memory, and therefore the identity of the place itself. Indeed, the perception of the landscape is today relegated compared to more conventional discourses and relating to the functional aspects of cities. Indeed, our interest in this subjective dimension, for the notions of image, the reconquest of the banks of the wadi does and eliminating pollution and not neglecting all the plural dimensions of the metropolitan development. When we arrive at the context of our research, a general impression not very pleasing of the emerging landscape, including the main questioning around which this research will be articulated as follows: the extent impact of the valley of El Harrach on the urban fabric of the city. And does the Oued El Harrach rehabilitation and preparation project and the results of water recycling definitively eliminate this phenomenon?

Keywords

Pollution • Capital • Algeria • Urban fabric Oued El Harrach • Tourism • Health • Economy • Sustainable development • Renewable energy • Water recycling the landscape

1 Introduction

Pollution from the environment has become a threat to human life in recent times due to the evolution and acceleration of life. The environment and the emergence of new materials and elements that are not compatible with the environment surrounding live aircraft and cause disruptions and negative impact on living organisms. Man is the only effect that can reduce the impact of these pollutants by exploiting them in useful areas. The types of pollution vary because of the different components of the environment.

We have air pollution, which is produced due to changes in the elements of the constituent air and thus affect human health and causes respiratory problems because the air is surrounding the human and contains the oxygen element which is necessary for breathing Pollution is not limited to concrete areas only, but visual pollution falls within the types of pollution of the environment.

It deforms any view of the human eye in the surrounding environment which causes discomfort and a negative impact on its mental health. There is noise pollution caused by the sounds of cars and machines in the areas as industrial and technological development increased, audio pollution

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increased. Therefore, pollution is a major preoccupation in the world, the Arab world, and third world countries, which suffer from this dangerous phenomenon. One of these countries is Algeria, which suffers from the pollution of various kinds, especially the big cities, and during this study we will address. The pollution of the city of Algiers, which the latter suffers from many types of pollution, including air, kilometers, and the pollution of this valley. For several reasons, including the dumping of industrial waste and the drainage of urban, water, and visual pollution of the city because of Oued El Harrach, which divides the capital from the east by 18 km and the pollution of this valley. For several reasons, including the dumping of industrial waste and the extent of the impact of Oued El Harrach on the urban man and urban fabric of the city?

Drainage of agricultural fertilizers all of which were planted in Oued El Harrach. Hence, we address the basic problems:

Is the project of rehabilitation and rehabilitation of Oued El Harrach and the recycling of water has resulted in the elimination of this phenomenon permanently?

2 Objectives of the Study

In this paper, we have targeted the main objective, which is to highlight the potential of Oued El Harrach as an element that stimulates a new and more rewarding image of the city of Algiers.

We have laid the solid foundations, understanding and mastering it in which the image of Oued El Harrach revealed in the Algerian scene through a sensory reading of the subject of the study in the surrounding geographical context.

Then, we have defined the criteria that allow it to present a specific case, and then qualify it as an environmental path.

Therefore, in this research, we conducted an evaluation study to prove the presence of pollution inside the Oued El Harrach and water pollution by conducting chemical analyzes of the valley's water. In the second stage, we learned about the reasons for the contamination of the valley, especially after the filtering projects that the government pursued the valley from waste residues. It is the deficit of the Baraki station designated for liquidation knowing that the station filter out about 50% of the remains of sewage homes, and the inability to complete the liquidation of industrial remnants of the industrial zone Oued Semar. Finally, we have developed solutions to eliminate pollution once and for all, by following some experiments in this field, including the Chinese experiment in 2015.

Because Oued El Harrach is a picture of its guests, the resulting image is a mirror that reflects our awareness and our culture. As for the city of Algiers, it will be a matter of choosing the best picture, the best mirror, reflecting its identity, conveying meaning, and giving lessons in life, in nature, for users to learn how to live in today's capital. Today is like yesterday and hope is for tomorrow. Human beings must take advantage of nature, its components, and the spirit of the place, to think of a happy river, a prosperous landscape, wonderful and healthy capital!

The first duty is not to consider how to do things today, but to know how we can give new strength, and new vitality to an existing goal which, once organized, will never change and will never die.

3 Methodology

Work in this study, we adopted the following plan for the study in several stages. The first stage: a descriptive study of the Oued visit responsible and to provide questions and collect maps and report Oued El Harrach institutions. Also know the effects of El Harrach at this stage, we relied on a survey wad place through a field visit to the site and took many pictures and Oued El Harrach pollution on the individual and urban fabric. In order to know the causes of pollution and what measures taken by the responsible authorities against this phenomenon and what is the proportion of pollution elimination Phase II: the stage of analysis of the results of the descriptive study of the site and Wadi Harrach and evaluation of the rehabilitation project in the elimination of pollution through the submission of statistics and results analysis laboratories Algeria. The third stage is the provision of solutions to reduce the phenomenon of pollution and exploitation of the valley for the production of new energy.

4 Study of El Harrach Vall

- **Description of the study area (Physical environment)**

4.1 Location of the Wilaya of Algiers

The wilaya of Algiers is located in Algiers in northern Algeria, it is bounded: in the North, by the Mediterranean Sea; in the East, by the wilaya of Boumerdès; in the West, by the wilaya of Tipaza; in the South, by the wilaya of Blida. The territory of the Wilaya of Algiers covers an area of 1,190 km^2 and has 2,882,897 inhabitants (Fig. 1).

