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Decision Support System to Select the Most Effective Strategies for Mitigating the Urban Heat Island Effect Using Sustainability and Resilience Performance Measures

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DECISION SUPPORT SYSTEM TO SELECT THE MOST EFFECTIVE STRATEGIES FOR MITIGATING THE URBAN HEAT ISLAND EFFECT USING SUSTAINABILITY AND RESILIENCE PERFORMANCE MEASURES

A Thesis

by

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ABSTRACT

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As climate change continues to alter the temperature of the cities, various urban heat island mitigation strategies (UHIMSs) are now needed to be employed to mitigate the effects of increasing temperatures. However, to ensure their resilience and sustainability, the effectiveness of such strategies should be evaluated using a set of criteria. According to a review of the literature, there is a need for a comprehensive model and performance assessment tool that considers the various characteristics and features that are significant in assessing whether the chosen strategies are viable candidates for minimizing the effects of urban heat island (UHI). As a result, the primary purpose of this study is to develop a decision support system (DSS) to assist decision-makers in reducing the effects of the UHI by allowing them to choose the most viable mitigation method/technique based on resiliency and sustainability concerns. The DSS would function as a performance measure selecting tool in form of a quick-selection-guide-sheet of most effective method(s)/technique(s). Therefore, this study has identified, categorized, and organized affecting parameters in a comprehensive hierarchical framework based on sustainability and resilience. The system starts by creating a list of objectives (sustainability and resilience), criteria (economic, environmental, social, vulnerability, and resistance to change),

attributes, and the most used mitigation methods for the UHI effect. The system's second component is the main engine (using Weighted Scoring method (WSM)), which is responsible for determining the best mitigation strategies - the system's predefined goal. The WSM is being used in this study to develop matrices to do a pairwise comparison of criteria, assign a relative weight to each criterion, score each strategy against each criterion, and calculate the weighted scores based on gathered data from expert's elicitation exercises. Decision-makers can analyze the UHIMSs after the matrix has been set up with weighted scores to find the best method that fits their needs (system objective). The third key component is the user-friendly interface, which combines the previous two components of the system and applies spreadsheets to present the best feasible mitigation strategy. The contribution this study seeks is to develop a DSS resembling a knowledge-sharing platform to support stakeholders like urban planners, architects, decision-makers, and policymakers in the extraction of UHIMSs, and in a wide scope, the expected benefit would be more sustainable more resilient design. In addition, this study serves as a foundation for the establishment of a dynamic computer-based decision support system (DSS) for selecting the most efficient UHIMSs.

DEDICATION

This thesis is dedicated to all my family. A special dedication to my husband, Nima and my daughter, Arina for their absolute love and support without them this would not have been possible and to my advisor Dr. Mohamed Abdel-Raheem. Overall, to God for allowing me to have this opportunity to help preserve a healthy environment in my community.

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CHAPTER I

INTRODUCTION

General Overview

The difference in air temperature between developed and undeveloped areas is explained by the Urban Heat Island (UHI) effect. Flat dark surfaces like roadways, parking lots, and tarred rooftops absorb and retain solar radiation during the day, then radiate the heat back into the air at night. In human-affected areas, construction development cause UHI. It is produced on a continuous basis as a result of energy consumption, heat loss, and wind obstruction. As a result, the temperature significantly rises. Excessive heat absorption in cities appears to have a variety of consequences, including continually rising air conditioning demands, which has negative implications for energy, water usage, and costs (Akbari & Konopacki, 2005). UHI increases air pollution and greenhouse gas emissions, as well as being linked to the occurrence of heat-related illnesses, endangering people's health. Species that are unable to adjust to the induced habitation temperature are at risk of extinction or decline. UHI impacts are increased as a result of climate change, worsening the situation further due to the apparent long-term impacts. Several mitigation techniques are now being implemented in metropolitan areas witnessing rising temperatures to reduce the effects of UHI. Reduced UHI intensity is achieved through green spaces (Wong & Yu, 2005), green roofs (Aloisio, 2017; Gibler, 2015), vertical gardens, urban forestry, water features such as sprinklers, permeable materials, retroreflective materials, phase change materials

(Zalba et al., 2003), and other methods. Mitigation techniques, on the other hand, have a wide range of effectiveness depending on their long-term sustainability and resilience.

The Problem

Problem that arises when it comes to selecting between most appropriate mitigation method(s) with respect to sustainability and resilience is lack of clear performance measures. Despite the fact that each and every one of these mitigation methods and techniques might reveal some extends of effectiveness in terms of sustainability and resilience, however, there is apparently an absence for an integrated performance measure selecting tool for decision makers to aid them in determining most suitable, effective and efficient methods of UHI mitigation.

Objective and Scope of Work

The purpose of this research is to establish a decision support system (DSS) for aiding decision makers involved in mitigating the impacts of the UHI effect by providing them a mean of selecting optimal applicable method/technique based on resiliency and sustainability approaches. The target DSS in this research, would function as a performance measure selecting tool in form of a quick-selection-guide-sheet of most effective method(s)/technique(s). A DSS in general is an information system that is a collection of integrated software applications and hardware. DSS can be either fully computerized or human-powered, or a combination of both. The contribution this study seeks is to develop a DSS resembling a knowledge sharing platform to support stakeholders like urban planners, architects, decision makers and policy makers in the extraction of UHIMS and in a wide scope the expected benefit would be more sustainable more resilient design.

Hypothesis

The main objective of the hypothesizes of this research is to test whether the experts have clear distinction between sustainability and resilience. The main hypothesizes of this research are classified as below:

- Hypothesis 1: It is hypothesized that selection of the most efficient UHIMSs depends on two main parameters of Sustainability and Resilience. Any change in the relative weight of importance of these two parameters will shift the results.
- Hypothesis 2: It is hypothesized that the criteria of the two main objectives (Sustainability and Resilience) should receive equal weights, i.e. the three pillars of sustainability (Environmental, Economic, and Social) will receive equal weights of importance, as well as the two main criteria of resilience (Vulnerability and Resistance to change).
- Hypothesis 3: It is hypothesized -based on literature review- that most experts will be biased towards Greenery methods as the most effective/efficient UHIMSs.

Methodology

This study's methodology is divided into five parts, which are depicted in Figure 1. The first stage is to do a literature study to identify and describe various terminology such as mitigation strategies, contributions from earlier research, limitations, and weaknesses that should be rectified. The second stage is to create a hierarchy of the criteria that influence the selection of heat island mitigation strategies. The next stage is to seek experts' advice and gather data using expert elicitation exercises. The fourth is the Weighted Scoring Method (WSM), which is the system's major engine. The final stage is to computerize the system and make a user-friendly spreadsheet program.

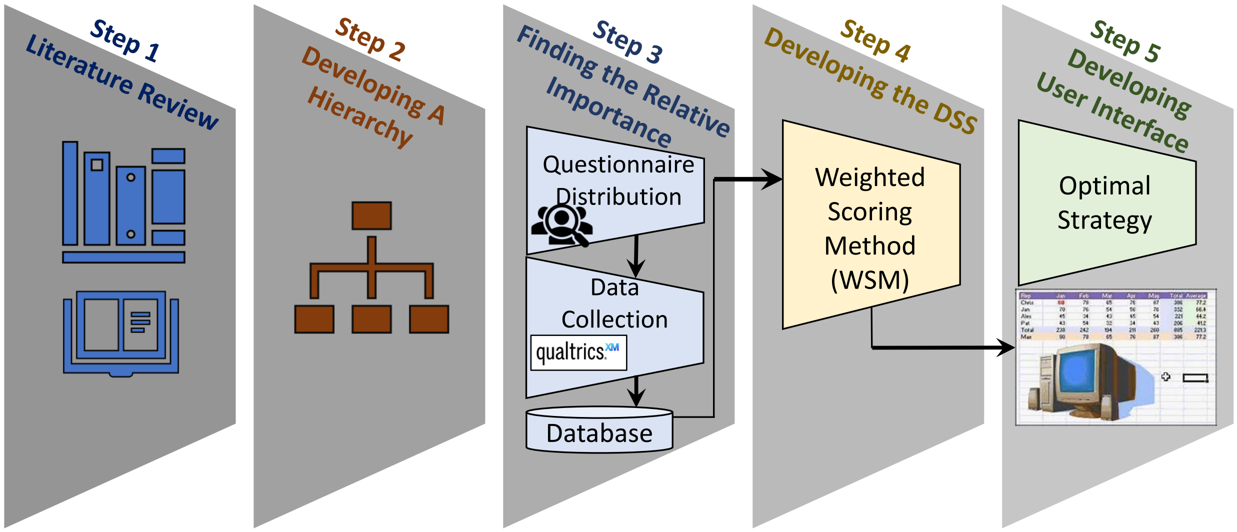


Figure 1: Framework of decision making for evaluating of UHIMSs

Thesis Organization

This thesis is divided into six main chapters in addition to this one. Chapter 2 provides an extensive review of theoretical background, models, techniques, and previous work conducted in the area of UHI effect. Chapter 3 presents the framework of decision support system. This chapter is about the model development description, introduction to WSM and its comparison with other MCDM techniques, software development, and hypothetical example. Data collection methods and descriptive statistics analysis will be discussed in Chapter 4, which will cover the design of expert elicitation exercises and how participants are chosen. The obtained results from data analysis will be discussed in Chapter 5. Finally, chapter 6 provides a comprehensive review of the thesis, as well as findings and recommendations for further research.

CHAPTER II

LITRETURE REVIEW

Introduction

UHI effect has been addressed over decades. In previous studies, many attempts have been done trying to provide new methods or techniques to mitigate anthropogenic heat specially in urban areas. Most of the techniques used in this regard come under one of the following classifications: 1) Greenery, 2) Cool Materials, and 3) Evaporative Techniques.

This chapter presents a detailed review of most of the previous work that has been conducted in the area of UHI effect. The reviewed work serves as a basis for this research. The reviewed work has been categorized under five main topics, which are: 1) Sustainability and resilience, 2) UHI effect and its mitigation strategies, 3) Leadership in Energy and Environmental Design (LEED), 4) Weighted Scoring Method (WSM), and 5) Decision Support System (DSS).

Sustainability

Since the literature about sustainability is widespread, this study aims to focuses mainly on the literature related to the impact of green building on the different aspects of sustainability which they are Social, Environmental and Economic sustainability.

The traditional definition of sustainable development is taken from the 1987 UN World Commission on Environment and Development report, also known as the Brundtland

Commission Report, “development that meets the needs of the present without compromising the ability of future generations to meet their own needs”. This raises the critical point that our current quality of life cannot be bought at the expense of future generations. Sustainability refers not only to environmental preservation and protection, but also to society's ability to sustain itself. Both of these objectives are interlinked (*Sustainable Infrastructure Framework Guidance Manual*, 2018).

Sustainability is a set of environmental, economic, and social conditions in which everyone in society has the ability and opportunity to maintain and improve their standard of living indefinitely without damaging the quantity, quality, or availability of natural resources and ecosystems (*Sustainable Infrastructure Framework Guidance Manual*, 2018).

The report of Our Common Future, issued by the World Commission on Environment and Development (Imperatives, 1987), formally put forward sustainable development strategies. The United Nations Conference on Environment and Development (UNCED), held in Rio de Janeiro in 1992, proposed the Rio Declaration on Environment and Development and Agenda 21 (McCammon, 1992). The agenda provides a separate section on promoting sustainable human settlement development in Chapter 7, focusing on improving settlement planning and management, providing integrated environmental infrastructure, and achieving sustainable settlement development for energy and transport systems. This is the embodiment of the concept of sustainable development in the field of buildings, as well as the concrete realization of green building.

The United States Environmental Protection Agency (USEPA) defines green building as environmentally responsible and resource-efficient building throughout its life-cycle from siting to design, construction, operation, maintenance, and deconstruction (Alawneh et al., 2019).

Sustainable development in green building technologies have three types of main goals, namely environmental goal, social goal, and economic goal.

As a tool to comprehensively assess the green level of products, LCA has been recognized worldwide and has become an important support for the development of green building in various countries (X. Yu & Su, 2015). In addition, the life cycle sustainability assessment (LCSA) will be another promising and integrated approach that encompasses three aspects of environment, economy, and society, which represent the three pillars of sustainable development, namely, environmental life cycle assessment (E-LCA), cost life cycle assessment (C-LCA), and social life cycle assessment (S-LCA) (Wang et al., 2011).

Zuo and Zhao summarized the existing knowledge system of green building and figured out that the existing research mainly focuses on the environmental aspect of green buildings; however, the other dimensions of sustainability such as social sustainability and cultural sustainability are neglected to a large extent (Zuo & Zhao, 2014).

Economic Sustainability

With the rapid development of the construction industry, energy consumption has become an increasingly severe problem and energy shortage has become a bottleneck for the development of economic sustainability (P. Xu et al., 2011).

Therefore, the high efficiency of energy utilization is increasingly a concern of governments and enterprises, showing the great significance of energy saving technologies for green building (Kua & Wong, 2012).

For instance, Sadineni et al. conducted a detailed technical review of building envelope components and their improvements in terms of energy efficiency; discussed different types of energy-saving walls, such as Trombe wall, ventilation wall, and glass wall; and made an introduction to the achievements of energy saving rooftops such as modern green roof, photovoltaic roof, radiation transmission barrier, and cooling system of evaporative roof (Sadineni et al., 2011).

The development of green building also comes with many challenges. Although green building seems to be more attractive from an environmental point of view, the costs are far higher than those of traditional building. For example, the existing green building materials have the problems of high production cost, complicated manufacturing process, and exclusive material selection, and they cannot be used repeatedly (Shi & Liu, 2019).

Economic sustainability is addressed as a "economic development conducted without depleting social and natural resources" (Sustainable Infrastructure Framework Guidance Manual, 2018).

Investment and upfront capital costs are often the key drivers in planning decisions; however, they omit the life-cycle costs of the project, risks and uncertainty, or the broader outcomes that impact the environment and society (Sustainable Infrastructure Framework Guidance Manual, 2018). This research considers these soft benefits and broader outcomes. So, the decision makers, architects, urban planners and etc. are less likely to overlook the sustainable returns on investment, such as lower utility costs, operations and maintenance costs, or less replacement costs. Therefore, in this study economic sustainability is classified in six main topics, such as: 1) Initial investment, 2) Installation cost, 3) Maintenance/Disposal cost, 4) Energy cost saving, 5) Replacement Cost, and 6) Salvage value.

Environmental Sustainability

Environmental sustainability is defined as responsible interaction with the environment to avoid depletion or degradation of natural resources and allow for long-term environmental quality. The practice of environmental sustainability helps to ensure that the needs of today's population are met without jeopardizing the ability of future generations to meet their needs (Environmental Sustainability: Definition and Application, 2013). According to Akadiri and Olomolaiye, the concept of environmental sustainability in green building was first proposed at the 1st International Conference on Materials Science in 1988 (Akadiri & Olomolaiye, 2012). Green building materials refer to healthy, environmentally friendly, and secure building materials, which are also called "healthy building materials" or "environmentally friendly building materials" in the international community (Shi & Liu, 2019). Many scholars talk about the impact of materials in enhancing the environmental sustainability of buildings (Ali & Al Nsairat, 2009; Hodges, 2005; Olgyay & Herdt, 2004; Pulselli et al., 2007; Vatalis et al., 2013). It is not only the materials that enhance the environmental sustainability of green buildings; Hwang and Tan summarized the research progress in the field of green building in recent years, analyzed the energy consumption of green building projects and its impact on the natural environment, called on the whole society to take necessary measures, and promoted the sustainable development of green building (Hwang & Tan, 2012). Some scholars believe that environmental sustainability of green building can be followed by green building project management (Kainer et al., 2009; Shenhar & Dvir, 2008; P. Wu & Low, 2010). Another factor affecting the environmental sustainability is argued in Envision. It is argued while improving sustainable performance is an essential and immediate goal, long-term goals should be directed toward restoration where practical. This is intended to reinforce the point that, to really contribute to sustainability, projects must do more than mitigate negative impacts. Mitigation is important, but does not contribute to the restoration of economic, environmental, and social conditions to sustainable levels (Sustainable Infrastructure Framework Guidance Manual, 2018).

The environmental impact and climate change produced in the construction process are also worth noticing in environmental aspect of sustainability. The new-built constructions, reconstructions, and demolition of buildings will result in the waste of resources and energy consumption, as well as a large amount of solid waste, and finally pollute the environment (Hong & Lin, 2015). The construction industry has been a leading carbon emitter for a long time. The simultaneous growth of building size, volume, and energy consumption intensity will inevitably bring tremendous carbon emission, which will be the focus of the further studies of energy conservation and emission reduction work in China (Bodart & De Herde, 2002). Since, green buildings have conflict with the sustainability concept into the construction process, an adaptation to various kinds of low-carbon and environmentally friendly materials to decrease the energy consumption and enhance the construction technical level of the project, would be a significant step.

This research categorizes environmental sustainability in six main topics, which are: 1) Air quality, 2) Stormwater management 3) Water Quality, 4) Heat intensity reduction, 5) Net embodied carbon, 6) Resource sustainability, 7) Suitability of climate of region, 8) Local cooling effect, and 9) Global cooling effect.