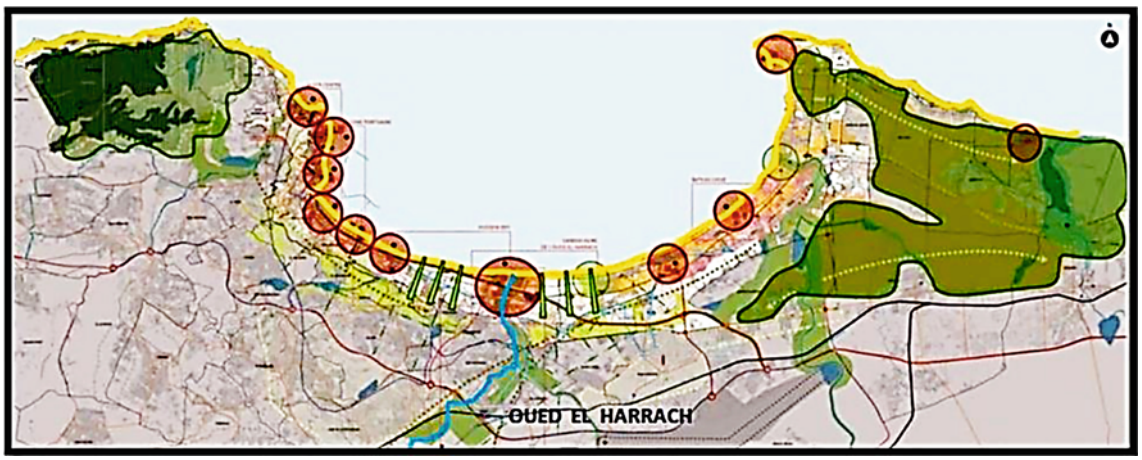

Fig. 1 Coherence diagram of the promenade with location of Oude El Harrach

4.2 Location of El Harrach in the Wilaya of Algiers

El Harrach Valley is one of the main rivers that cross the wilaya of Algiers. It has its source in the Atlas Blidéen and the Sahel and covers a large watershed of more than 1200 km^2. After crossing the plain of Mitidja, it enters the wilaya of Algiers to travel about 18 km to its mouth in the Mediterranean Sea. Oued El Harrach has a total length of 67 km, of which nearly 19 km in the capital, while the rest of its course extends to the wilayas of Blida and Medea. The area of intervention of the present study concerns the main course of the Oued El Harrach within the administrative boundaries of the Wilaya of Algiers, which is a linear course of 18.2 km (12.5 km at the upstream of the RN5 and 5.7 km downstream of the RN5) (Fig. 2).

4.3 Hydrology

Oued El Harrach crosses the plain of Mitidja from the city of Bougara and irrigates agricultural areas all around, thanks to its tributaries, Oued Lakha, Oued Bou Maane, Oued Djemâa, Oued Bab Ali, and Oued El Terro. But its main tributary is the Oued Smar which crosses an industrial zone of the eastern suburbs of Algiers. The average flow of Oued El Harrach is 4–5 m^3/s but can go from zero during the dry period to 3000 m^3/s during floods. It feeds on rainwater, inputs from its confluents, urban and industrial wastewater, runoff and repressed seawater. Mission 1 made it possible to quantify and qualify the hydrological functioning of the El Harrach Valley during flooding (Tables 1 and 2; Figs. 3 and 4).

4.4 Climate

Algiers enjoys a mediterranean climate. It is known for its long hot and dry summers. Winters are mild and wet; snow is rare but not impossible. The rains are abundant and can be diluvian. It is usually warm mostly from mid-July to mid-August. Algiers has an average rainfall of 600–800 mm of water per year which makes it possible to classify the site among the sub-humid bioclimatic stage with high agricultural value. Floods can be dangerous and cause considerable human and materials damages.

The climate of Algiers is tempered by the contrary movements of cold north winds and hot from the inside. In

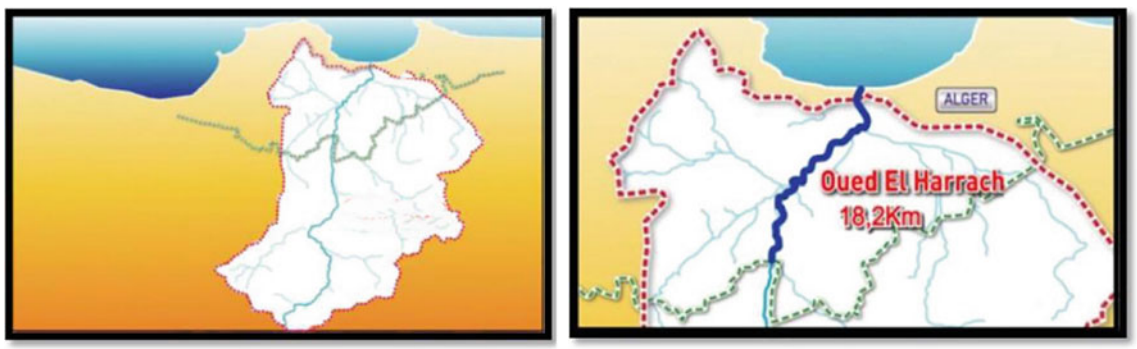

Fig. 2 Views of the perimeter and the course of Oude El Harrach

Table 1 Flood flows from the Oude El Harrach at the mouth to significant return times

Return period (years)	2	5	10	20	50	100	200
Q (m^3/S)	220	615	1190	1540	2015	2365	2715