Social Sustainability

In social sustainability, social wellbeing is comprehensively addressed. To be socially sustainable, the systems and processes proposed for executing a project should be contributing to the objectives of creating healthy, livable, equitable, diverse, vital, and sustainability-aware workforces and communities (Ma, 2011). Many studies have been conducted to address different aspects of sustainability in various industrial sectors. The majority of these studies focused on a single aspect of sustainability rather than incorporating all the three dimensions in one comprehensive model (Abdel-Raheem & Ramsbottom, 2016). Some of the previous studies mainly have focused on social aspects of sustainability in green buildings (Ahmad et al., 2019; Karji et al., 2019; Olakitan Atanda, 2019; Stender & Walter, 2019; X. Zhao et al., 2019). According to the mature assessment systems for green buildings such as LEED, BREEAM, and GB tool, Ali and Al Nsairat developed the green buildings rating system for Jordan with greater emphasis on social and economic sustainability (Ali & Al Nsairat, 2009).

"Envision" poses two questions with respect to social sustainability: "Are we doing the project right?" and, more critically, "Are we doing the right project?". Regarding to Envision, this research focuses on social sustainability in four main topics as below:

Equity and social Justice: It refers to the responsibility of a society to ensure that civil and human rights are preserved and protected for each individual, and that all persons are treated equally and without prejudice regardless of race, color, wealth, religion (creed), gender, gender expression, age, national origin (ancestry), disability, marital status, sexual orientation, or military status. This includes "environmental justice," which refers to the fair treatment and meaningful engagement of all people with regard to environmental protection (Sustainable Infrastructure Framework Guidance Manual, 2018).

Preserve historic and cultural recourses: This topic is addressed as preservation of the historic and cultural resources that make communities unique and that, once lost, cannot be truly replaced. Cultural resources can drive community attractiveness, livability, and tourism that in turn supports economic activity and a strong tax base. While protection is a necessary first step, there are often opportunities to highlight, enhance, or facilitate the continuance or utilization of historic and cultural resources (Sustainable Infrastructure Framework Guidance Manual, 2018).

Enhance views and local character: This topic addresses a project's visual impact on the community and its surroundings. Communities may value views of natural settings (e.g., bodies of water, mountains, parks, forests) or manmade structures (e.g., iconic/historic buildings, avenues, skylines). A project must consider its relationship to the viewing public and the community feature. A project may block views of a community feature or, if located within the same view of the feature, may diminish the quality of the view. In the latter case, projects can adopt the local character of its surroundings in order to minimize its impact. Beyond its function, infrastructure often has the potential to enhance the beauty and attractiveness of a community (Sustainable Infrastructure Framework Guidance Manual, 2018).

Enhance public space and amenities: Public amenities can be in urban or natural settings and may include, but are not limited to, parks, plazas, trails, playgrounds, recreational facilities, and wildlife refuges. Enhancing public space can also include beautification of streets, sidewalks, or right of ways. For natural settings such as parks and wildlife refuges, "public" refers to space accessible for human recreation and enjoyment (Sustainable Infrastructure Framework Guidance Manual, 2018).

Resilience

Every year, nations are faced with damages and large numbers of deaths due to natural hazards. Resilience to these hazards has become a growing challenge in the current global discourse on the climate change adaptation. The emergence of resilience thinking due to increasing intensity and frequency of natural catastrophes, requires buildings to be not only sustainable but also resilient (Phillips et al., 2017). Previous studies suggest developing a coherent sustainability and resilience framework to gain greater resilience at a minimum environmental cost (Eakin & Wehbe, 2009; Nelson et al., 2007; Phillips et al., 2017).

According to Holling, resilience was first introduced to the academic literature as “a measure of the persistence of systems and their ability to absorb change and disturbance and still maintain the same relationships between populations or state variables” (Holling, 1973a). The concept of resilience is gaining momentum in academia and practice in response to “the damage caused by the overexploitation of resources” (Lizarralde et al., 2015) which causes the earth's climate to change and deviate from historical climate data (Champagne & Aktas, 2016). Whereas the core idea of sustainability is to reduce negative impacts on the environment to avoid changes, resiliency is about adaptation to change (Lizarralde et al., 2015). Due to the broad nature of the many fields affected by the topic, the essence of resilience remains elusive (D. Zhao et al., 2015).

The popular definition of resilience is “having the capacity to persist in the face of change, to continue to develop with ever-changing environments” (Folke, 2016). The earlier studies on resilience refer to “the return rate to equilibrium upon a perturbation,” or sometimes define it as “bouncing-back after disturbance or recovery time, or recovery to what you were before” (Folke, 2016). Resilience is also defined as the “capacity of a system to absorb disturbance and reorganize while undergoing [a] change to retain essentially the same function, structure, and identity” (Walker et al., 2004). Xu et al. (L. Xu et al., 2015) examined the contribution of resilience for sustainability science and provided seven definitions of resilience as psychological, engineering, ecological, social economic, social-ecological resilience and resilience engineering. Since the wide application of resilience in multiple disciplines, urban planners define resilience as recovery from an event or a disaster, while the insurance sector sees resilience through the lens of risk and hazard mitigation (Jennings et al., 2013). Regarding to this, Zhao et al. (D. Zhao et al., 2015) think of resilience as “the capacity of a residential structure to absorb external stresses; retain function; reduce industrial risk; and help vulnerable people, organizations, and systems persist". Also, resiliency is defined by Envision as "The ability to successfully adapt to and/or recover readily from a significant disruption." (Sustainable Infrastructure Framework Guidance Manual, 2018).

Some scholars believe that although the motive forces behind sustainability (environmentalism) and resilience (protection against shocks) may be different, the outcomes of these processes are often synergistic (Hewitt et al., 2019). Some recent studies try to explain the complex interactions between resilience and sustainability through a secondary assessment (literature reviews, building code analysis, etc.) (Lizarralde et al., 2015; Marjaba & Chidiac, 2016; Meacham, 2016; Roostaie et al., 2019; X. Zhang & Li, 2018).

It is generally assumed that green buildings may offer more advantages in terms of resilience than ordinary buildings, and some research supports this goal of holistic integration (Phillips et al., 2017; X. Zhang & Li, 2018). Some of those advantages include energy generation on site, less energy needed to operate building systems (with some systems like treatment plants or ventilation systems having the option to be shut down during emergencies for further energy savings), less water consumption due to water saving fixtures, and cost savings (despite infrastructure redundancies) due to more efficient systems. These advantages of green buildings can play a crucial role in pursuing self-sufficiency in urban buildings by allowing a building the ability to maintain shelter and provide certain services for occupants by decreasing, or even removing, dependence on external resource supply networks. In that sense, efforts to promote sustainability in green buildings support resiliency (Hewitt et al., 2019).

However, there are also associated points of divergence. For instance, an increase in redundant building systems in pursuit of resilience can lead to increased energy needs, undermining sustainability goals (Hewitt et al., 2019). Baniassadi, et al. argue that in cooler heatreliant climates, building codes are in tension with resilience to extreme heat events, leading to more vulnerability (Baniassadi et al., 2018). Other scholars believe that existing policies and current rating systems for sustainability are not well aligned with resilience goals, and require significant modification to be synergistic (Lizarralde et al., 2015; Marjaba & Chidiac, 2016; Meacham, 2016; Roostaie et al., 2019; X. Zhang & Li, 2018).

Envision concludes that in a resilience approach, short- and long-term risks, high fixed costs, and heavy reliance on resources are reduced. In this approach, life-cycle considerations, flexibility and durability to extend the useful life of the constructed works are addressed. Also, more recognition is given for designs that incorporate deconstruction principles and enable reuse and up-cycling of materials and equipment (Sustainable Infrastructure Framework Guidance Manual, 2018). This research addresses resilience in two main sub-categories of “vulnerability” and “resistance to change”.

Vulnerability

The extreme meteorological events due to global warming are a source of growing concern for cities and urban populations, because high temperatures reached during heat waves are often increased due to UHI effect (Basara et al., 2010; Gabriel & Endlicher, 2011; J. Tan et al., 2010). As a result, vulnerability of urban areas are the main concerns of public and institutional stakeholders (see for instance, (Hamin & Gurran, 2009; Lambert-Habib et al., 2013). The greatest vulnerability exists in the inner-city areas. This result is in accordance with similar work done in the USA (Harlan et al., 2006; Reid et al., 2009) and is the consequence of the increased temperatures associated with the UHI in this area. Many of the root causes of the UHI (for example, lack of greenspace, high anthropogenic heat output, significant built form) can be linked to vulnerable groups and therefore a feedback loop is created (Tomlinson et al., 2011).

Some scholars and researches discuss this topic in various studies. For instance, Lemonsu proposes in a research to what extent city-wide actions can have an impact on urban heat island effect and heat wave vulnerability (Lemonsu et al., 2015). However, some researchers believe that city shape influence on UHI and, consequently, on heat wave vulnerability. Higher densities may exacerbate UHI, in turn generating the need for more cooling and increasing energy use (Hamin & Gurran, 2009; Mees & Driessen, 2011). Some researches focused on mapping heat risk and vulnerability in various environments (Räsänen et al., 2019; Sun et al., 2019), more importantly in the area of global climate change and heat waves (French et al., 2019; Lapola et al., 2019; Madsen et al., 2019). In this area of study, researchers attempt to apply theoretical and technical methods, like as statistical (Bozorgi et al., 2018; Firozjaei et al., 2018; J. Li et al., 2017; X.-J. Qiao et al., 2019, 2019; Z. Qiao et al., 2014; L. Xu et al., 2015; Zander et al., 2018), energy-balance, numerical (Chang et al., 2018; Oke et al., 2017), analytical (Shashua-Bar & Hoffman, 2002), and physical models (Allegrini, 2018). In some cases, air temperature and land surface temperature (Basara et al.) data are graded ,evaluated, and observed from meteorological sections from the perspective of climate vulnerability or human exposure (Aboubakri et al., 2019), in other studies, some vulnerability and risk indexes are developed, such as manual indicator removal, Monte Carlo simulation and variance-based global sensitivity analysis (Feizizadeh & Kienberger, 2017; Mainali & Pricope, 2017).

Resistance to change

As uncertainties and challenges like climate change are grappled with contemporary cities, urban resilience has become an considered concept (Carmin et al., 2012; Leichenko, 2011). The proposed definition of urban resiliency by Meerow is as “Urban resilience refers to the ability of an urban system-and all its constituent socio-ecological and socio-technical networks across temporal and spatial scales-to maintain or rapidly return to desired functions in the face of a disturbance, to adapt to change, and to quickly transform systems that limit current or future adaptive capacity." (Meerow et al., 2016). In this definition, urban resilience is dynamic and offers multiple pathways to resilience (e.g., persistence, transition, and trans- formation). It recognizes the importance of temporal scale, and advocates general adaptability rather than specific adaptedness. The urban system is conceptualized as complex and adaptive, and it is composed of socio-ecological and socio-technical networks that extend across multiple spatial scales. Resilience is framed as an explicitly desirable state and, therefore, should be negotiated among those who enact it empirically (Meerow et al., 2016). Holling uses resilience to explain the ability of an ecological system to continue functioning—or to "persist"—when changed, but not necessarily to remain the same. This contrasts with "engineering resilience," which focuses on a single state of equilibrium or stability to which a resilient system would revert after a disruption (Holling, 1973a). By referring to resilience as resistance to change, a dominant area of focus in the literature is referred to disturbances due to climate change (Leichenko, 2011; Wardekker et al., 2010) or hazards and disasters (Burby et al., 2000; Godschalk, 2003; Pelling, 2003). Surprisingly few definitions of urban resilience precisely address resistance to change. According to Desouza and Flanery, urban resiliency is "ability to absorb, adapt and respond to changes in urban systems". However, several definitions include or acknowledge the need to adapt (Desouza & Flanery, 2013; Wardekker et al., 2010). "A system that can tolerate disturbances (events and trends) through characteristics or measures that limit their impacts, by reducing or counteracting the damage and disruption, and allow the system to respond, recover, and adapt quickly to such disturbances" is the definition provided by Wardekker that refers to adaptiveness in this regard. (Wardekker et al., 2010). This research considers three aspect of social, environmental, and economical of resistance to change with sub-factors such as climate/ecological changes, initial cost, operation cost, durability, trends (Fashion), and aesthetics.

Urban Heat Island Effect (UHI)

Urban areas are usually warmer than their rural surroundings, a phenomenon known as the “heat island effect.” As cities develop, more vegetation is lost and more surfaces are paved or covered with buildings. The change in ground cover results in less shade and moisture to keep urban areas cool. Built-up areas also evaporate less water, which contributes to elevated surface and air temperatures. Properties of urban materials, in particular solar reflectance, thermal emissivity, and heat capacity, also influence the development of urban heat islands, as they determine how the sun’s energy is reflected, emitted, and absorbed (USEPA, 2017).

Heat islands can affect communities by increasing summertime peak energy demand (Akbari & Konopacki, 2005; USEPA, 2017), air conditioning costs, air pollution and greenhouse gas emissions (USEPA, 2017), heat-related illness and mortality (Mastrangelo et al., 2007; Reid et al., 2009; USEPA, 2017), and water quality (USEPA, 2017), and outdoor thermal comfort (Steeneveld et al., 2011).

To reduce these adverse effects, numerous strategies have been proposed, collectively called urban heat island mitigation strategies (UHIMSs) (Alexandri & Jones, 2008; Chatzidimitriou et al., 2013; Chow et al., 2011, 2011; Hendel et al., 2016; Santamouris et al., 2012; Santamouris & Kolokotsa, 2016; Song & Park, 2015; USEPA, 2017).

Previous Studies about UHI Effect

Currently, dozens of urban heat island mitigation strategies (UHIMS) exist, including the use of green spaces (Chow et al., 2011; He & Zhu, 2018; Lu et al., 2012), green/cool roofs

(Castiglia Feitosa & Wilkinson, 2018; Herath et al., 2018; Herrera-Gomez et al., 2017; Imran et al., 2018; Y. K. Yang et al., 2017, 2019; L. Zhang et al., 2019a, 2019b), vertical green systems (Alexandri & Jones, 2008; Castiglia Feitosa & Wilkinson, 2018; Herath et al., 2018), street trees (Shashua-Bar et al., 2010), green parking lots (Park et al., 2016), water bodies (Chatzidimitriou et al., 2013), sprinklers (Hendel et al., 2016), permeable materials (H. Li et al., 2013), reflective materials (Song & Park, 2015) and heat storage materials (Saffari et al., 2018). The effectiveness of these strategies varies significantly across the configuration of the planning and design variables (J.-D. Qi et al., 2019; Synnefa et al., 2011; Y. Zhang et al., 2017). For example, the surface temperature difference between black and white asphalts can reach 7.7 °C (Synnefa et al., 2011). Existing studies have concluded there are numerous variables mediating the performance of UHIMS such as planning and design variables (Deilami et al., 2018); vegetation species (Feyisa et al., 2014); vegetation height (Chow et al., 2011); canopy cover (Feyisa et al., 2014); green coverage ratio (Takebayashi & Moriyama, 2009); water body coverage (O'Malley, Piroozfar, Farr, & Pomponi, 2015); water flow rate and sprinkler particle size (Hendel et al., 2016); surface color (Synnefa et al., 2011); surface density (H. Li et al., 2013); and construction materials (Mat Santamouris, Synnefa, & Karlessi, 2011). A significant number of UHIMS and variables are miscellaneous and uncharacterized, requiring a representation for standardizing UHIMS.

Empirical evidence has revealed that the performance of UHIMS varies significantly not only across the types of UHI mitigation (UHIM) techniques but also responds to the climatic, demographic, and developmental context of cities (Adelia et al., 2019; Chun & Guldmann, 2014; Liang et al., 2020). On the one hand, different cooling mechanisms used by UHIM techniques have distinguishing peculiarities of heat loss, presenting a variety of cooling potentials. For example, the latent heat that is mainly from the surrounding air and water has a significant cooling performance some 600 times that of the sensible heat (Santamouris & Kolokotsa, 2016). On the other hand, cities' contextual factors like climate, population density and land use, are the determinants of the heat flux, anthropogenic heat release and heat losses, which considerably affects urban energy balance. Therefore, performance outcomes are an interwoven result of the type of the UHIM techniques pursued and the urban context (Lai et al., 2019; Parsaee et al., 2019; Ramakreshnan et al., 2018). In addition, links between UHIM techniques and their sustainability and resilience performance are lacking.

Limitation and Contribution of Previous Studies

Regarding the performance of UHIMS, intensive outcomes of UHIMS have been measured to understand their real contribution to issues like air temperature reduction (Lu et al., 2012); land surface temperature reduction (Chow et al., 2011); energy saving (M Santamouris et al., 2007); cardiovascular disease reduction (Richardson et al., 2013); overweight prevention (Richardson et al., 2013); mental health maintenance (Beyer et al., 2014); asthma prevention (Lovasi et al., 2013); improve air quality and public health, reduce the city's contribution to greenhouse gas emissions, reduce the cost of air conditioning for both residential and commercial customers (Rosenzweig, Solecki, & Slosberg, 2006).