Source Baraki station hydrographs

Table 2 Results of the modelization rain, flow for the main affluents of the Oude El Harrach

Return period	Value	Watershed		
		Oude djamaa	Oude ke ma	Oude smar
		(S = 233 km^2)	(S = 262 km^2)	(S = 210 km^2)
T = 10 years	Modeled flow (m^3/s)	230	240	165
	Offset of the flood peak at the confluence with the El Harrach Valley	~0 h	~ +0.50 h	~ +0.75 h
T = 20 years	Modeled flow (m^3/s)	300	315	195
	Offset of the flood peak at the confluence with the El Harrach Valley	~0 h	~ +0.50 h	~ +0.75 h
T = 50 years	Modeled flow (m^3/s)	395	415	235
	Offset of the flood peak at the confluence with the El Harrach Valley	~ 0 h	~ +0.50 h	~ +0.50 h
T = 100 years	Modeled flow (m^3/s)	460	485	290
	Offset of the flood peak at the confluence with the El Harrach Valley	~0 h	~ +0.30 h	~ +0.50 h
T = 200 years	Modeled flow (m^3/s)	520	545	350
	Offset of the flood peak at the confluence with the El Harrach Valley	~0 h	~ +0.50 h	~ +0.50 h

Source Baraki station hydrographs

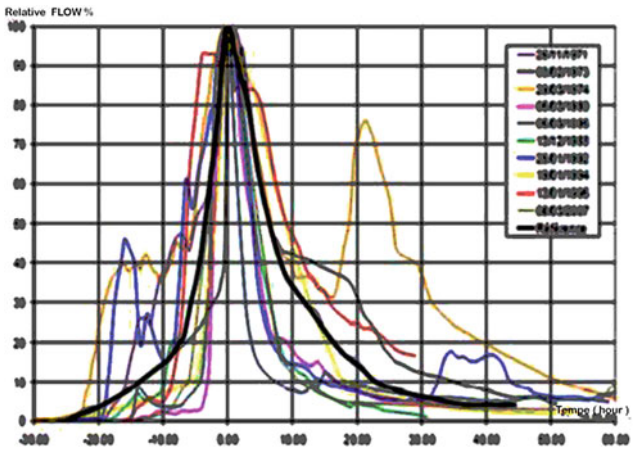

Fig. 3 Relative hydrographs of floods measured at Boracay Station

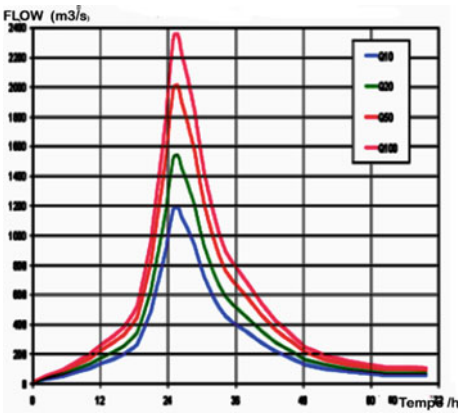

Fig. 4 Standard hydrographs at the mouth

winter, they can be formidable and cause violent storms or eddies at sea while heavy rains regularly cause upwelling supplying Oued El Harrach.

The waters of Oued El Harrach stagnate, sometimes creating marsh areas and endemic foci and infectious diseases.

4.5 Urban

The urban structure:

From the name of the wadi (the river) running through this neighborhood. The mouth of this river played a very important role in the capture of Algiers and Penon, the rock in front of Algiers occupied by the Spaniards. In fact, at the

beginning of the sixteenth century, at the call of one of the Algerian autochthonous dignitaries who saw the gradual loss of the authority of the city before the occupation of Penon by the Spaniards, one of the brothers Barbarossa hid his fleet before taking Algiers by surprise on the south-east side.

The district of Algiers was named Maison Carrée by the French, who made it the industrial zone of the city. Thus, during colonization, both El Harrach and Hussein Dey were satellite cities of Algiers where Algerians and French Indians did not coexist, due to clear residential segregation. This city was a residential area for a wealthy French, but a real ghetto for Algerians, especially those driven by the rural exodus.

El Harrach also wrote a great sports history page with boxing and football. After independence, El Harrach gradually became a district of Algiers, and later chief town of Daïra with a new division into districts, such as Mohammadia (Lavigerie), Belfort, Bellevue, The Park, Oued Smar, Five Houses, The Dunes, Maritime Pines, and Beaulieu.

We distinguish the continuous urban fabric that represents spaces structured by buildings, roads, and artificially covered surfaces cover most of the ground.

The discontinuous urban fabric represents spaces structured by buildings, roads, and artificially covered surfaces that coexist with vegetated surfaces and bare ground, which occupy discontinuously large areas.

Industrial zone: the whole of this class represents artificially covered areas (cemented, asphalted, asphalted, or stabilized zones), without vegetation, occupying most of the soil. These areas also include buildings and/or vegetation (Fig. 5).

5 Description of the Initial State of the Site and Its Environment

5.1 Initial Pollution

On the upstream part of the watershed (at the level of the Atlas Blidéen), Oude El Harrach is relatively clean. The Oude is then responsible for various types of pollution as it flows toward the Mediterranean Sea of the domestic, industrial, and agricultural order (Figs. 6 and 7).

In the urban crossing and to its mouth, especially in the industrial communes (Gué de Constantine and El Harrach), Oude El Harrach has a very low concentration of dissolved oxygen, not exceeding 1 mg/l.

Its waters are highly polluted (photo), inevitably causing eutrophication of this environment which becomes a medium enriched in organic matter, nitrogen and phosphorus. The value of the pollutant load that the water of the Wadi receives daily far exceeds their capacity of natural self-purification (Cf. the results of the analyzes in appendix) (Fig. 8).

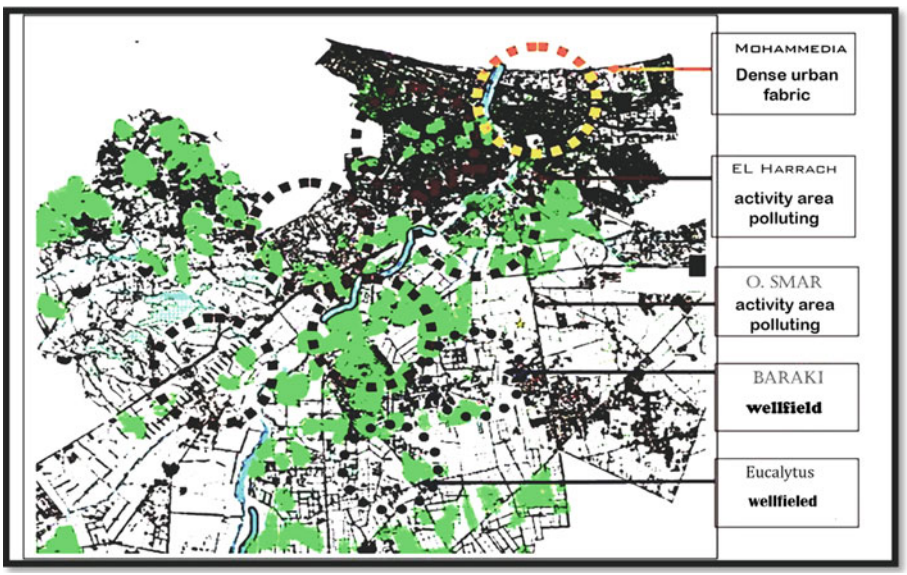

Fig. 5 Ecological and socio-economic issues related to flood and pollution hazards

Fig. 6 Picture Highway bridge to Dar El Bei

Fig. 7 Picture initial state of the upstream site

Fig. 8 Pictures view of the waters of Oude El Harrach from the ring road bridge

Among the forms of pollution experienced by the waters of this river, appear heavy metals that result from discharges emitted by various industries and craft units along the wadi. Due to the diversification of chemicals used in agriculture, the effluents from these units are characterized by chemical pollution.

5.2 Pollution of Agricultural Origin

The Mitidja, the seat of a strong agricultural activity, contributes to the pollution of the Oude by insecticides, herbicides, and fertilizers. Given the diversification of the chemicals used, effluents from riparian agricultural units are characterized by chemical pollution. Besides, the unjustified use of fertilizers in this highly agricultural region only accentuates pollution and increases the risk of contamination of the surface and deep waters of this ecosystem.

5.3 Industrial Pollution

The first pollution by the vases was observed on the upstream part of the investigated line, from "El Megrounet" to the bridge of the new Baba Ali—Boudouaou ring road. The color of the water is dark brown. The main cause of this pollution seems to be the activities of the sandpit Souk El Had, which intervenes directly in the minor bed and proceeds to wash the alluvium with the water of the wadi, the rejections being done also in the Oued. Since the survey of ground, a decree of the closure of the sandpit Souk El Had has been signed. Another high pollutant load affects sediments located on the banks of Oued El Harrach and is caused by spills from many industries located in the industrial zones of Gué de Constantine, El Harrach, and Oued Smar. These include the dumping of the pulp mill at Baba Ali, and the Oude Smar, which is the receiving environment of the entire industrial area nearby.

Fig. 9 Pictures show wastewater discharge centers for homes and industrial waste

5.4 Domestic Pollution

In general, the tributaries of Oude El Harrache serve as vectors for domestic wastewater. Discards are sometimes made directly in the minor bed of El Harrache wadi. This shows the first domestic pollution from the bridge of the new ring road. Direct discharges are becoming more frequent as the wadi crosses urbanized areas. This is particularly the case for the Oued Ouchaïah, which is a collector of domestic wastewater, mixed with those of some industrial units (Fig. 9; Table 3).

6 Description of the Impacts of Pollution on the Environment and Human Health

The environmental elements, which will be affected by the negative impacts of Oude El Harrache, are the physical environment through the water resources, the air, and the human environment.

6.1 On Human Health

Pollution has an impact on our health. Elderly people and children are the most sensitive. Also, residents of Algeria's municipalities are exposed to a large amount of industrial waste and wastewater in the Harrache Valley, causing air and water pollution.

- Risks to short-term atmospheric pollution during a period of high atmospheric pollution and the next few days, studies show an increase in hospitalizations, due in particular to an increase in heart attacks (fatal or not).
- Long-term health risks an individual exposed to long-term air pollution, even at low doses, is more likely to be affected by the cardiopulmonary disease (myocardial infarction, asthma, etc.).

The risks of cancer are also greater. Air pollution contributes to a decline in fertility, an increase in infant mortality, and a weakening of the immune system.