In regards to materials which have cooling effect in mitigating the effect of UHI, literature reviews show some contributions and limitations which are mentioned in the following. Rossi et al. by conducting experimental campaign and novel analytical model show that retro-reflective materials could be effectively applied as coatings on urban paving and building envelope, in order to reflect the solar radiation beyond the urban canyon and the urban canopy in general (Rossi et al., 2014). Moreover, Liu et al. believe that evaporation-enhancing permeable pavement could contribute substantially to UHI mitigation, and was a maximum 9.4 °C cooler than conventional permeable pavement. There are a number of problems to be solved before the application of evaporation-enhancing permeable pavement. What kind of material that capillary column adopted plays a most important part? And a paver with effective water absorption capacity is also necessary, because it can help the water lifted by capillary columns reach surface of the pavement. Evaporation-enhancing permeable pavement may be a good choice for low impact development in a region with a high groundwater table (Liu et al., 2018). Because the amount of water retained in pavers is limited, many studies have attempted to enhance the evaporation capacity by replenishing the reused or reclaimed water in the pavers (Qin, 2015; Yamagata et al., 2008). Other scholars such as Liu et al. argue that although, the permeable pavement is effective in green infrastructure that can improve stormwater hydrology and mitigate urban inundation, its performance can be sharply weakened when it is used in an area having a high-water table and low-permeability soil (Liu, Li, et al., 2020). Pasetto et al. believe that cool road pavements can be really considered as a valuable technological solution to mitigate UHI effect. Basic chromatic characteristics and mechanical properties of such materials were also investigated to evaluate prospective correlations with the thermal response as well as real field applicability. Moreover, they believe that specific efforts are also required to enhance and optimize the mechanical performance of the materials while maintaining their ability in urban heat island mitigation (Pasetto et al., 2019).

Other experts such as Yang et al. (2017) utilize a validated occupancy probabilistic input model to estimate different building retrofitting solutions on the impact of building energy consumption and further as the basis for building cooling associated anthropogenic heat study. The anthropogenic heat in an area depends on many factors as the variation of the energy consumption, transportation characteristics, and geographical location etc. In their study, only anthropogenic heat from buildings are considered in the campus areas without taking into account of transportation and geographical location. While this is the limitation of their study, the focusing point of this paper on the building anthropogenic heat generation is dominated by cooling requirements in tropical climates (J. Yang et al., 2017). Chun and Guldmann explore the urban determinants of the UHI, using two- dimensional (2-D) and three-dimensional (3-D) urban information as input to spatial statistical models. One should bear in mind the limitation in using satellite images associated with their acquisition time. Since satellite orbital periods are constant, Landsat TM always passes over the State of Ohio with a 16-day repeat cycle at 10:00 am. This makes it impossible to capture surface temperatures at other times, such as early morning, late afternoon, or nighttime (Chun & Guldmann, 2014).

In the area of relationship between urban form and heat island intensity, the limitation and contributions are as following. For example, Liang et al. (2020) say that firstly, the resolution of the MODIS LST data is limited and much coarser than land use data used in their study. Second, they do not consider temporal variations of the UHI intensity because they use the annual UHI intensity. Since the drivers of the UHI effect vary from daily to annual scales. Third, their study uses urban boundaries derived from land use products to calculate the UHI, and the foot- print of the heat island effect has not been considered (Liang et al., 2020). Other scholars such as Yin et al. (2018) in their study confirm that urban form metrics had a clear influence on LST and some effective suggestions were put forward, there are still some limitations. The spatial resolution of LST data based on TM ETM+ image of 30 m may be not precise enough. Some other remote sensing products with higher spatial resolution such as Quick Bird and SPOT map should be employed in order to gain more accurate conclusions in following research (Yin et al., 2018). Moreover, Adelia et al. (2019) believe that their research on effects of urban morphology on anthropogenic heat dispersion considers one incoming wind direction, which is perpendicular to the street canyon as it is commonly considered as the worst-case scenario in urban wind simulation. To provide more systematic building design guidelines, various incoming wind directions will be considered in the future study (Adelia et al., 2019).

With regards to evaporative techniques there are some limitations. For instance, Gober et al. (2009) use watered landscapes to manipulate urban heat island effects. They argue that they would have more confidence in the results if there were more cases, especially cases with more intermediate levels of water use and more typical distributions of land cover (Gober et al., 2009). Other researches such as Tominaga et al. (2015) evaluate computational fluid dynamics (CFD) simulations of the evaporative cooling effect from water surfaces in a micro-scale urban environment via validation and application studies with various configurations. They argue that their research has the following limitations, which need to be addressed in future work:

"Steady computations were performed for peak load conditions. Therefore, the effect of heat storage on materials could not be considered. This may cause an under- or over-estimation of the cooling effect of the water surface since it disregards the temporal fluctuations in wind velocity and direction.

Detailed distinctions of land use such as building materials, vegetation, and artificial heat release were not considered. These must be included in future studies to improve the prediction accuracy for actual urban environments.

The presented evaluation of the CFD model performance was limited to qualitative comparisons. A quantitative comparison can be performed if the above considerations are taken into account." (Tominaga et al., 2015).

Regarding to greenery methods/techniques in mitigating urban heat island effect, some researchers believe that when water and irrigation factor are not the main concerns, urban vegetation may well be a cost-effective strategy for cooling buildings and neighborhoods (McPherson et al., 2005; Santamouris, 2014). Here there are some limitations revealed from reviewing the literatures such as a study done by Tan et al. (2016) demonstrate that tree planting in conjunction with proper planning is an effective measure to mitigate daytime UHI. The three-dimensional microclimate model ENVI-met (version 3.1) is used to analyze the proposed planning methods for tree planting in the two studied areas individually. They believe that the albedo and the thermal transmittance cannot be assigned to individual building element separately. These disadvantages of the model limit its use to daytime situation and unsuited for nocturnal cooling and UHI analysis (Z. Tan et al., 2016).

Urban Heat Island Mitigation Strategies (UHIMSs)

Currently, all over the globe various mitigating methods/techniques, and green rating systems are being practiced in order to achieve resiliency by reducing vulnerability of urban areas facing ever rising temperatures and to compensate for effects of the UHI. Among different approaches deployed to lessen UHI intensity, most noticeable ones are as Greenery, Cool Material Usage in Construction, and Evaporative Techniques. Among the current green rating systems, this research focuses on LEED and Envision. These methods, techniques, and rating systems are detailed and briefly described in the following.

Greenery. Shade trees and smaller plants such as shrubs, vines, grasses, and ground cover, help cool the urban environment. Yet, many U.S. communities have lost trees and green space as they have grown. This change is not inevitable. Many communities can take advantage of existing space, such as grassy or barren areas, to increase their vegetative cover and reap multiple benefits. Trees and vegetation help cool urban climates through shading and evapotranspiration. The use of trees and vegetation in the urban environment brings many benefits, including lower energy use, reduced air pollution and greenhouse gas emissions, protection from harmful exposure to ultraviolet (UV) rays, decreased stormwater runoff, potential reduced pavement maintenance, and other quality-of-life benefits. At the same time, communities must also consider the costs of an urban forestry program and any potential negative impacts of increasing tree and vegetation cover (U.S. EPA, 2008c)

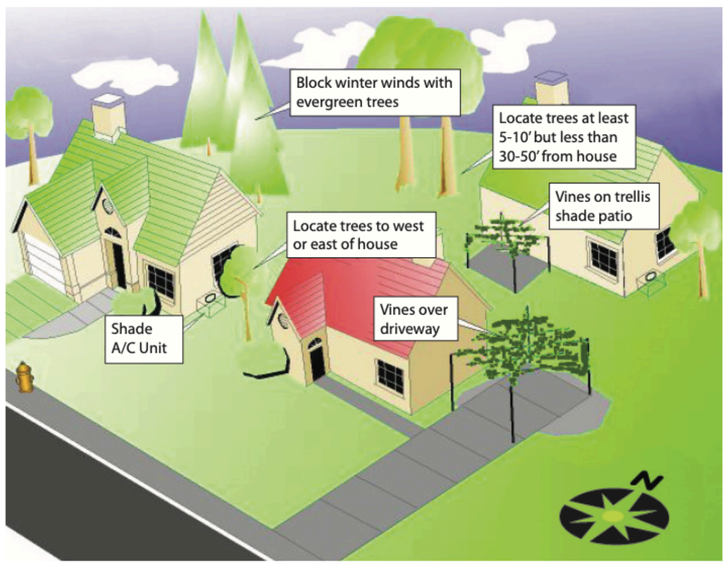


Figure 2: Tree placement to maximize energy savings

Green roofs. They are an emerging technology that can help communities mitigate urban heat islands. A green roof is a vegetative layer grown on a rooftop. As with trees and vegetation elsewhere, vegetation on a green roof shades surfaces and removes heat from the air through evapotranspiration. These two mechanisms reduce temperatures of the roof surface and the surrounding air. The surface of a vegetated rooftop can be cooler than the ambient air, whereas conventional rooftop surfaces can exceed ambient air temperatures by up to 90°F (50°C).2 Green roofs can be installed on a wide range of buildings, including industrial, educational, and government facilities; offices; other commercial property; and residences. With regard to urban heat islands, green roofs work by shading roof surfaces and through evapotranspiration. Using green roofs throughout a city can help reduce surface urban heat islands and cool the air. A green roof can be as simple as a 2-inch (5 cm) covering of hardy, alpine-like groundcover, generally termed an “extensive” system, or as complex as a fully accessible park complete with trees, called an “intensive” system. Green roofs provide many of the same benefits that trees and other ground level vegetation provide. Green roofs have an advantage, though, in that they can be used in dense, built-up areas that may not have space for planting at the ground level (U.S. EPA, 2008b).

Table 1: Benefit-Cost Elements for Green Roofs (U.S. EPA, 2008b)

Benefits/Costs	Energy, Hydrology, and UHI Benefits	Other Benefits
Private Benefits	Reduced energy use	Noise reduction
	Extended service life	Aesthetic value
		Food production
Public Benefits	Reduced temperature	Reduced air pollutants
	Reduced stormwater	Reduced greenhouse gases
	Reduced installation costs (from widespread technology use)	Human health benefits
Private Costs	Installation	N/A
	Architecture/Engineering	
	Maintenance	
Public Costs	Program administration	N/A

Vertical gardens. In addition to green roofs, building owners can install green walls, sometimes referred to as living walls or vertical gardens. These walls can involve placing trellises or cables in front of exterior walls and allowing vines to grow up them, or can be more elaborate, with plants actually incorporated into the wall.

Cool materials. Cool pavements refer to a range of established and emerging materials. These pavement technologies tend to store less heat and may have lower surface temperatures compared with conventional products. They can help address the problem of urban heat islands, which result in part from the increased temperatures of paved surfaces in a city or suburb. Understanding how cool pavements work requires knowing how solar energy heats pavements and how pavement influences the air above it. Properties such as solar energy, solar reflectance, material heat capacities, surface roughness, heat transfer rates, thermal emittance, and permeability affect pavement temperatures (U.S. EPA, 2012).

Current cool pavements are those that have increased solar reflectance or that use a permeable material. Some of these pavements have long been established—such as conventional concrete, which initially has a high solar reflectance. Others are emerging—such as micro surfacing, which is a thin sealing layer used for maintenance. Some pavement applications are for new construction, while others are used for maintenance or rehabilitation. Not all applications will be equally suited to all uses. Some are best for light traffic areas, for example. Further, depending on local conditions—such as available materials, labor costs, and experience with different applications—certain pavements may not be cost effective or feasible. Generally, decision-makers choose paving materials based on the function they serve. Potential cool pavements are such as Conventional asphalt pavements, Conventional concrete pavements, Other reflective pavements (Resin based pavements, Colored asphalt and colored concrete, Non-vegetated permeable pavements (Porous asphalt, Rubberized asphalt, Pervious concrete, Brick or block pavers), and Vegetated permeable pavements (Chip seals, White topping, Ultra-thin white topping, Micro surfacing) (U.S. EPA, 2012).

Installing cool pavements can be part of an overall strategy to reduce air temperatures, which can result in a wide range of benefits such as reduced energy use, air quality and greenhouse gas emissions, water quality and stormwater runoff, increased pavement life and waste reduction, and quality of life benefits (Nighttime illumination, Comfort improvements, Safety). Cool pavement costs will depend on many factors including the region, local climate, Contractor, time of year, accessibility of the site, underlying soils, project size, expected traffic, the desired life of the pavement (U.S. EPA, 2012).

Cool roofs. Cool roofing can help address the problem of heat islands, which results in part from the combined heat of numerous individual hot roofs in a city or suburb. Cool roofing products are made of highly reflective and emissive materials that can remain approximately 50 to 60°F (28-33°C) cooler than traditional materials during peak summer weather. Building owners and roofing contractors have used these types of cool roofing products for more than 20 years. Traditional roofs in the United States, in contrast, can reach summer peak temperatures of 150 to 185°F (66-85°C), thus creating a series of hot surfaces as well as warmer air temperatures nearby (U.S. EPA, 2008a).

There are generally two categories of roofs: low-sloped and steep-sloped. A low-sloped roof is essentially flat, with only enough incline to provide drainage. It is usually defined as having no more than 2 inches (5 cm) of vertical rise over 12 inches (30 cm) of horizontal run, or a 2:12 pitch. These roofs are found on the majority of commercial, industrial, warehouse, office, retail, and multi-family buildings, as well as some single-family homes. Steep-sloped roofs have inclines greater than a 2-inch rise over a 12-inch run. These roofs are found most often on residences and retail commercial buildings and are generally visible from the street (U.S. EPA, 2008a).

The use of cool roofs as a mitigation strategy brings many benefits, including lower energy use, reduced air pollution and greenhouse gas emissions, and improved human health and comfort. At the same time, there can be a cost premium for some cool roof applications versus traditional roofing materials. Cool roofs can have a wintertime heating penalty because they reflect solar heat that would help warm the building. Although building owners must account for this penalty in assessing the overall benefits of cool roofing strategies, in most U.S. climates this penalty is not large enough to negate the summertime cooling savings (U.S. EPA, 2008a).

Evaporative cooling techniques. Evaporative cooling techniques using spraying mist water has been the recent focus of attention as a method of mitigating the thermal environment during the summer. The temperature of dry air can be dropped significantly through the phase transition of liquid water to water vapor (evaporation). In urban environments, sprinkles, pools, ponds, and rivers can be treated as small water bodies. Field observations reported in several studies have revealed the cooling effects of water bodies on the micro-scale environment. De La Flor and Domínguez argued that ponds and fountains can be effective air conditioning systems in open spaces because of their ability to keep water temperatures lower than air temperature along with their low reflectivity (de la Flor & Domínguez, 2004). Murakawa, et al. stated that the air temperature drops above a river exceeded 5 ◦ C on clear days during warmer seasons and that the cooling effect of a 260-m wide river propagates up to 400-m away when sea breezes blow along the river (Murakawa et al., 1991). Nishimura, et al. demonstrated that a water pond in a park reduced the air temperatures on its leeward side by 1–2 ◦ C. When waterfalls and fountains were added, air temperature reductions of up to 4–5 ◦ C were measured at a distance of approximately 10 m on the leeward side of the pond (Nishimura et al., 1998). Xu, et al. observed the influence of a water body on thermal comfort on very hot days in the World Expo garden (J. Xu et al., 2010). Their results showed that the water body effectively improves human comfort in the littoral zone. An area 10–20 m from the water's edge showed the greatest improvement in thermal comfort (Tominaga et al., 2015). Hathway and Sharples found a mean daytime cooling of over 1.5 ◦ C above a river in spring, based on a field survey (Hathway & Sharples, 2012).

Green Rating Systems

LEED Green Rating Systems

There are many examples of international rating systems all over the world (Shwe et al., 2017). They are all set on the same fundamental principles and play a great role in developing sustainable practices to mitigate the environmental risks and problems (Shin et al., 2017). Leadership in Energy and Environmental Design (LEED) rating system is the most widely used green building rating system in the world and increasingly recognized as exemplary tool among scholars and practitioners (Shwe et al., 2017). Since it was launched in U.S. at 1993 by the authority of US Green Building Council, it has been investigated by many scholars, to examine its efficiency. It has been approved that there is about 25-30% more energy efficient of the LEED certified buildings. A LEED rating system is a reliable indicator of a sustainable built environment; that demonstrate a building's ability to provide significant benefits (Shin et al., 2017).

This system covers five sectors of building industry: 1) Building Design and Construction, 2) Interior Design and Construction, 3) Building Operations and Maintenance, 4) Neighborhood Development, and 5) Homes Design and Construction.

It is found that a number of studies compare green building rating systems (GBRSs) including the LEED system in terms of their qualitative and quantitative differences, benefits and their role in decision making (Mattoni et al., 2018) as well as their related geographical references (Doan et al., 2017). Other scholars focus on GBRSs in terms of their comprehensiveness, effectiveness and accuracy of assessment criteria (Chen et al., 2015). More studies refer to their variations with regards to popularity and market influence, availability and methodology (Nguyen & Altan, 2011) as well as their rate of adoption (Bernardi et al., 2017; Lavy & Fernández-Solis, 2009).

Researchers find that construction of green buildings with LEED certification reduces the temperature of urban environments compared to the effect of non-LEED buildings (Shin et al., 2017). In addition to this, they believe that "the LEED buildings' coefficient shows that one certified building within the 30-m boundary, regardless of its certification level, could have an effect of lower the surrounding temperature by -0.35°C. This is a noteworthy result as it shows that the certified buildings do have an effect on lower the temperature of their surroundings." (Shin et al., 2017). Other researches focus on the regional benefits of LEED construction. They find a very small negative effect on UHI in correlation with the presence of LEED-certified buildings, but they caution that correlation does not equal causation. It means "With the analysis results, it is hard to affirm that LEED certification and the mass effect of LEED buildings do have significant influence on regional climate." (Kim & Gu, 2015). In addition to this, Donghwan, Yong, and Hyoungsub expand the scope of the research to include data from two more states, Texas and Florida, in addition to California. The authors' findings are largely the same: LEED buildings do not cause a large effect on regional temperatures. However, the slight temperature change that does exist appears more distinctly in places that LEED buildings are more compactly concentrated. They say that "despite the fact that the three states present slightly different results, by looking at the variance in coefficients, it can still be said that the temperature change is more distinct when the LEED certificates are clustered." They believe that with both LEED certification levels and the mass effect of LEED buildings do not have significant influence on regional climate." (Donghwan et al., 2015).