Table 3 Heavy metal pollution sources according to Baize and Janiec (1994)

Cadmium	Phosphate fertilizers; metal surface treatment industries; plastic stabilization industry; manufacture of accumulators and automobile radiators; rubber manufacturing; dyes; runoff from taxiways
Cuivre	Water pipe; electric wires; automotive radiators; heating apparatus; surface treatment
Zinc	Pharmaceutical or household products; water pipes; paintings; battery; galvanizing; surface treatment
Nickel	Manufacture of steels and special alloys; surface coating by electrolysis; hydrogenation of oils and organic substances; painting manufacture; lacquer and cosmetics
Mercure	Pharmaceutical or household products; production and use of antifungals; electrical appliances; electrolytic products of chlorine and soda; paintings; pulp paper; manufacture of vinyl chloride and urethane
Chrome	Tannery; manufacture of special alloys; surface treatment industries
Plomb	Water pipes; battery trays; paintings; additives for gasoline; runoff water from taxiways; pharmaceutical and iron and steel industries; photographic workshops; televisions
Sélénium	Manufacture of paints and dyes; glass; semiconductors; insecticides; alloys
Arsenic	Pesticides; herbicides; fungicides; insecticides; rat poisons; defoliants; wood preservatives; solar cells; semiconductors; electrography; catalysis; pyrotechnics; ceramics; pharmaceutical products; hair removal in tannery and tannery; hardening of copper and lead; manufacture of batteries

Source National Hydric Resources Agency (ANRH)

6.2 On the Environment

One of the Japanese researchers reported that the water pollution of this valley, which was once more suitable for fishing and swimming, was 400 times higher than the standards approved by the World Health Organization. It contains dangerous waste such as lead, chlorine, zinc, chromium, arsenic, which carries a high risk of more than 30 times the standards adopted globally.

6.3 The Impact of Urbanization

Wastewater and industrial waste in Oude El Harrache include a high percentage of nitrates, chlorine, sodium Magnesium, and phosphorus that accumulate and are highly concentrated in soil and then transported to building materials.

Through the process of absorption of water-saturated areas into dry areas, it is known that the salts in water have turned into salt on with varying electrical charges in the power of water.

Depending on the nature of salt and the degree of pores of building materials, salts pose a significant risk to building materials and blood its physical structure, increase the danger of water inside the building material, and the evaporation factor salts increase the concentration of crystallized salts inside and outside the building materials.

6.4 Visual Pollution

Visual pollution is the total damage to landscapes. Wad al-Harrach contributes significantly to the Algerian capital because of industrial and household waste in the spread of this pollution phenomenon—Distort the general landscape of the capital and the spread of garbage and waste in the region.

- Oude El Harrache is also a source of deformation of the city of Algiers, and this is due to many reasons, including the spread of houses to Qasadriya on the banks of the valley, especially the city of Samar and spread this phenomenon with some other phenomena such as the spread of social pests and crime.
- The deterioration of the urban fabric and the spread of chaotic buildings (Figs. 10 and 11).

Fig. 10 Picture shows the spread of tin homes

Fig. 11 Picture distribution of waste

6.5 The Impact of Pollution of the Valley on the Tourist and Economic Side

This area is considered a tourist and economic at the same time primarily because of the commercial and tourist projects such as the Grand Mosque, the commercial complex Ardis, the square of Sablat, and the land station Kharuba and the neighboring industrial areas Baba Ali and the bridge Constantine Baraki.

It is not possible to make optimal use of the shoreline facilities without observing the problem of the marine

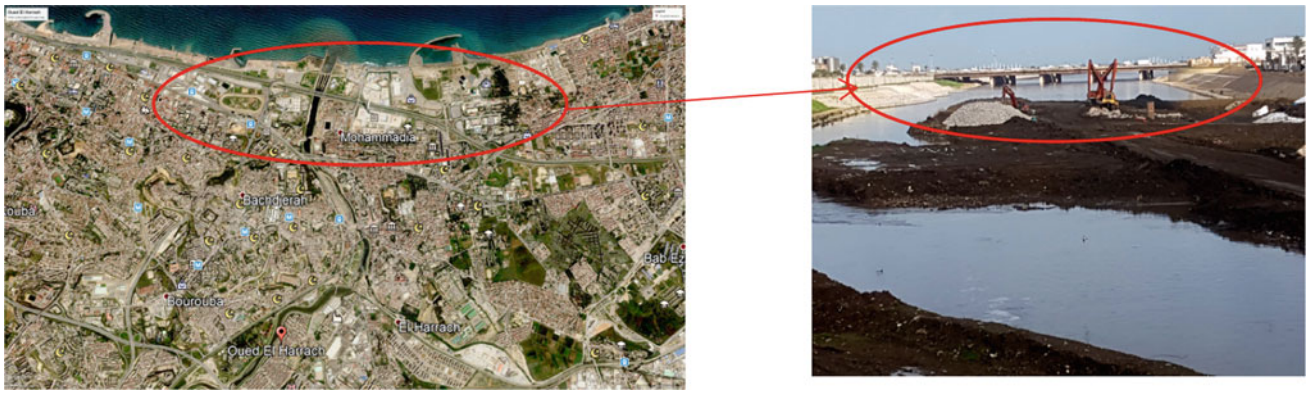

Fig. 12 Pictures shows Oude El Harrach place in the Mediterranean

pollution of the mediterranean, especially the result of the flow of oils emitted from ships or water flowing from Wadi Harrach, which are obstacles that can be reflected in the cost of this park and do not allow that Be the perfect beach in the state of Algeria

- The spread of bad smell in the surrounding area contributing
- Contributing to the decline in tourism and recreational activities in the economy of the region in particular and the region of Algeria in general (Fig. 12).