Envision Rating System

Envision is a generic guidance and decision support tool for sustainable infrastructure design and evaluation (Sustainable Infrastructure Framework Guidance Manual, 2018). It was developed in 2012 in collaboration between the Institute for Sustainable Infrastructure (ISI) and the Zofnass Program for Sustainable Infrastructure at the Harvard Graduate School of Design. Envision is a framework that includes 64 sustainability and resilience indicators, called 'credits', organized around five categories: Quality of Life, Leadership, Resource Allocation, Natural World, and Climate and Resilience. These collectively address areas of human wellbeing, mobility, community development, collaboration, planning, economy, materials, energy, water, siting, conservation, ecology, emissions, and resilience. These indicators collectively become the foundation of what constitutes sustainability in infrastructure (Sustainable Infrastructure Framework Guidance Manual, 2018).

Envision is designed as a holistic sustainability rating system for all types and sizes of both public and private infrastructure. A key value of Envision is its universal applicability to all infrastructure. Envision application has ranged across all infrastructure sectors from one million to multi-billion-dollar projects. Envision is not intended to evaluate interior, conditioned, buildings with the primary purpose of human occupation, such as offices, schools, single family homes, or multi-unit residential buildings (Sustainable Infrastructure Framework Guidance Manual, 2018).

According to Envision researchers, the greatest impediment to the inclusion of Envision in the US is a combination of the following factors: an unwillingness to try sustainability rating systems because of a lack of quantitative data, the existence of multiple rating systems instead of a few comprehensive and tested methods, and an assumed increase in cost. Tiffany (2017) believes the US is at the forefront of including the Envision rating system in the planning and design of projects. The US case studies elucidating the lessons learned from projects applying Envision will provide insight into the potential successes and challenges (Tiffany, 2017). Gardel et al. argue the importance of identifying lessons learned to select an adequate rating system for four sewer projects in Omaha, Nebraska. These projects used the Envision Rating System during their respective planning and design phases (Gardels, McMeekin, et al., 2012). Similarly, Blackwelder et al. conducted a case study of lessons learned when applying Envision to the planning and design of a 2.5 billion-dollar pipeline project in Dallas, Texas (Blackwelder et al., 2016). Sheesley et al. conducted evaluating a port project in Everett, Washington, that applied Envision retroactively to the design phase (Sheesley et al., 2014). Furthermore, Binney investigated the potential gains to project delivery through retroactive inclusion of Envision to a drinking water project in Aurora, Colorado (Binney, 2014). Sheesley et al. (2014) conducted a case study of an oil field facility in Long Beach, California that retroactively applied the Envision framework to the project's planning and design phase (Sheesley et al., 2014).

The main goal of the above case studies is applying the frameworks of Envision to raise the management of sustainability for infrastructure projects. Envision is the most flexible rating system with application to the widest range of projects whilst meeting the sustainable objectives of different municipalities (Tiffany, 2017).

Multi Criteria Decision Making (MCDM)

Multi-criteria decision-making (MCDM) has been widely utilized as an appropriate approach for decision problems involving several criteria. Several methods have been proposed for MCDM, where the most common were developed using mathematical modeling to ease the process of decision-making such as Weighted Scoring Method (WSM), Analytical Hierarchy

Process (AHP). For more comprehensive information on these methods, the coming paragraphs, describe and compare the main characteristics of each method and its benefits and limitation. Consequently, considering the requirements and specifications of these methods as well as the benefits and shortcomings of MCDM methods, this research adopts the WSM methods to develop the DSS.

Urban Heat Island due to its significant effects on the society, the environment, and the economy has been a concern specially on megacities. (Bathaei & Abdel-Raheem, 2021). Although, several studies have presented UHIMSs and their level of effectiveness, there are problems in assessing its mitigation strategies as suitable candidates based on Resilience and sustainability criteria. Therefore, MCDM methods can be used to evaluate these problems. In the literature, MCDM methods are widely applied to handle green building decision-making problems. These studies are briefly summarized as below:

Some scholars have utilized Weighted Scoring System in area of construction, sustainability, and green. Similarly, Bakhoum and Brown establish the sustainability criteria related to structural materials by developing a sustainable scoring system. This system includes a list of sustainable factors that affect the process of structural materials selection. These factors lead to definition of the sustainable properties of structural materials during their life cycle and link the material's sustainable properties to the design of the structural element (Bakhoum & Brown, 2012). Hemphill, McGreal, and Berry devise a thorough method to measure the effectiveness of urban regeneration projects with the goals of sustainability in mind, but these metrics focus little on contaminated sites or financial issues and utilize a scoring system (An Indicator-Based Approach to Measuring Sustainable Urban Regeneration Performance: Part 1, Conceptual Foundations and Methodological Framework - Lesley Hemphill, Jim Berry, Stanley

McGreal, 2004, n.d.; An Indicator-Based Approach to Measuring Sustainable Urban Regeneration Performance: Part 2, Empirical Evaluation and Case-Study Analysis - Lesley Hemphill, Stanley McGreal, Jim Berry, 2004, n.d.). In construction area, Assaf and Jannadi apply multi-criterion decision-making model for contractor prequalification selection (Assaf & Jannadi, 1994).

Existing literature reveals that due to many qualitative and/or subjective attributes in green building assessment, it is difficult to measure them while getting experts' judgments and stakeholders' opinion. A rating system also needs to incorporate some important attributes, such as embodied water, economic conditions, embodied carbon, loss of habitat, greenhouse gas emission, BIM, geographical and climatic conditions, and social and cultural aspects of the region, which are not considered in the existing rating systems. Moreover, users and stakeholders expect such rating systems to be user-friendly when evaluating the greenness of a building (Vyas et al., 2019). Therefore, AHP is applied by many researches in this area. For example, Qingkui and Junhu study on the supplier evaluation in green supply chain based on AHP (Qingkui & Junhu, 2009). Yu conducts a research on the evaluation of construction of green sustainable development of a College based on AHP method (L. Yu, 2016). Vyas et al. develop a green building assessment tool that can rate the greenness of new buildings in India using AHP (Vyas et al., 2019). Doczy and AbdelRazig propose a model using AHP to optimize the selection of a design alternative given a project's conflicting objectives: net-zero, Leadership in Energy and Environmental Design (LEED), and cost (Doczy & AbdelRazig, 2017). Bhatt and Macwan present a conceptual model for the assessment of sustainable commercial buildings with the AHP (Bhatt & Macwan, 2016). Hui-Jing (2014) evaluate system for different assessment index in green building system based on group experts Analytic Hierarchy Process (Hui-Jing, 2014).

AbdelAzim et al. develop an energy efficiency rating system for existing buildings in Egypt using AHP (AbdelAzim et al., 2017). It seems that there is a lack of literature in applying AHP techniques in urban heat island effect. Few researches have been done in this regard such as Wu et al. applies AHP analysis technique to management of natural resources and the urban-heat island effect using a fuzzy analytic hierarchy process in the Miaoli County of Taiwan (K.-Y. Wu et al., 2009). Future work may include applying the same methodology for other aspects of green buildings and urban heat island effect.

Weighted Scoring Method (WSM)

Scoring is a way of research object assessment which is justified with statistics. A score is generated, which estimates the weight of future factors and outlines the probability of future events. The scoring model gives scores to specific alternatives, and those scores form a foundation on which operational decisions are taken in the course of further analysis. WSM combines quantitative and qualitative measures as an aid to operational decision making and provides systematic process for selecting alternatives based on multiple criteria (see Figure 3).

Consider there are i alternatives {A1, A2, …, Ai} and j criteria {C1, C2, …, Cj}. In WSM, the weights (percentages) (Wn) are assigned to each criterion so they add up to 100% (Jadhav & Sonar, 2009). Then, a score (S) is assigned to each criterion for each alternative based on Table 2:

Table 2: Comparison scale (adapted from Saaty 1980)

Score	Description
1	Equal Preference
3	Slight Preference
5	Average Preference
7	Above Average Preference
9	Major Preference
2,4,6,8	Intermediate Level

In the next step, the scores (Sij) are multiplied weights (Wn) and total weighted scores will be calculated. The final score for alternative Ai is calculated using Equation 1. Where W n is relative importance of nth criterion; Sij is score of alternative Ai on criterion Cj (see Table 3).

[1] $S(Ai)=\sum WnSij$

Table 3: The decision table

Alternatives	Criteria				Score
	W1	W2	…	Wn	
	C1	C2	…	Cj	
A1	S11	S12	…	S1j	S (A1)
A2	S21	S22	…	S2j	S (A2)
.	.	.	.	.	.
Ai	Si1	Si2	…	Sij	S (Ai)

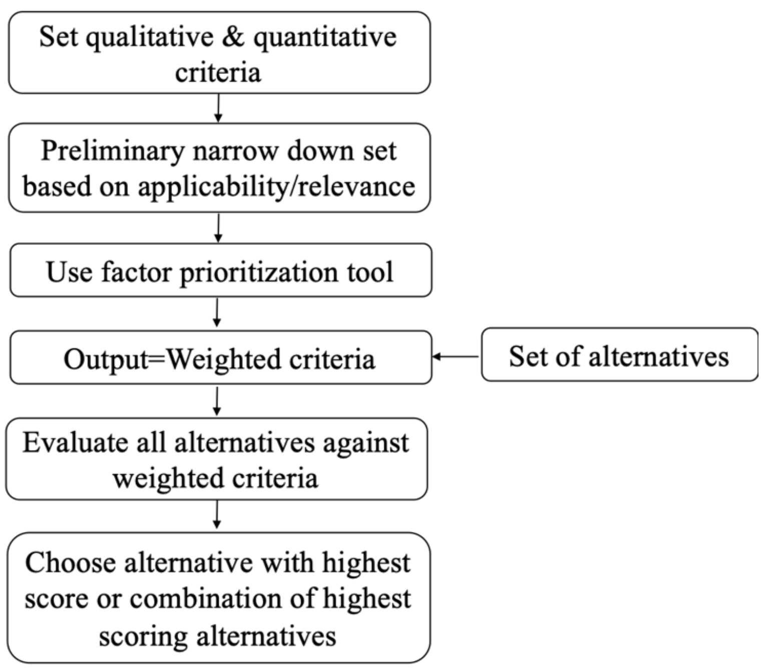


Figure 3: Flowchart of weighted scoring method (WSM)

Analytical Hierarchy process (AHP)

The Analytic Hierarchy Process (AHP) as one of the multiple criteria decision-making tools is built by Thomas L. Saaty to systematically define priorities and solve complex decision-making issues (Forman & Gass, 2001). It is a method of measurement based on pairwise comparisons between parameters and experts' judgments to find the weight of each parameter (Saaty, 2008). In fact, this method provides the criteria of a complex decision-making process in a hierarchical structure to be measured and synthetize (see Figure 4).

AHP methodology has three main functions listed as below:

- Structure complexity
- Measurement
- Synthesis

Structural complexity defines the complexity of a decision-making process by identifying and organizing the various criteria affecting decisions in a hierarchical structure in which the top of hierarchy represents overall objectives (goal) and the lower levels represent criteria, sub-criteria, and alternatives.

In the measurement function part, a comparison matrix is set up as each level of hierarchy to compare pairs of criteria and sub-criteria. A set of questions like "What is the relative importance of criteria Ci with respect to criteria Cj?" is asked to establish the weights of criteria. In order to make the judgments possible for both qualitative and quantitative criteria, a set of numerical values are described (see Table 4). For each criterion, it is necessary to evaluate the consistency of the matrix, by calculating the eigenvalues to compare with the random consistency according as matrix size. The decision maker must review the comparisons and improve them if there is a consistency problem.

Similarly, some other questions seek the performance score (Aij) obtained by comparing alternative Ai to alternative Aj relative to the criterion Ci. Where Aij=1/Aji and Aii=1.

The last stage calculates aggregate performance value for alternatives and rank them according to their performance using Equation 2 below:

[2] $S_i = \sum W_j A_{ij}$

Where Si is overall score of ith alternative, Wj is importance (weight) of jth criterion, and Aij is relative score of ith alternative with respect to jth criterion (Jadhav & Sonar, 2009).

Table 4: Pair-wise comparison judgments (Jadhav & Sonar, 2009)

Judgment	Values
X is equally preferred to Y	1
X is moderately preferred over Y	3
X is strongly preferred over Y	5
X is very strongly preferred over Y	7
X is extremely preferred over Y	9
Intermediate values	2,4,6,8
Preference of Y compared to X	1/2, 1/3, 1/4, 1/5, 1/6, 1/7, 1/8, 1/9

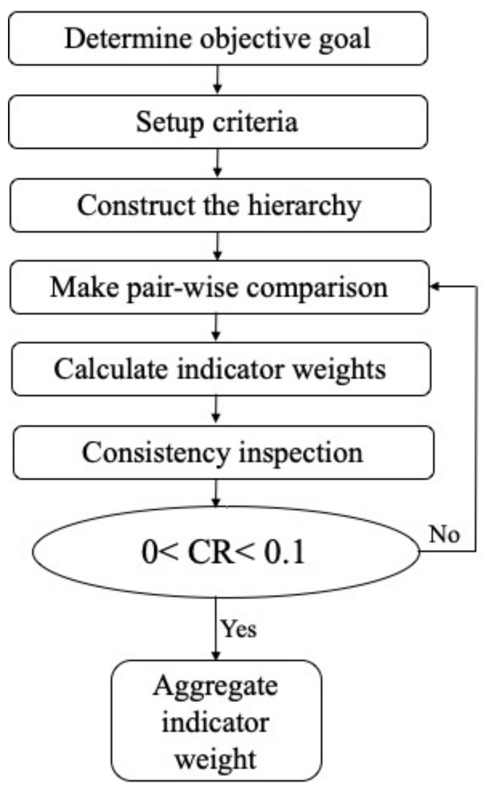


Figure 4: Flow chart of Analytical Hierarchy Process (AHP) (Liu, Eckert, et al., 2020)

Analytical Network Process (ANP)

The ANP as a generalization of the AHP is also developed by Saaty (1996). The ANP extends the AHP to problems with dependence and feedback. The ANP allows for more complex inter-relationships among decision elements by replacing the hierarchy in the AHP with a network, in which the relationships between levels are not easily classified simply as hierarchical versus non- hierarchical, or direct versus indirect (Meade & Sarkis, 1999) (see Figure 5). Hence, a hierarchical framework with a linear top-to-bottom form is not appropriate for complex systems. In addition to the merits of AHP, the ANP provides a more generalized model in decision- making without making assumptions about the independency of the higher-level elements from lower-level elements and also of the elements within their own level. A two-way arrow or arcs among different levels of criteria may graphically represent the interdependencies in an ANP model. If interdependencies are present within the same level of analysis, a looped arc may be used to represent such interdependencies (Jharkharia & Shankar, 2007). The influence of the elements in the network on other elements in that network can be represented with a Super Matrix. The structure difference between an AHP hierarchy and a network is given in Figure 6.

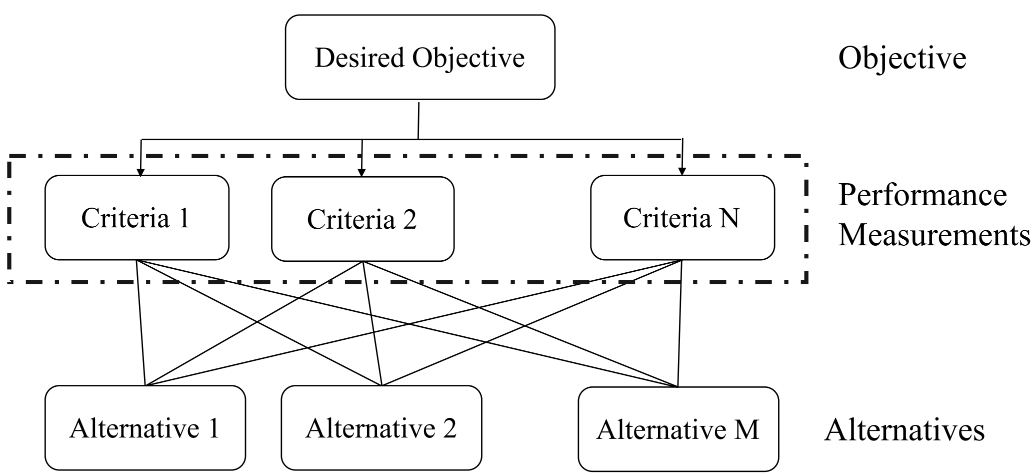


Figure 5: ANP network hierarchy structure (Saaty, 1996)

The process of the ANP comprises the following four steps (Saaty, 1996; Saaty & Vargas, 2013).

Step 1: Model construction. A problem is decomposed into a network in which nodes corresponds to clusters. The elements in a component can interact with some or all of the elements of another cluster. Also, relation- ships among elements in the same cluster can exist. These relationships are represented by arcs with directions. In general, the ANP is a coupling of two parts. The first consists of a control hierarchy or network of criteria and sub-criteria that control the interactions in the system under study. The second is a network of influences among the elements and clusters. The network varies from criterion to criterion.