The image and the map show us the location of the meeting of Oude El Harrache and the Mediterranean Sea, which divides the beach of the two halves.

And the dumping of residues and waste from the valley, which has led to marine pollution due to the deterioration of tourism in the region because of the pollution of the beach and the decline of the economic side of the region and Oude El Harrache.

6.6 Impact of Pollution on Heritage

The analysis done on the heritage character of the site based on the principle of protection of the cultural heritage of the region prescribes that the cultural heritage, consisting of property around Oued El Harrach, reflects the identity of the inhabitants of this area. The architectural heritage has been affected by the problem of environmental pollution according to the diversity and diversity of its natural and human resources both as a result of the toxic gases circulating in the air that originate from the Wadi al-Harrache, such as sulfur compounds that turn on its interaction with moisture and precipitation to sulfuric acid acids that damage the building materials from corrosion of stones and blacksmith roofs due to dust and fumes in addition to industrial renaissance and what has started from the production of many liquid, solid, and gaseous wastes that are put into the environment, and soil pollution and groundwater due to misuse of pesticides, fertilizers, and agrochemicals, not to mention the waste of different urban areas. All of these were poured into Oude El Harrache.

7 Description of the Development Work at Wadi Harrache and the Brraki Purification and Purification Barrki

7.1 Development Works of Oued El Harrach

The development work on the banks of Oude El Harrache was officially launched on June 13, 2012, by the Minister of Water Resources Abdelmalek Sellal. The cost of this project, which is scheduled to be completed by December 2015, is 38 Bn Algerian dinars (380 M€). Its realization was entrusted to the Algerian-Korean group (Cosider-Daewoo E & C). This project is part of the management plan for the Bay of Algiers, which is part of the strategy of rehabilitation of the city of Algiers, which extends until 2029 and whose cost is more than 2 € meds. This project consists of the hydraulic and landscaping of the wadi on a line of 18.2 km from the mouth of the Mediterranean Sea to the territorial limit with the wilaya of Blida. The project of its rehabilitation concerns the re-calibration, the re-profiling of the bed of the wadi and the banks, the realization of three filtering gardens, the installation of systems of control and monitoring of the quality of the water, as well as the flood alert, the construction of bridges and footbridges and the construction of pumping stations with a capacity of 90,000 cubic meters per day. The rehabilitation of El Harrach wadi will also focus on the establishment of recreational areas and bathing, he said, adding that the unpleasant odors from this river would soon be no more than a bad memory (Fig. 13).

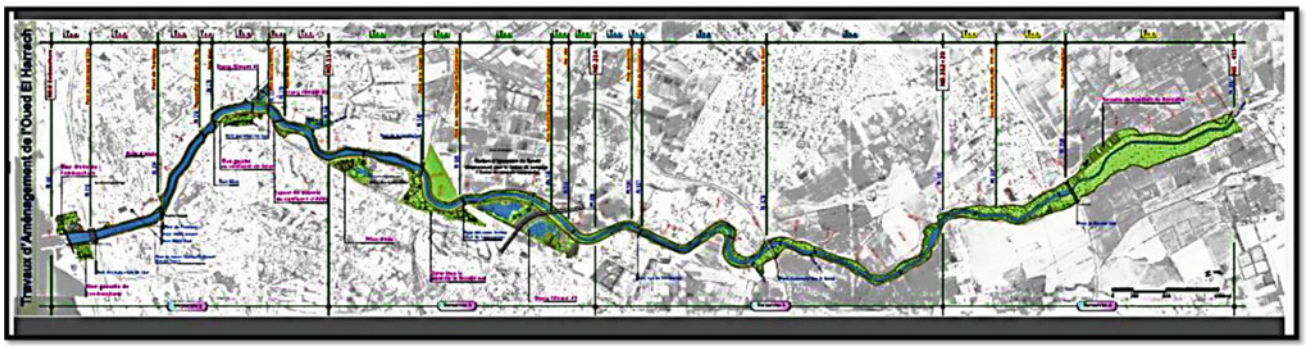

Fig. 13 Map identification of Wadi Harrach re-preparation areas

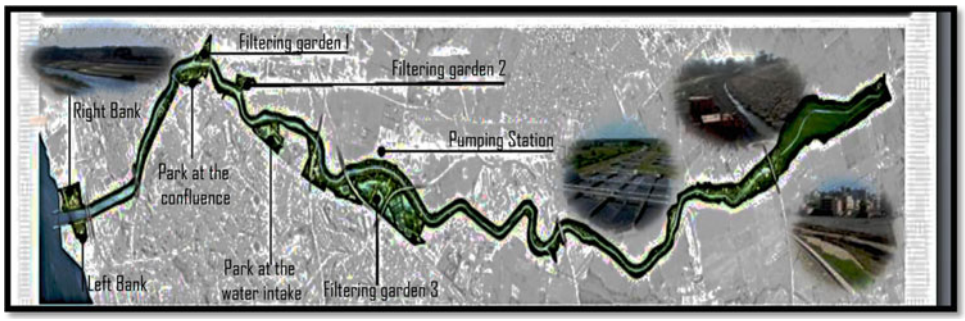

Fig. 14 The map shows the location of the Baraki station with the author's treatment

Physical consistency of the project

Hydraulic facilities = 18.2 km, landscaping, pumping station for the support of low water flow, warning and flood control system, and control of the water quality (Fig. 14).

7.2 Description of the Water Purification and Purification Plant of the City of Baraki, Algiers

- Sewage treatment plant (900,000 pe).
- Biological treatment with activated sludge, including a pumping station, a pretreatment step, and sludge treatment with two stages of anaerobic sludge digestion and dewatering.
- Rehabilitation of existing treatment plants and pumping stations.
- BOD (Design-Build-Operate) project: operational management of the station for 24 months.
- Baraki is the main sewage treatment plant in Algiers and the second largest facility of its kind in Algeria.
- WABAG's services included
  - review and diagnosis of existing facilities,
  - the dismantling and rehabilitation of existing structures,
  - supply, installation, and commissioning of equipment
  - operation/maintenance.

8 Analysis of the Results of the Descriptive Study of Oude El Harrache and the Re-configuration Project in Algiers

After the descriptive study of the site of Oude El Harrache and the project of retrofitting and the impact on the urban fabric and human health of the capital and also its impact on the situation economic, tourist, and historical area of Wadi Harrach and what we found.

8.1 Biological Pollution

Biological oxygen demand (BOD5)

BOD5 expresses the amount of oxygen required for the biological degradation of organic matter in water. It is substantially proportional to the water content of biodegradable organic matter and therefore to the number of microorganisms and inversely proportional to the dissolved oxygen content. It depends, among other things, on the nature of the dissolved organic matter, the presence or the absence of inhibitory elements of the microbial flora (heavy metals, hydrocarbons, detergents…). Indeed, the profile of the BOD5 shows the presence of a significant mineral load with important values. Throughout the site, the concentration of BOD5 is relatively high compared to that detected in other sites suggesting excessive releases of pollutants of organic and industrial origin (Table 4).

Table 4 Simplified grid for the assessment of the quality of surface waters in Chapman and Kimstach (1996)

O2 dissous	DBO5	DCO	NH+4	Phosphoro total	Coliformes fécaux
Mg/l	MgO2/L	MgO2/L	Mg NH+4/L	Mg P/L	Par 100 ml
>7	<3	<20	<0.1	<0.1	<20
7–5	3–5	20–25	0.1–0.5	0.1–0.3	20–200
5–3	5–10	25–40	0.5–2	0.3–0.5	2000–20
3–1	10–25	40–80	2–8	0.5–3	>20000
<1	>25	>80	>8	>3	–

NO pollution

Excessive pollution

Source: National Hydric Resources Agency (ANRH) the author's treatment

8.2 Inability to Disinfect

The inability of the purification unit to clean up the water and cleanse the city of Baraki. Algiers: reasoning we have the rate of liquidation within one day is 900 thousand cubic meters in one day and the rate of pumping Wadi Harrach is 2.5 m^3 in one second means within an hour and the soul of the soul.

$$2.5 * 3600\,m^3/S = 9000\,m^3/S$$

In one day, by comparison, we find that: the rate of the Harrach is about double or more than the filter rate of the station

- Other causes of displacement station: that the filter station is dedicated to the liquidation of sewage water for homes only and not for the industrial areas next to the Oude El Harrache, which flows into the Harrach. The state proposed a project called the Wali Project of Algiers and the cleaning of the industrial establishments for their waste and the promise of its disposal in the valley as a preliminary solution to the problem. The number of such institutions is around 5,700, which have not yet done so in Wadi Al Harrach and are committed to the Convention.

So, you can find a list up to now and show that you analyzed and the photos that were taken recently for the wad Harrach.

8.3 The Failure of the State Project to Eliminate Pollution

From the above study of the project of intervention and retrofitting and Oude El Harrache that the goal of the project is the smooth elimination of pollution in all kinds of exploitation of these. The region is economically and touring important for Al Harrache as we have noticed during the study of Al-Wad site. However, the project of re-initialization and intervention on the Oude El Harrache in Algiers to eliminate the pollution is final for several reasons including:

- The inability of the purification and purification plant in the city of Baraki to liquidate the valley.
- Continuation of industrial establishments for industrial waste disposal.
- Stay away from the state of the main objective of the project is to eliminate the pollution and focus on the final re-preparation of the valley.
- The non-elimination of pollution cannot exploit this region economically and in tourism, because air pollution and water is still.

Widespread in the region and the spread of the smell of bad and other problems such as it is not possible to make optimal use of the facilities of the beach of the cables without observing the problem of marine pollution of mediterranean level, especially the result of the flow of oils emitted from ships or water flowing from Wadi Harrach, which are obstacles that can be reflected on the cost of this park and do not allow the beach to be ideal in the state of Algeria. The historical value of the area has also deteriorated due to pollution.

8.4 The Proposed Solutions

After studying the results of the pollution analysis and Oude El Harrache, we find that the pollution is an existing waste and affects the man and his environment and this after the

measures are taken by the state to permanently eliminate this phenomenon and therefore we offer solutions to completely eliminate pollution. The first solution, which is the obvious solution, is the installation of a new filtering station to filter and disinfect the water, to be twice as large as a Baraki station and to be dedicated to the liquidation of wastewater and industrial waste. It costs the state a large financial envelope that affects the economy.

- The second solution is the best solution to eliminate pollution and exploitation of the valley to produce new energy, electricity electrochemically or microbially, which is the method of producing electrical energy through wastewater from homes and industrial waste. This method was discovered by Sunni researchers in 2015 to increase the sustainability of waste and wastewater.