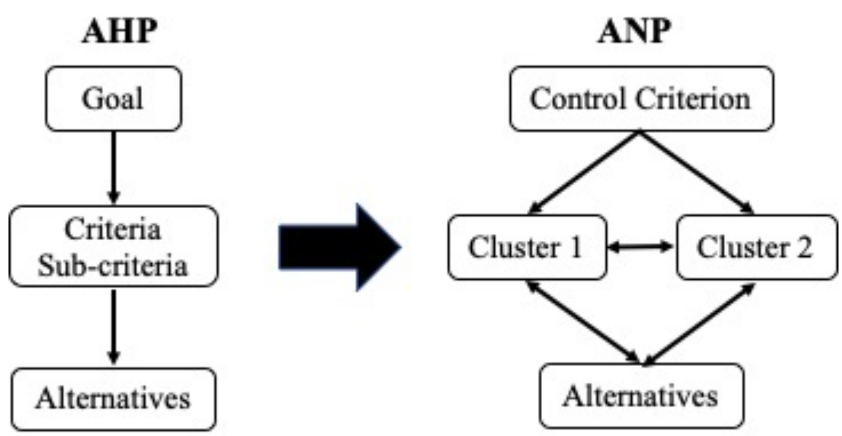


Figure 6: Structural differences of AHP and ANP

Step 2: Pairwise comparison and local priority vectors. In this step, the elements are compared pair wisely with respect to their impacts on other elements. The way of conducting pairwise comparisons and obtaining priority vectors is the same as in the AHP. The relative importance values are determined on a scale of 1 to 9, where a score of 1 indicates equal importance between the two elements and 9 represents the extreme importance of one element compared with the other one. A reciprocal value is assigned to the inverse comparison; that is, aij 1⁄4, 1/aji where aij denotes the importance of the ith element compared with the jth element.

Also, aii 1⁄4 1 is preserved in the pairwise comparison matrix. Then, the eigenvector method is employed to obtain the local priority vectors for each pairwise comparison matrix. Besides to test consistency of a pairwise comparison, a consistency ratio (CR) can be introduced with consistency index (CI) and random index (RI). If the CR is less than 0.1, the pairwise comparison is considered acceptable.

Step 3: Super matrix formation. The local priority vectors are entered into the appropriate columns of a super matrix, which is a partitioned matrix where each segment represents a relationship between two clusters. Consider a network that has been decomposed into N clusters, represented by C1, C2, ..., CN, and the elements in Ck,1 k N are ek1, ek2, ..., eknk, where nk is the number of elements in Ck clusters. The super matrix has the following forms:

$$
W = \begin{array}{c c} & \begin{array}{ccc} C_1 & C_2 & \cdots\ C_N \\ e_{11} \ldots e_{1n1} & e_{21} \ldots e_{2n2} & e_{N1} \ldots e_{NnN} \end{array} \\ \begin{array}{c} C_1 \begin{array}{c} e_{11} \\ \ldots \\ e_{1n1} \end{array} \\ C_2 \begin{array}{c} e_{21} \\ \ldots \\ e_{2n2} \end{array} \\ C_N \begin{array}{c} e_{N1} \\ \ldots \\ e_{NnN} \end{array} \end{array} & \begin{bmatrix} W_{11} & W_{12} & \cdots & W_{1N} \\ W_{21} & W_{22} & \cdots & W_{2N} \\ W_{N1} & W_{N2} & \cdots & W_{NN} \end{bmatrix} \end{array}
$$

A matrix segment, Wij, represents a relationship between the Ci cluster and the Cj cluster. Each column of Wij is the local priority vector obtained from the corresponding pairwise comparison, representing the importance of the elements in the Ci to an element in the Cj. When there is no relationship between clusters, the corresponding matrix segment is a zero matrix. Then, pairwise comparisons should also be conducted on the clusters, which is to develop weights matrix. The super matrix can be transformed into the weighted super matrix, each of whose columns sums to one. Finally, the weighted super matrix is transformed into the limit super matrix by raising it to powers. The reason for multiplying the weighted super matrix, is to capture the transmission of influence along all possible paths of the super matrix.

Step 4: Final priorities. When the super matrix covers the whole network, the finial priorities of elements are found in the corresponding columns in the limit super matrix. If there is not only one criterion in control hierarchy, repeat Step 3 to calculate another super matrix. Finally, additional calculations should be made for obtaining final priorities (see Figure 7).

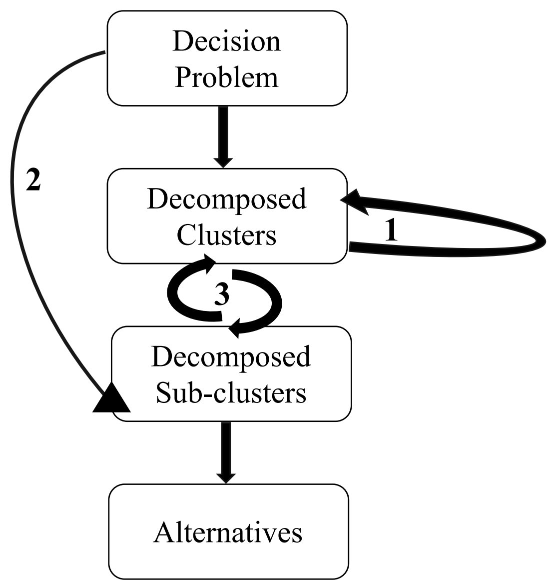


Figure 7: Analytic Network Process Flowchart

Artificial Neural Network (ANN)

ANN (Artificial neural networks) may be considered to be a system for processing information modelled after how the human brain works; these artificial networks, however, do not reproduce the exact structure of the human brain insofar as this last is extremely complex. The human mind, in fact, is the home of various types of thought processes, be they rational, formalized, and conscious, be they less rational and formalized but still conscious, or be they thought processes that are not rational, formalized or conscious. ANNs to some degree reproduce the non-formalized thought that originates from the thick web of neurons that make up the cerebral mass. In general, it consists of a collection of simple nonlinear computing elements whose inputs and outputs are tied together to form a network (Kuo et al., 2002) (see Figures 8 , 9).

ANNs consist of a number of interconnected processing nodes called neurons. The neurons are usually organized in a sequence of layers, including an input layer, a single or a set of intermediate layers, and an output layer. The input layer receives input data to the network but does not perform any computations. The output layer gives the network's response to the specified input. The intermediate layers, which are also called the hidden layers, are typically connected to the input and output layers. Each neuron in the hidden and output layers receives the signals from all the neurons in a layer above it and then performs a weighted summation and transfer function of the inputs (S. Wu et al., 2007). Although ANN achieves good results in evaluating and ranking alternatives and furthermore, the trainability and applicability of its techniques to addressing general multi-attribute utility methods problems are also confirmed (Kuo et al., 2002) an ANN, as employed for recognition purposes, generally lacks the ability to be developed for a given task within a reasonable time (Kuo et al., 2002).

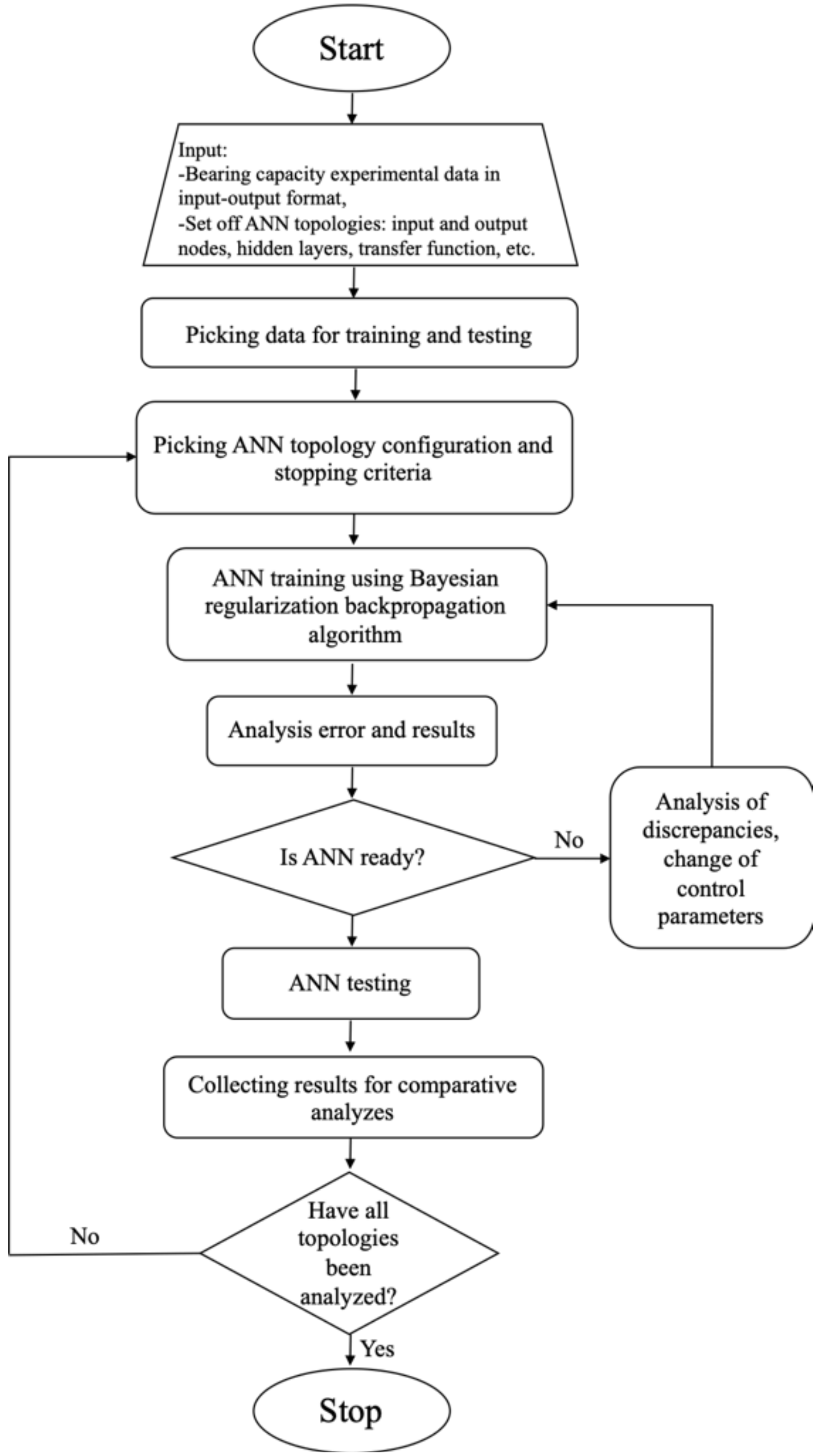


Figure 8: Flowchart of artificial neural network (ANN) (Bagińska & Srokosz, 2019)

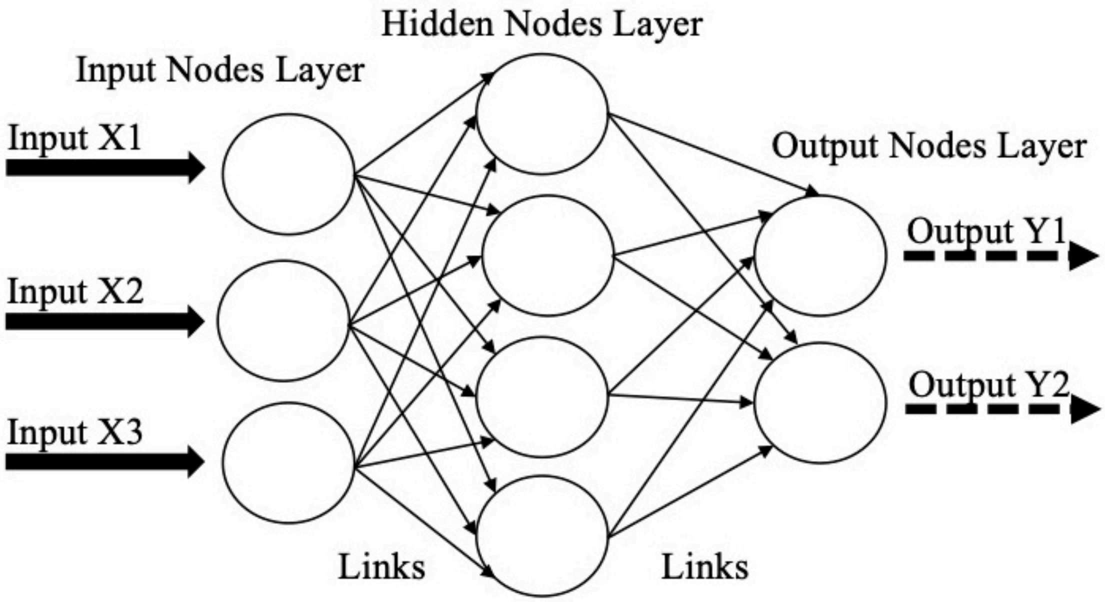


Figure 9: Architecture of the Artificial Neural Network (ANN)

Decision Support System (DSS)

Decision Support System (DSS) is defined broadly by Daniel Power as "interactive computer-based systems that help people use computer communications, data, documents, knowledge, and models to solve problems and make decisions. DSSs are ancillary or auxiliary systems; they are not indented to replace skilled decision makers." (Power, 2002).

Decision Support Systems should be considered when two assumptions seem reasonable: first, good information are likely to improve decision making; and second, managers need and want computerized support. Anecdotes and research show that some computer-based DSS can provide managers with analytical capabilities and information that improves decision making (Power, 2002). According to Daniel Power, taxonomies of DSS is as follow:

- Communication-driven DSS: It supports more than one person working on a shared task; examples include integrated tools like Microsoft's NetMeeting.

- Data-driven DSS: It emphasizes access to and manipulation of a time series of internal company data and, sometimes, external data.
- Document-driven DSS: It manages, retrieves, and manipulates unstructured information in a variety of electronic formats.
- Knowledge-driven DSS: It provides specialized problem- solving expertise stored as facts, rules, procedures, or in similar structures.
- Model-driven DSS: It emphasizes access to and manipulation of a statistical, financial, optimization, or simulation model. Model- driven DSS use data and parameters provided by users to assist decision makers in analyzing a situation; they are not necessarily data-intensive.

Characteristics of DSS are as below:

- Facilitation: DSS facilitate and support specific decision- making activities and/or decision processes.
- Interaction: DSS are computer-based systems designed for interactive use by decision makers or staff users who control the sequence of interaction and the operations performed.
- Ancillary: DSS can support decision makers at any level in an organization. They are NOT intended to replace decision makers.
- Repeated Use: DSS are intended for repeated use. A specific DSS may be used routinely or used as needed for ad hoc decision support tasks.
- Identifiable: DSS may be independent systems that collect or replicate data from other information systems OR subsystems of a larger, more integrated information system.

- Task-oriented: DSS provide specific capabilities that support one or more tasks related to decision-making, including: intelligence and data analysis; identification and design of alternatives; choice among alternatives; and decision implementation.
- Decision Impact: DSS are intended to improve the accuracy, timeliness, quality and overall effectiveness of a specific decision or a set of related decisions.
- Supports individual and group decision making: It provides a single platform that allows all users to access the same information and access the same version of truth, while providing autonomy to individual users and development groups to design reporting content locally.
- Comprehensive Data Access: It allows users to access data from different sources concurrently, leaving organizations the freedom to choose the data warehouse that best suits their unique requirements and preferences.
- Easy to Develop and Deploy: DSS delivers an interactive, scalable platform for rapidly developing and deploying projects. Multiple projects can be created within a single shared metadata. Within each project, development teams create a wide variety of re-usable metadata objects.
- Integrated software: DSS's integrated platform enables administrators and IT professionals to develop data models, perform sophisticated analysis, generate analytical reports, and deliver these reports to end users via different channels (Web, email, file, print and mobile devices).
- Flexibility: DSS features are flexible and can be altered according to need providing a helping hand in the work process.

The Sustainable Urbanization Strategy highlights that cities should institute effective planning and administrative systems to avoid the continued development in inappropriate locations. As urban development is driven by a large variety of factors (Kröger & Schäfer, 2016), there is no single appropriate solution. It is possible to incorporate decision support systems to optimize problems. Based on this, one is able to determine urban growth patterns (Cai et al., 2015). This is crucial to predict potential future changes, and to incorporate decision support systems in environmental management (Ghodousi et al., 2017). As decision support systems are not independent systems and they are used by decision-makers, there is a need for these technological solutions to be supported by a methodological framework (Nyerges et al., 2016) that describes how such systems can be used by people.

The use of projections of the future state of decision support systems can successfully integrate drivers of climate and land use changes and enable their impact assessment (Rukundo & Dogan, 2016). One of the most common relations between land development and climate issues in the UHI. The UHI interacts in different scales, from the human body to city size (Mirzaei, 2015) and therefore its impact should be analyzed using a more complex approach. The UHI modelling is a complex matter due to the multi-factor characteristics of the phenomenon.

Literature reviews reveal that much studies have not been done in applying a comprehensive DSS for evaluating the UHIMSs based on sustainability and resilience parameters. Kazak (2018) develops a decision support system to evaluate the measures against UHI by land use planning (Kazak, 2018), and the UHI effect of urban green areas can also be evaluated. Qi et al. (2020) develop a prototype and framework as a knowledge sharing platform supporting stakeholders like urban planners, architects, decision makers and policy makers in the extraction of UHIMS (J. Qi et al., 2020). Mahdiyar et al. develop a decision support system

(DSS) for selecting the optimum type of GR for residential buildings in Kuala Lumpur (Mahdiyar et al., 2019). Ramakreshnan et al. conclude that "To build a consolidated central UHI data repository via a network of distributed databases associated with a particular region to disseminate current UHII data for awareness creation, emergency responses and to aid policy making process. Such central data repository able to function as a decision support system that enable the policy makers and researchers to obtain and analyze massive reams of data for making decisions, tailoring interventions and formulating policies" (Ramakreshnan et al., 2019).

In the area of green building, further efforts have been undertaken to develop knowledge-based or expert DSS for assistance in material selection. Seyfang, Trusty, and Woolley argue that choosing the right materials for a particular project can be a very complex decision-making task, given that the selection process is influenced and determined by numerous preconditions, decisions and considerations. They suggested the idea of a decision support system (DSS) as a useful aid in making quick and critical decisions during crucial material selection process (Seyfang, 2010; Trusty, n.d.; Woolley, 2006). Yang apply a DSS that associates with the corresponding attributes and performance characteristics of low-cost green building materials and components (J. Yang & Ogunkah, 2013). Abdallah et al. develop automated decision support system (DSS) that is designed to optimize the selection of green building measures which can be used to upgrade existing buildings. They argue that an automated DSS is designed to identify optimal building upgrade decisions and credit points from the available alternatives in the LEED rating system for Existing Buildings (LEED-EB). This rating system provides several green upgrade measures which are classified into seven main divisions including: Sustainable Sites (SS), Water Efficiency (WE), Energy and Atmosphere (EA), Material and Resources (MR), Indoor Environmental Quality (IEQ), Innovation in Operation (IO), and Regional Priority (RP).

Each of these divisions includes performance requirements that specify the required measures to achieve LEED points (Abdallah et al., n.d.).

Summary and Conclusion

This chapter presented a detailed review of all the previous works attempts done in the area of UHI effect. Currently, all over the globe various mitigating methods/techniques are being practiced in order to achieve resiliency by reducing vulnerability of urban areas facing ever rising temperatures and to compensate for effects of the UHI. Among different approaches deployed to lessen UHI intensity, most noticeable ones are as Greenery, Cool Material Usage in Construction, Green Roofs, and Evaporative Techniques. Problem that arises when it comes to selecting between most appropriate mitigation method(s) with respect to sustainability resilience is lack of clear performance measures. This chapter review DSS as an interactive computer-based system that help people use computer communications, data, documents, knowledge, and models to solve problems and make decisions. In this regards it take the benefits of WSM as decision support techniques. Moreover, LEED and Envision are review among green rating systems which play a great role in developing sustainable practices to mitigate the environmental risks and problems.

CHAPTER III

SYSTEM STRUCTURE

Introduction

This chapter deals with the design and development of Usable Multi-Criteria Decision Making (MCDM) model and flexible Decision Support Systems (DSS). The motivation for this research stems from the lack of proper decision support tools available to support the decision makers in dealing with selection of the optimal UHIMSs based on sustainability and resilience.

System Description

This part presents a thorough description of the methodology adopted in developing a framework for the decision support system for evaluating the UHIMSs (see Figure 1). The system begins by identifying the list of objectives (sustainability and resilience) criteria (Economic, Environmental, Social, Vulnerability, and Resistance to Change), attributes, and the most practiced mitigation strategies addressing the Impact of UHI (see Figure 10). Then the second part of the system is the main engine (using WSM as the decision support system) which is responsible for finding the optimum mitigation alternatives –the predefined objective of the system. This research uses Weighted Scoring Method (WSM) to create matrices that criteria are evaluated against; in other words, each strategy is scored against each criterion and weighted scores are obtained based on survey feedbacks and information collected via sets of questioners and assigning relative weights to each criterion. Once the matrix is set with weighted scores, decision-makers can evaluate the alternatives to get the best method that best matches their need (system objective). The third part is the user-friendly interface that encompasses the first two parts of the system and shows the best optimal mitigation alternative using spreadsheets.

System Objectives

The main two objectives of the UHIMSs framework are sustainability and resilience (see Figure 10). Sustainability is defined as "a set of environmental, economic, and social conditions in which all of society has the capacity and opportunity to maintain and improve its quality of life indefinitely without degrading the quantity, quality, or availability of natural resources and ecosystem" (*Sustainable Infrastructure Framework Guidance Manual*, 2018). According to the definitions of sustainability and its mainstream theory, it is based on three main pillars (3Ps) of environmental, social, and economic sustainability. Therefore, applying sustainability to mitigation strategies of the UHI effect requires achieving all 3Ps of sustainability. For instance, green roofs improve air quality (Environmental Sustainability) reduce energy costs in long term (Economic Sustainability), and enhance local views and landscapes (Social Sustainability).

Resilience is defined as "a measure of the persistence of systems and their ability to absorb change and disturbance and still maintain the same relationships between populations or state variables" (Holling, 1973a). Illustrated in Figure 8, resilience is categorized in two main parts of Vulnerability and Resistance to Change. For example, from a Resistance to Change point of view, green roofs might not be very resilient, because they cannot last very long due to damage caused by the weathering effect. From a vulnerability point of view, green roofs or vertical gardens can mitigate the UHI effect. However, they can increase pollen production which potentially exacerbating allergies and respiratory disease (Hoverter, 2012).

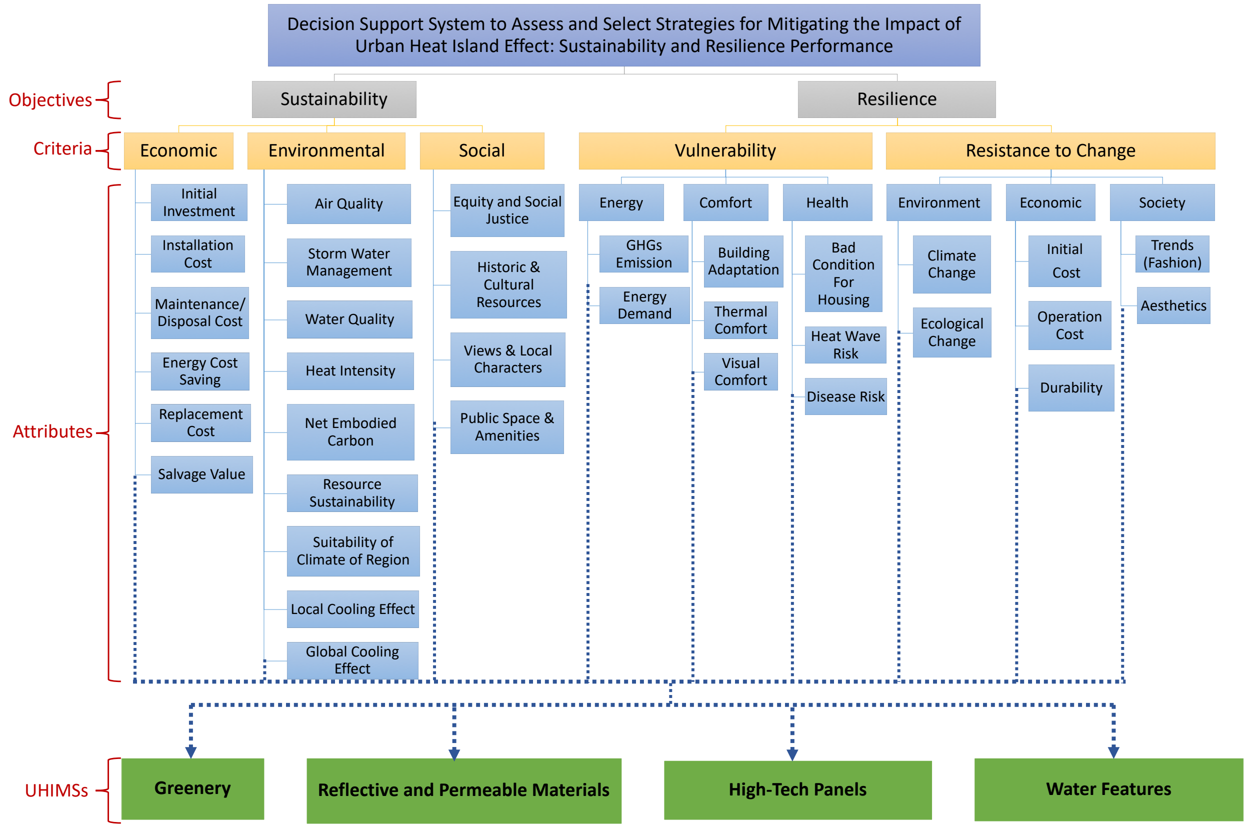


Figure 10: Hierarchy of affecting criteria in decision making on UHIMSs

System Criteria-Sustainability

Economic Sustainability is addressed as an "economic development conducted without depleting social and natural resources" (*Sustainable Infrastructure Framework Guidance Manual*, 2018). From an economic standpoint, sustainability requires that current economic activity not disproportionately burden future generations. For example, in temperate-to-warm climates, cool roofs are cost-beneficial because of their relatively low cost and their potential for long-term cost savings in energy use (Hoverter, 2012).

Environmental Sustainability addresses the restoration of natural resources and ecosystem services. The practice of environmental sustainability helps to ensure that the needs of today's population are met without jeopardizing the ability of future generations to meet their needs (*Environmental Sustainability: Definition and Application*, 2013). The performance of

UHIMSs based on environmental sustainability attributes is what sought in this research. It is important in a way that some methods, like porous pavements, although they increase water quality, decrease stormwater runoff, but they have high net embodied carbon due to the energy consumed in the process of manufacturing cement.

Social Sustainability is about the meeting of human needs and quality of life (U.S. EPA, 2008a). To be socially sustainable, the UHIMSs and their executive processes should be contributing to the objectives of creating healthy, livable, equitable, diverse, vital, and sustainability-aware workforces and communities. For instance, despite the benefits of photovoltaic materials in reducing the UHI effect, they may block views of a community feature or, if located within the same view of the feature, diminish the quality of the view.

System Criteria-Resilience

Vulnerability from a resilience standpoint is the ability of the system to mitigate possible/probable impacts on users due to the presence of the selected system. The air conditioning system used to cool down the temperature is an example of having negative impacts on users with noises associated with operating the systems or the higher electricity built due to electricity consumption. Resistance to Change is addressed in a definition of resilience as “the ability of an urban system and all its constituent socio-ecological and socio-technical networks across temporal and spatial scales-to maintain or rapidly return to desired functions in the face of a disturbance, to adapt to change, and to quickly transform systems that limit current or future adaptive capacity” (Meerow et al., 2016).

System Attributes

Economically, UHIMSs with lower Initial Investment, Installation Cost, Maintenance/Disposal Cost, Energy Cost Saving, Replacement Cost, higher Salvage Value contribute to sustainability criteria. The Energy Cost Saving means a reduction in the cost of energy and related operation and maintenance expenses due to applying the techniques of UHI mitigation. For example, the comparison between cool roofs and green roofs: cool roofs lower summer cooling costs. But they cause higher winter heating costs due to the reflection of heat in the cold seasons. Green roofs, in contrast, act as insulation and so can lower energy costs in both summer and winter (retaining heat indoors) make them preferable in more northern climates where cool roofs are not recommended (Chopra et al., 2005). The Salvage Value criterion can be defined as the estimated book value of a method/technique of the UHI effect after its lifetime is complete. For example, although photovoltaic panels have an average lifespan of 20 years, their salvage value might decrease since they might lose performance levels and power warranties over years.

Environmental sustainability attributes are addressed to assess UHIMSs concerning their ability in increasing Air Quality, Stormwater Management, Water Quality, the Sustainability of Resources, Creating a Suitable Condition in the Region, and Cooling Effects (Global/Local), as well as decreasing Heat Intensity and Net Embodied Carbon. Net Embodied Carbon is the sum of greenhouse gas emissions for a material or product that was used in the process of its production and completion(*Sustainable Infrastructure Framework Guidance Manual*, 2018). For example, while porous pavements are known as a very effective technique for reducing run-offs and stormwater, their production process involves high consumption of energy in the process of manufacturing cement and high emission of GHGs in the area. Local/Global Cooling Effect are important attributes when it comes to environmental sustainability. For instance, in comparison with cool roofs, green roofs provide more environmental benefits such as reducing stormwater runoff, lessening urban runoff pollution, and capturing greenhouse gases and particulate matter.

However, green roofs may provide fewer global cooling effects than cool roofs, although they may be more effective for local cooling. Cool roofs reflect the sun's energy into the upper atmosphere, thus cooling not only the surrounding area but the planet as a whole through the albedo effect (global cooling). Green roofs, by contrast, absorb water from their soil and emit it back into the air, where ambient heat converts the water into vapor, a process known as evapotranspiration. While it cools both individual buildings and surrounding areas, the heat can be trapped near the earth by greenhouse gases.

Social sustainability attributes used in this research for assessing the UHIMSs are Equity and Social Justice, Historic and Cultural Resources, Views and Local Character, and Public Space & Amenities (*Sustainable Infrastructure Framework Guidance Manual*, 2018). These attributes concern preserving and protecting civil and human rights for each individual, historic and cultural resources, enhancing visual comfort on communities and their surroundings, creating spaces accessible for human recreation and enjoyment. For example, urban forestry is considered as one of the effective techniques in mitigating anthropogenic heat, however, it can cover security cameras, block business and traffic signs, and impede motorist or pedestrian visibility. Moreover, the installation of greenery methods nearby the historic monuments can pose a threat to their structure due to the roots of vegetation and increase in the level of humidity as well. Another example is photovoltaic panels. They may block views of a community feature or, if located within the same view of the feature, may diminish the quality of the view.

Vulnerability-Energy refers to the ability of the proposed system to protect from the anticipated impact of the system on the users due to energy consumption or demands consequences. The two noticeable attributes in this part are Greenhouse Gases (GHGs) and Energy Demand. For instance, using sprinklers is an example of these attributes. While mitigation methods like light color materials do not demand any energy for operation or generate GHGs, others like water sprinklers or fountains indirectly generate GHGs due to their dependency on electricity for running.

Vulnerability-Comfort refers to the ability of the proposed system to protect from the anticipated impact of the system on the users that night violate the user's comfort, like disturbed visual or thermal comfort. Vulnerability-Comfort, in other terms, is the level of adaption capacity of buildings or users in face of the impact of applied UHMISs. Comfort incorporates the creation of spaces of physical and mental wellbeing, ambient qualities, and a sense of security. A lack of comfort is likely to be experienced by habitants of urban areas due to heat retention. Building Adaptation, Thermal, and Visual Comfort are the attributes that have a contribution in this regard. An example of thermal comfort is evaporative techniques. In dry climates, they can significantly enhance comfort by balancing the moisture level hence lowering the real feel temperature. Although, they are effective in enhancing the comfort level especially in a dry climate, some of the humidity-related health issues are generated by evaporative techniques. A good example of visual comfort is retroreflective panels. They can cause glare which causes discomfort to other species. In a similar example, light color materials rely on enhancing a natural heat-shedding effect known as passive radiative cooling but, they can cause unwanted glare which violates the visual comfort for the users.

Vulnerability-Health attributes refer to the unsuitable condition of a building, health risk conditions, and heatwave risk due to impacts of installed UHIMSs. One of the contributions of UHIMSs is health issues. Cool pavements are a good example of this. They lead to reduce the temperature of stormwater runoff into local water bodies. Minimizing overheated runoff can preserve aquatic ecosystems and especially protect wildlife vulnerable to temperature increases

(Hoverter, 2012). For example, although greenery techniques are effective in mitigating the effects of UHI, the plants could generate pollen or aggravating forms of pollen which might consider as a risk of developing allergies or asthma diseases for some users.

Environmental resistance to change is defined as the ability of UHIMSs to recover from disturbances and to tolerate or adapt to climate and ecological change attributes. For example, cool roofs might not have a high level of resistance to change. They generally have high reflectance, but weathering and dirt accumulation can lower the solar reflectance of them over time (Hoverter, 2012). Similarly, photovoltaic panels can be a feasible alternative to mitigate the impact of UHI, however, the installation of them is vulnerable and they might not be suitable in the tropical climate prone to hurricanes or severe weather conditions. Also, climate change factors could have some effects on porous pavements. Unlike their effectiveness, an urban area with a cold climate must take care that water does not freeze within porous pavements which causes cracking.

Economic resistance to change addresses the degree of resistance of UHIMSs to changes in the economy in terms of Initial Cost, Operation Cost, and Durability. As an example, fountains might not be economically efficient over time because of reliance on electricity and changes in the prices of electricity, whereas using greeneries for example “regional flora”, may not be affected by the changes in the economy over time. The price of local flora usually stays within a reasonable margin of the price. The Durability attribute shows the ability of UHIMSs to resist wear and decay, last for a longer lifecycle, and does not require major maintenance or replacement over time. For instance, green roofs lessen the temperature variability of roof surfaces and protect the waterproofing membrane from UV-radiation, ozone which accelerate aging in traditional roofs' waterproofing. Therefore, green roofs can increase the lifespan of a roof, saving the building owner money in the long term (Hoverter, 2012).