  Advantages:

- Elimination of pollution and new energy production at the same time.
- Achieve the sustainability of the Wad Harrach area and increase the economic value by providing the logical and electrical product of the valley—exploitation of the valley as a tourist front.
- Energy production in this way and fuel production is a measure of sustainability, said Chinese researcher Feng Yong, assistant professor of biological systems engineering.

9 Conclusion

At the end of our study, the results of the Wadi El Harrach study give the importance of the Algiers Valley site, geographically, economically, and tourism, but the phenomenon of pollution valley and the main source is the man on the road to pour the remains of sewer houses and throw away industrial waste, institutions, and others that we built to study the results on the impact of human tissue and urban of this phenomenon is dangerous pollution brought by a 400 times on pollution familiar to the World Health Organization measure, so the state of many measures to eliminate pollution completely, but the results of the study show us the remains of contamination Table 5 Algeria analysis documents laboratories so that we can say that the state has failed to eliminate these. The phenomenon is due to several reasons, including disability, wastewater treatment plant, and disposal industrial waste. We have therefore proposed many solutions to eliminate this dangerous phenomenon.

- The opening of a new station equivalent to twice the capacity of the Baraki plant from the purification of wastewater and industrial waste.
- The exploitation of the valley for the production of new electric energy on the electrochemical road or Mekobia and thus we can eliminate the pollution and reach the sustainability of the principle of sustainability.

Annex

See Table 5.

Annex N ° 02: The Legislative Framework of Analysis

The development of this study took into account the regulations in force below:

1-Law No. ° 05-12 of August 04, 2005, modified and completed relating to water.

2-Law No. 03-10 of 19 July 2003 on the protection of the environment in the context of sustainable development.

3-Law No. 01-10 of 03 July 2001 on the Mining Law.

4-Law No. 01-19 of 12 December 2001 on the management, control, and disposal of waste.

5-Law No. 04-20 of 25 December 2004 on the prevention of major risks and disaster management, including the framework for sustainable development.

6-Law No. 07-06 of 13 May 2007 on the management, protection, and development of green spaces.

7-Executive Decree No. 09-376 of 16 November 2009 laying down the conditions for the prohibition of the extraction of alluvial materials in wadi beds and wadi sections presenting a risk of degradation, and the methods of exploitation in the sites allowed.

8-Executive Decree No. 07-145 corresponding to May 19, 2007 determining the scope, content, and approval procedures for environmental impact studies and notices.

9-Executive Decree No. 07-144 of 19 May 2007 establishing the nomenclature of establishments classified for the protection of the environment.

10-Executive Decree No. 06-198 of 31 May 2006 defining the regulations applicable to classified installations.

11-Executive Decree No. 06-141 of 19 April 2006 defining the limit values for discharges of effluents and discharges of industrial liquid effluents.

12-Executive Decree No. 06-138 of 15 April 2006 regulating the emission into the atmosphere of gases, fumes, particulate, liquid, or solid vapors, as well as the conditions in which their control is exercised.

Table 5 Annex N ° 01: Results of chemical analyzes Laboratory code: 633/12 CNTC

Paramétres	Unités	Valeur Limites	Norm	Résultats	C/NC
Ph à 10%	Unité ph	–	NFT 90008	7.25	–
Température	°C	–	NFT90-100	22.00	–
N global	mg/kg	–	J. Rodier	12380.00	–
Aluminum	mg/kg	–	T90-119	1108.25	–
Argent	mg/kg	–	T90-112	0.2008	–
Arsenic	mg/kg	–	T90-119	0.8075	–
Bérylium	mg/kg	–	T90-136	02704	–
Cadmium	mg/kg	–	T90-112	0.2814	–
Chlore	mg/kg	–	J. Rodier	0.127	–
Chrom3+	mg/kg	–	T90-112	4.2003	–
Chrom5+	mg/kg	–	J. Rodier	17.2841	–
Chromate	mg/kg	–	J. Rodier	0.7407	–
Cuivre total	mg/kg	–	T90-112	158.4056	–
Cobalt	mg/kg	–	T90-112	0.1536	–
Cyanure	mg/kg	–	NFT90-107	4.1079	–
DBO5	mg/kg	–	NFT90-103	630.00	–
DCO	mg/kg	–	NFT90-101	6084.00	–
Etain	mg/kg	–	NFT90-112	0.2814	–
Fer	mg/kg	–	T90-112	978.8641	–
Fluorure	mg/kg	–	NFT90-004	38.1964	–
Hydrocarbure totaux	mg/kg	–	NFT90-114	0.5106	–
Matiére en Suspension	mg/kg	–	NFT90-105	5368.0	–
Magnésium	mg/kg	–	T90-112	3.3900	–
Mercure	mg/kg	–	NF EN1438	0.8074	–
Nickel	mg/kg	–	T90-112	20.6841	–
Nitrite	mg/kg	–	J. Rodier	<0.05 C°	–
Phosphore total	mg/kg	–	NFT90-123	2.690	–
Phénols	mg/kg	–	J. Rodier	5.2009	–
Plomb	mg/kg	–	T90-112	27.3246	–
Sulfure	mg/kg	–	J. Rodier	0.474	–
Sulfate	mg/kg	–	NFT90-009	480.69	–
Zinc et composes	mg/kg		T90-112	238.4111	–

Source Directorate of Laboratories—National Center for Technologies and Consulting—CPE.CNTC. SPA REF N ° 2245

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