Social resistance to change refers to the ability of UHIMSs to resist the change in society such as Trends and Aesthetics. Trend refers to a general direction in which something is developing or changing. It means that something is an indicator of whether it is in style/fashion in society. As mitigation methods used in UHI are dealing with people, it is unavoidable not to consider the taste of people in them. If two or more methods are similar or close in the scoring system, it is preferable to choose one that is leaning more toward the trends of the application area. For instance, when two methods of vertical gardens and light-colored materials have the same or close ranks in the scoring system, light color materials might be selected by users who follow minimalist design trends. Aesthetics is the ability of UHIMSs to have resistance to change in the level of attractiveness. The built environment should foster a connection to people's senses and not reflect alienation from them. For example, the mitigation methods used in residential and urban areas might be different from industrial areas as the integrity of beauty in design is a noticeable factor to consider while choosing one method over another. So, photovoltaic panels might be very suitable in industrial zones, but not be aesthetically appealing in residential ones.

Alternatives

There are multiple types of mitigation strategies when it comes to UHI effect. This research classified them in four main groups of "Greenery", "Reflective and Permeable Materials", "High-Tech Panels", and "Interactive Water Features" (see Figure 11).

Greenery methods. They contribute to reduce surface roughness and ambient temperature, increase evapotranspiration and enhance human health and comfort. They can be everything from Urban Forestry (city parks and traditional streetscaping, like trees and planters) to more modern adaptations, like Green Roofs (U.S. EPA, 2008b), and Vertical Gardens (Green Walls) (Weinmaster, 2009). The use of trees and vegetation in the urban environment brings many benefits, including lower energy use, reduced air pollution and greenhouse gas emissions, protection from harmful exposure to ultraviolet (UV) rays, decreased stormwater runoff, potentially reduced pavement maintenance, and other quality-of-life benefits.

Reflective and permeable materials/high-tech panels. They decrease the temperature and heat by reflecting a broad spectrum of light, reducing solar absorption and increase thermal emittance, vaporizing the moisture content in a pavement structure, storing or supplying heat at their melting/freezing temperature, and converting solar energy into electricity. They are categorized in “Permeable Pavements” (U.S. EPA, 2012), “Light-Color Pavements” (U.S. EPA, 2012), “Cool Roofs” (U.S. EPA, 2008a), “Phase Change Materials (PCMs)” (Zalba et al., 2003), “Photovoltaic (PV) Materials/Panels” (Brito, 2020; Efthymiou et al., 2016; Tian et al., 2007), and “Near-Infrared (NIR) Reflective Materials” (Cui, 2012; Xie et al., 2019). They have some benefits and shortcomings. For instance, despite the effectiveness of cool roofs in reducing the cooling thermal loads or diminishing the UHI effects, they are prone to extreme thermal stress which negatively affects their lifespan and workability (Pisello et al., 2017). The main benefit of PV panels in mitigating the UHI effect is sustainably generating demanded electricity (Efthymiou et al., 2016). However, the impact of PV materials on urban climate is small (Brito, 2020) and they have a lower impact on mitigating the UHI effect. One of the benefits of NIR Reflective Materials’ application is a reflectance without affecting the visual environment or causing glare issues. The development of cool pavement in dark color with high reflection to mitigate the UHI effect would be feasible by the usage of NIR reflective coating (Xie et al., 2019).

Interactive water features (Evaporative Techniques). They have been the methods of mitigating the thermal environment during the summer by spraying mist water. The temperature of dry air can be dropped significantly through the phase transition of liquid water to water vapor (evaporation). Field researches reported in some studies have shown the evaporative cooling effect of water bodies on the micro-scale environment (Hathway & Sharples, 2012).

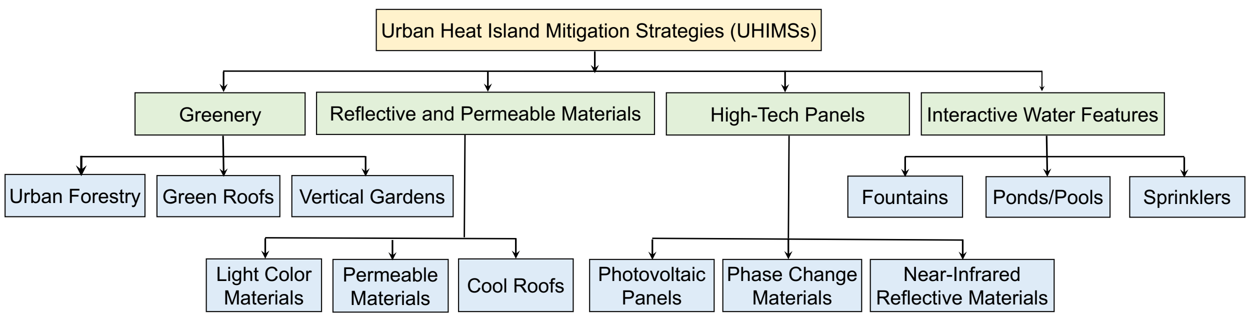


Figure 11: Architectural System of DSS

Model (System) Development

The system is composed of three main parts, each of which has certain attributes and functions. The first component is a user interface, where system data are collected, maintained, and prepared to be processed using spreadsheets. The second part is the main engine (using WSM as the decision support system) which is responsible of finding the optimum mitigation alternatives –the predefined objective of the system. The last part is output display which shows the best optimal mitigation alternative using a spreadsheet. Figure 12 shows the system architecture. The broken and solid lines in the model show the interaction capabilities of the DSS.

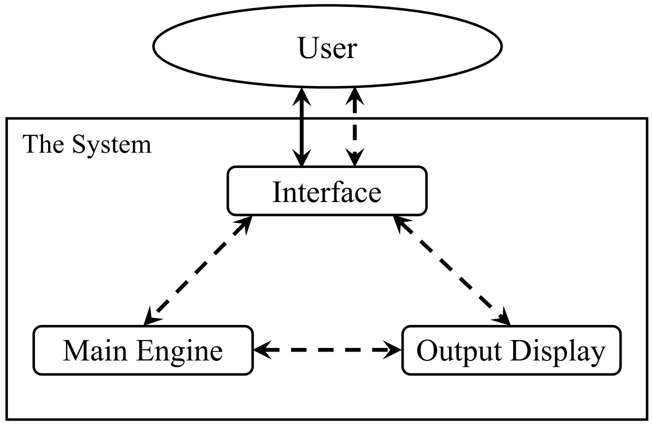


Figure 12: Architectural System of DSS

User Interface

It is a link for easy communication between the system and the human DM. In DSSs, the interface should be an adaptive interface (see Figure 13). It should not be restrictive and inflexible. It should provide system support in easy to use, enjoyable and usable formats. It should provide graphical/textual representation of the problem and allow the user to interact with the system. The system could also decide on what the appropriate methods of visualization for the DM are given the task and the context. Because this component is the one that is directly viewed and used by the user, he/she may think that this is the system. Therefore, ease-of-use and consistency of features are important factors for perceived usefulness and success of the system. User interface should be a customizable interface which allows the users to adjust the interface to their own preferences. For example, if a user wants to see the weights in table format, she/he can click on the “table” page (see figure 16) and the weights will be in the table format. If she/he wants to see it in graphical format, he can click on the “graph” page (see figure 17).

The main function of the user interface is to act data, where all necessary data are collected, and prepared to be processed. It has some attributes which are mentioned below:

- The UI as a knowledge base with a capability to store, retrieve, and process data demands flexibility in exporting and importing data.
- The knowledge base should be manageable in the sense of largeness of capacity, easiness of editing, modifying, and updating, convenience in displaying data, and speedy processing.
- To have high accessibility, and compatibility with other necessary software.
- To ease processing data to and from the system main engine, and the output subsystem it is necessary to have a programmable environment.

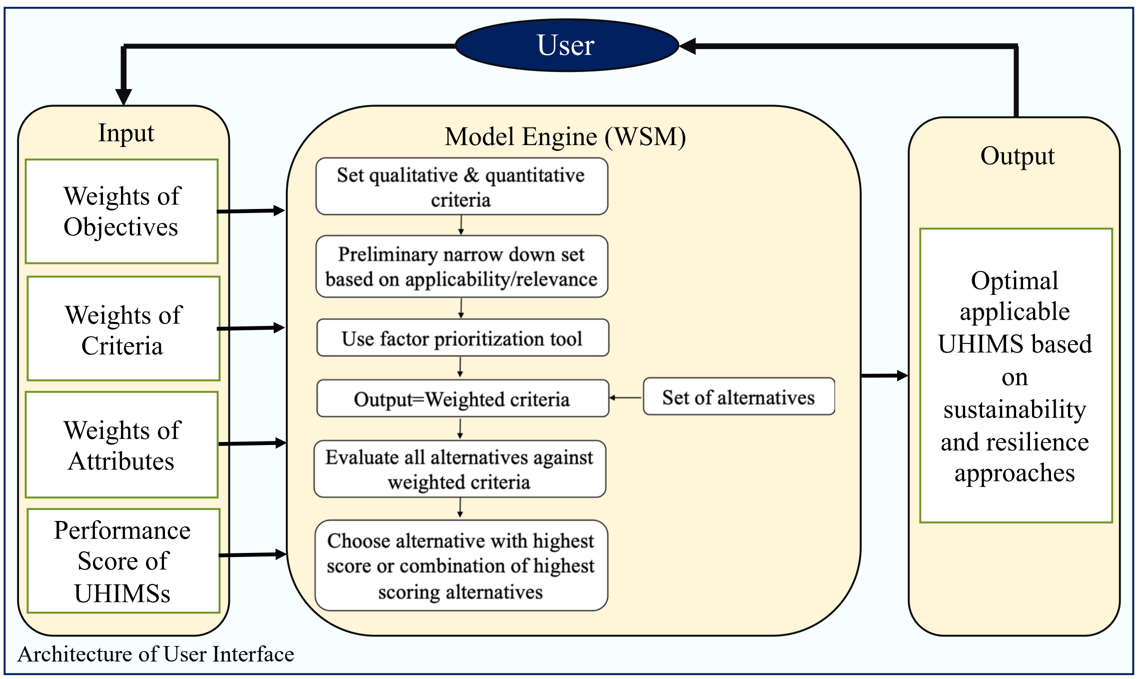


Figure 13: Architectural System of User Interface

In this research, spreadsheets are used for collecting, maintaining, and preparing data to be processed. Its compatibility and compliance with other Microsoft Office products facilitate the process of importing and exporting from and to them, as well as creating the necessary reports. The home page is the first page in the user interface. By pressing the start key, users will advance to the next page (see Figure 14).

Figure 14: User Interface's Home page

The linkages to the different components of the user interface are provided on the Menu page (see Figure 15). Expert elicitation exercises are used to collect and analyze all of the data presented in the user interface. All of the cells relating to weights and scores, on the other hand, can be changed.

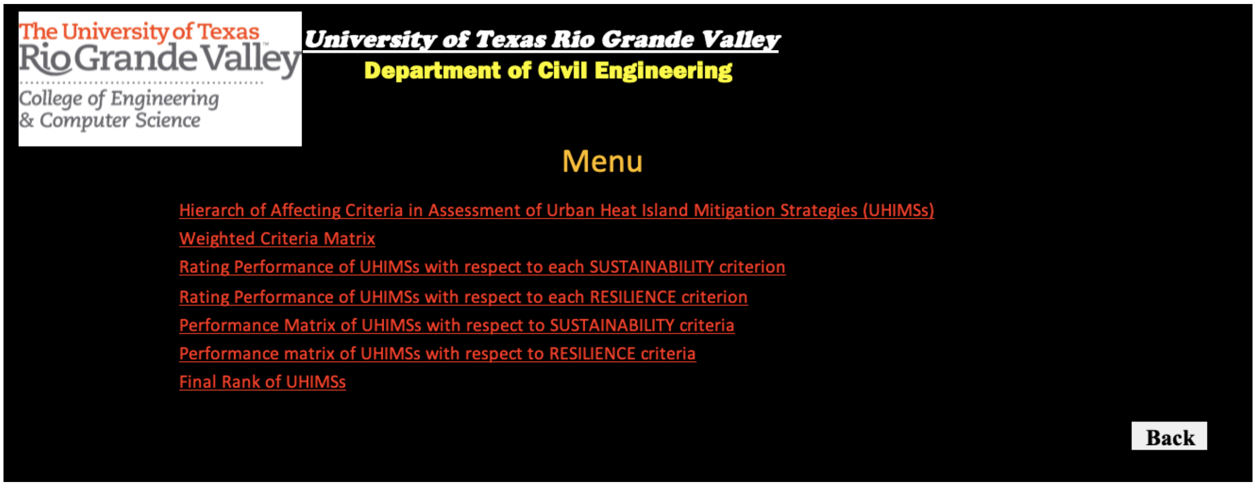


Figure 15: User Interface's Menu page

The users will be able to access the research's weighted criteria and attributes in tabular or graphic format on the next two pages. The cells are set up in such a way that the weighted criteria and attributes can be changed (see figures 16 and 17).

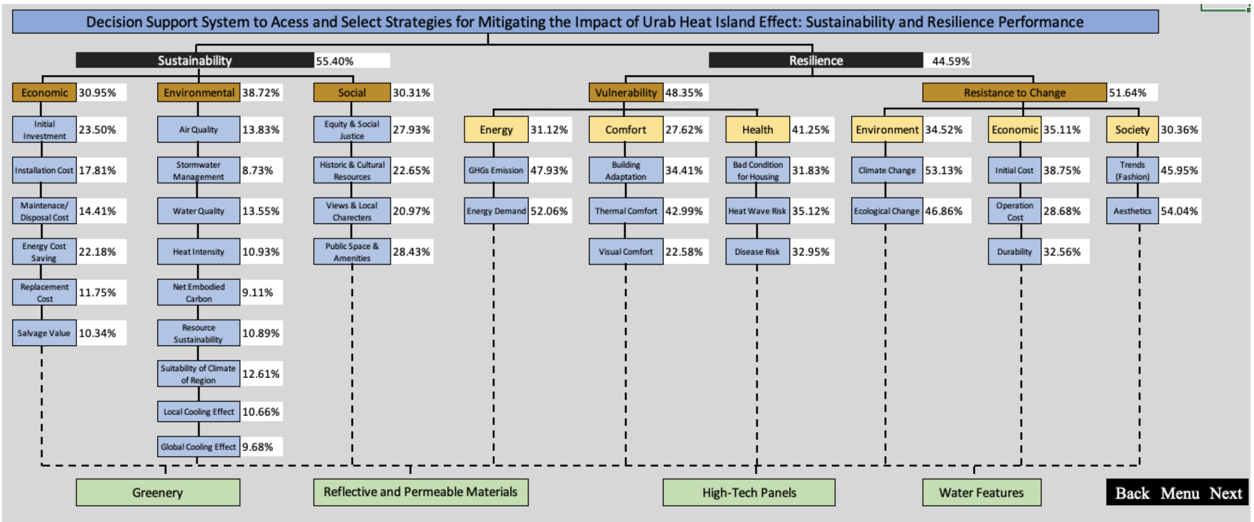
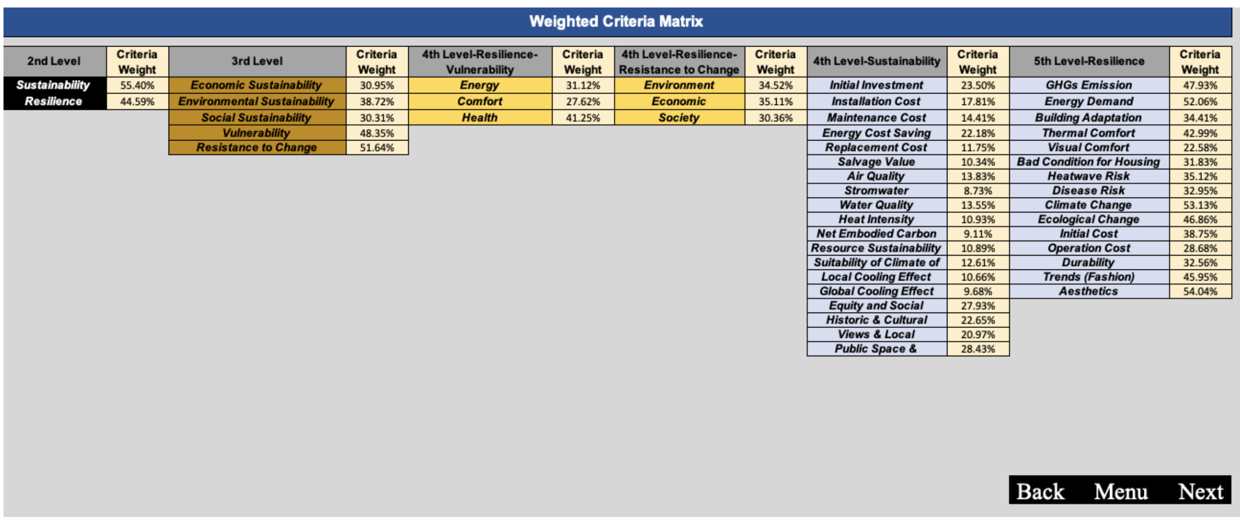


Figure 16: User Interface's Weighted Hierarchy of Criteria & Attributes page



Weighted Criteria Matrix

2nd Level	Criteria Weight	3rd Level	Criteria Weight	4th Level-Resilience-Vulnerability	Criteria Weight	4th Level-Resilience-Resistance to Change	Criteria Weight	4th Level-Sustainability	Criteria Weight	5th Level-Resilience	Criteria Weight
Sustainability	55.40%	*Economic Sustainability*	30.95%	*Energy*	31.12%	*Environment*	34.52%	*Initial Investment*	23.50%	*GHGs Emission*	47.93%
Resilience	44.59%	*Environmental Sustainability*	38.72%	*Comfort*	27.62%	*Economic*	35.11%	*Installation Cost*	17.81%	*Energy Demand*	52.06%
		Social Sustainability	30.31%	*Health*	41.25%	*Society*	30.36%	*Maintenance Cost*	14.41%	*Building Adaptation*	34.41%
		Vulnerability	48.35%					*Energy Cost Saving*	22.18%	*Thermal Comfort*	42.99%
		Resistance to Change	51.64%					*Replacement Cost*	11.75%	*Visual Comfort*	22.58%
								Salvage Value	10.34%	*Bad Condition for Housing*	31.83%
								Air Quality	13.83%	*Heatwave Risk*	35.12%
								Stromwater	8.73%	*Disease Risk*	32.95%
								Water Quality	13.55%	*Climate Change*	53.13%
								Heat Intensity	10.93%	*Ecological Change*	46.86%
								Net Embodied Carbon	9.11%	*Initial Cost*	38.75%
								Resource Sustainability	10.89%	*Operation Cost*	28.68%
								Suitability of Climate of	12.61%	*Durability*	32.56%
								Local Cooling Effect	10.66%	*Trends (Fashion)*	45.95%
								Global Cooling Effect	9.68%	*Aesthetics*	54.04%
								Equity and Social	27.93%		
								Historic & Cultural	22.65%		
								Views & Local	20.97%		
								Public Space &	28.43%		

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Figure 17: User Interface's Weighted Criteria Matrix Page

The users will be able to find the rating scores of UHIMSs performance-based sustainability and resilience in the next page. However, the cells are set up in such a way that the scores can be changed (see figures 18 and 19).

UHIMSs' Rating Performance-Sustainability			Greenery	Reflective & Permeable Materials	High-Tech Panel	Water Features
Sustainability Criteria	Economic	Initial Investment	6.17	5.40	5.37	4.77
		Installation Cost	5.90	5.70	5.63	4.53
		Maintenance Cost	5.00	4.97	6.67	4.83
		Energy Cost Saving	6.57	5.70	6.03	5.13
		Replacement Cost	4.97	4.77	6.60	5.10
		Salvage Value	6.03	5.30	4.13	4.53
	Environmental	Air Quality	7.27	4.90	5.07	5.07
		Stromwater Management	7.87	4.00	3.33	6.17
		Water Quality	7.43	4.20	2.83	6.33
		Heat Intensity	7.93	6.27	5.03	6.77
		Net Embodied Carbon	6.00	4.63	5.10	5.50
		Resource Sustainability	7.23	5.60	5.07	5.73
		Suitability of Climate of Region	7.20	6.23	5.13	6.37
		Local Cooling Effect	7.20	5.70	4.53	6.63
		Global Cooling Effect	5.83	6.17	5.37	4.57
	Social	Equity and Social Justice	7.20	4.00	4.77	6.30
		Historic & Cultural Resources	5.67	4.97	4.13	5.03
		Views & Local Characters	7.43	4.73	3.87	6.13
		Public Space & Amenities	7.97	4.73	3.27	6.57

Likert Scale 0) Not Applicable, 1) Very Low, 3) Low, 5) Average, 7) High, 9) Very High, 2, 4, 6, & 8) Intermediated Levels

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Figure 18: User Interface's UHIMSs' Rating Sustainability Performance Page

UHIMSs' Rating Performance-Resilience				Greenery	Reflective & Permeable Materials	High-Tech Panel	Water Features
Resilience Criteria	Vulnerability	Energy	GHGs Emission	6.80	3.80	6.53	2.90
			Energy Demand	5.70	5.10	4.80	3.83
		Comfort	Building Adaptation	6.07	7.00	7.13	2.77
			Thermal Comfort	7.03	5.30	4.33	6.77
			Visual Comfort	7.70	3.47	3.40	7.20
		Health	Bad Condition for Housing	5.53	5.80	3.60	5.40
			Heatwave Risk	7.10	4.87	2.67	5.47
			Disease Risk	5.07	5.60	5.10	4.87
	Resistance to Change	Environment	Climate Change	7.17	4.13	6.50	2.90
			Ecological Change	7.27	2.73	2.67	3.77
		Economic	Initial Cost	6.67	3.07	3.23	6.30
			Operation Cost	6.73	3.13	3.43	6.43
			Durability	5.37	6.30	6.67	2.93
		Society	Trends (Fashion)	7.67	5.03	3.93	6.20
			Aesthetics	8.30	3.67	4.10	7.93

Likert Scale 0) Not Applicable, 1) Very Low, 3) Low, 5) Average, 7) High, 9) Very High, 2, 4, 6, & 8) Intermediated Levels

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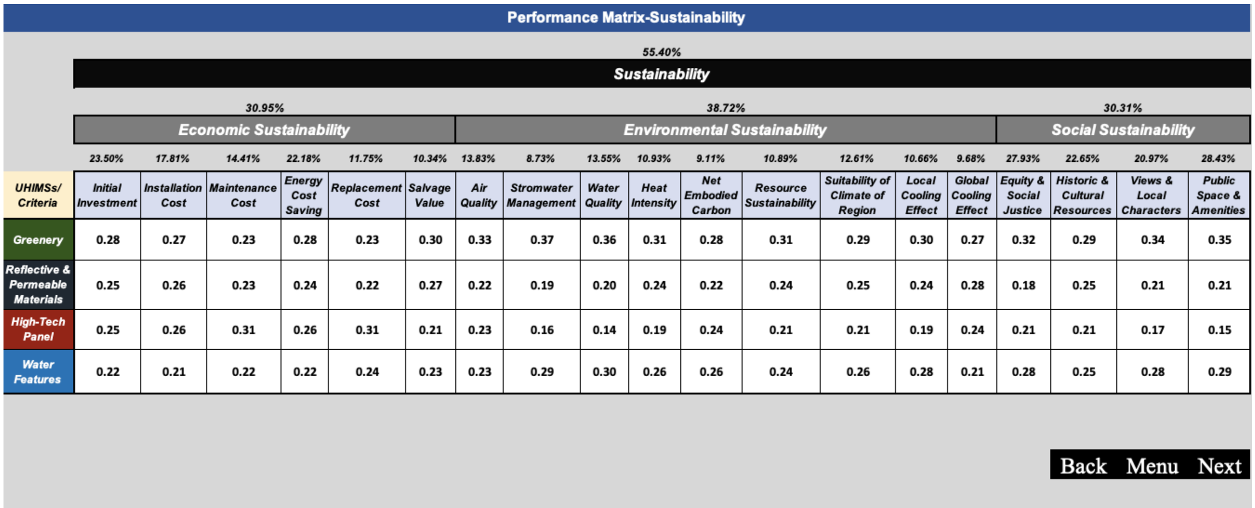
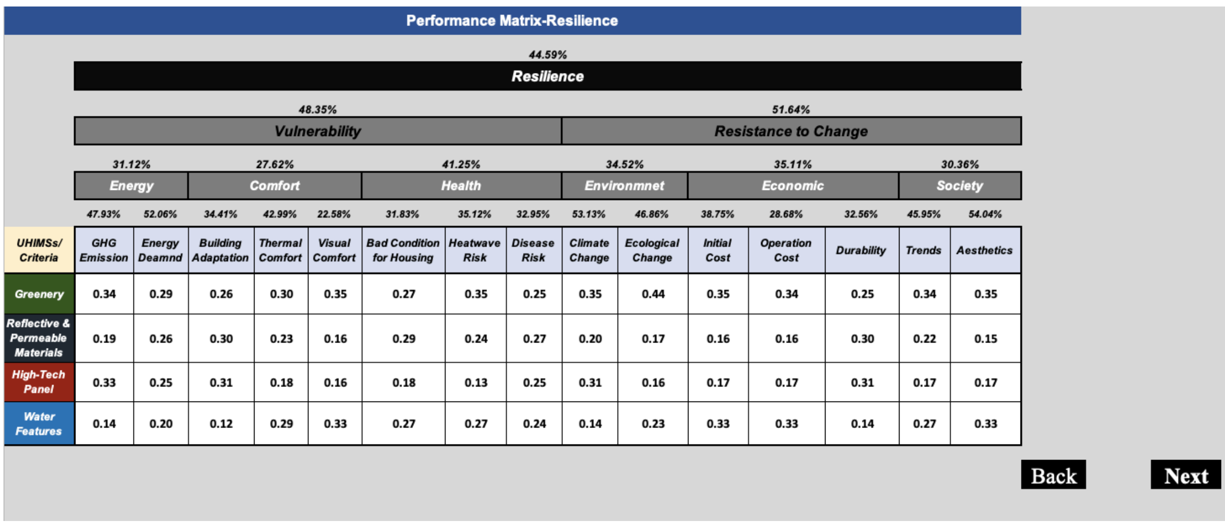
Figure 19: User Interface's UHIMSs' Rating Resilience Performance Page

The Performance Matrix-Sustainability/Resilience pages were created using the UHIMS scores normalized to percentages. Unlike the previous pages, the cells on this page are fixed and cannot be changed (see figures 20 and 21).


Performance Matrix-Sustainability

	Sustainability 55.40%																		
	Economic Sustainability 30.95%						Environmental Sustainability 38.72%									Social Sustainability 30.31%			
	23.50%	17.81%	14.41%	22.18%	11.75%	10.34%	13.83%	8.73%	13.55%	10.93%	9.11%	10.89%	12.61%	10.66%	9.68%	27.93%	22.65%	20.97%	28.43%
UHIMSs/ Criteria	Initial Investment	Installation Cost	Maintenance Cost	Energy Cost Saving	Replacement Cost	Salvage Value	Air Quality	Stromwater Management	Water Quality	Heat Intensity	Net Embodied Carbon	Resource Sustainability	Suitability of Climate of Region	Local Cooling Effect	Global Cooling Effect	Equity & Social Justice	Historic & Cultural Resources	Views & Local Characters	Public Space & Amenities
Greenery	0.28	0.27	0.23	0.28	0.23	0.30	0.33	0.37	0.36	0.31	0.28	0.31	0.29	0.30	0.27	0.32	0.29	0.34	0.35
Reflective & Permeable Materials	0.25	0.26	0.23	0.24	0.22	0.27	0.22	0.19	0.20	0.24	0.22	0.24	0.25	0.24	0.28	0.18	0.25	0.21	0.21
High-Tech Panel	0.25	0.26	0.31	0.26	0.31	0.21	0.23	0.16	0.14	0.19	0.24	0.21	0.21	0.19	0.24	0.21	0.21	0.17	0.15
Water Features	0.22	0.21	0.22	0.22	0.24	0.23	0.23	0.29	0.30	0.26	0.26	0.24	0.26	0.28	0.21	0.28	0.25	0.28	0.29

Figure 20: User Interface's Sustainability Performance Matrix Page


Performance Matrix-Resilience

	Resilience 44.59%														
	Vulnerability 48.35%								Resistance to Change 51.64%						
	Energy 31.12%		Comfort 27.62%			Health 41.25%			Environmnet 34.52%		Economic 35.11%			Society 30.36%	
	47.93%	52.06%	34.41%	42.99%	22.58%	31.83%	35.12%	32.95%	53.13%	46.86%	38.75%	28.68%	32.56%	45.95%	54.04%
UHIMSs/ Criteria	GHG Emission	Energy Deamnd	Building Adaptation	Thermal Comfort	Visual Comfort	Bad Condition for Housing	Heatwave Risk	Disease Risk	Climate Change	Ecological Change	Initial Cost	Operation Cost	Durability	Trends	Aesthetics
Greenery	0.34	0.29	0.26	0.30	0.35	0.27	0.35	0.25	0.35	0.44	0.35	0.34	0.25	0.34	0.35
Reflective & Permeable Materials	0.19	0.26	0.30	0.23	0.16	0.29	0.24	0.27	0.20	0.17	0.16	0.16	0.30	0.22	0.15
High-Tech Panel	0.33	0.25	0.31	0.18	0.16	0.18	0.13	0.25	0.31	0.16	0.17	0.17	0.31	0.17	0.17
Water Features	0.14	0.20	0.12	0.29	0.33	0.27	0.27	0.24	0.14	0.23	0.33	0.33	0.14	0.27	0.33

Figure 21: User Interface's Resilience Performance Matrix Page

The last page of the user interface is the Final Rank of UHIMSs. Here is the last step where decision makers will find the optimal score of UHIMS based on sustainability (and/or) resilience and their subcategories (see Figure 22).

Final Rank of UHIMSs

	Greenery	Reflective & Permeable Materials	High-Tech Panel	Water Features
Sustainability	0.30	0.23	0.21	0.25
Economic Sustainability	0.27	0.25	0.26	0.22
Environmental Sustainability	0.31	0.23	0.20	0.26
Social Sustainability	0.33	0.21	0.18	0.28
Resilience	0.33	0.22	0.22	0.24
Vulnerability	0.30	0.25	0.23	0.23
Energy	0.32	0.23	0.28	0.17
Comfort	0.30	0.24	0.22	0.24
Health	0.29	0.27	0.18	0.26
Resistance to Change	0.35	0.19	0.21	0.25
Environmental	0.39	0.18	0.24	0.18
Economic	0.31	0.20	0.22	0.27
Society	0.34	0.18	0.17	0.30
Sustainability & Resilience	0.31	0.22	0.22	0.25

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Figure 22: User Interface's Final Rank of UHIMSs Page

Main Engine

The Main engine is responsible for carrying out all the operations as a part of the evaluation process of alternatives and up till the fulfillment of the objective of the system. It is designed to use WSM by accommodating certain matrices for evaluating the different strategies of urban heat island effect.

Output Display

The final output is displayed in Spreadsheets (see figure 22). The advantages of spreadsheet are their effectiveness in handling various number of data in terms of organization, modification, large capacity, and consistency. Furthermore, spreadsheets are to be used as a database in numerous add-ins programs seeking to facilitates the use of the output data in further computer operations. As per this, Microsoft Excel program is used in this purpose. The most advantages of using Excel is one of the user friendly, most popular spreadsheet programs, compatible with most software, and its programmable environment.

Application Example of WSM in A Hypothetical Example

The following is the process of the application of the WSM:

List all relevant qualitative and quantitative criteria affecting decisions in a hierarchical structure in which the top of hierarchy represents overall objectives (goal) and the lower levels represent criteria, sub-criteria, and alternatives.

Determine the level of importance of each criterion. The importance of one criterion over another can be major preference (given 9 points), above average preference (given 4 points), average preference (given 7 point), slight preference (given 5 points), equal preference (given 1 point), and intermediate level (2, 4, 6, 8).

- Establish the total raw score of each criterion.
- Calculate the weight for each criterion.
- Evaluate each alternative for each criterion. The assigned scoring system in this evaluation is 1-9 points on a scale of poor (1), Fair (3), Good (5), Very Good (7), Excellent (5), and Intermediate Level (2, 4, 6, 8).
- Multiply the rank of each alternative with the weight of each criterion.
- The alternative with the highest score is the winner.

Assessment of three selected UHIMSs (Green Roofs, Permeable Materials, and Cool Roofs) based on economic-sustainability criteria is carried out by using WSM in this hypothetical example (see Figure 23).

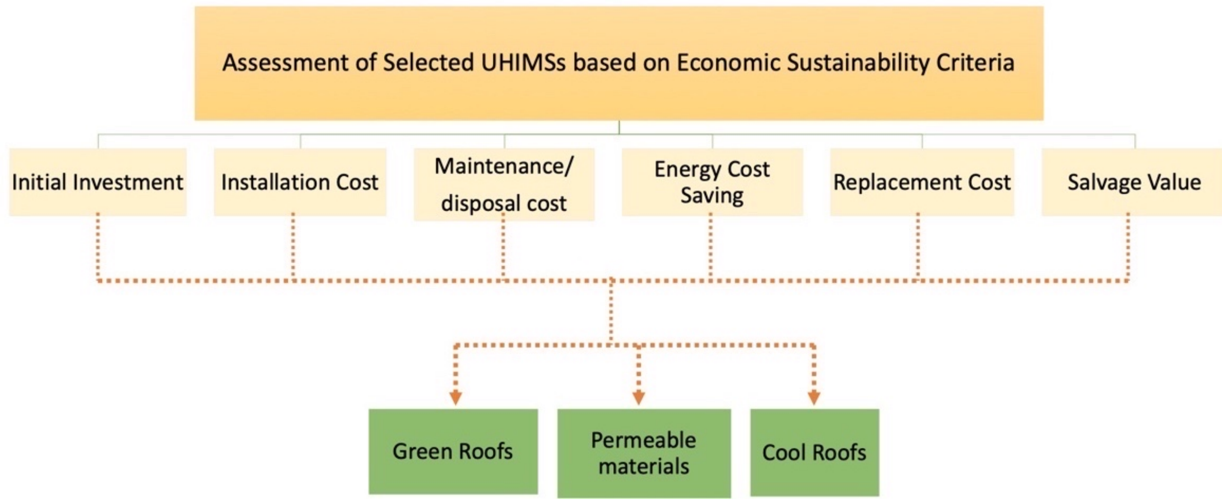

Figure 23: Hierarchical structure for assessing three selected UHIMSs (Green Roofs, Permeable Materials, and Cool Roofs) based on economic-sustainability criteria

Firstly, a weight is assigned to each criterion depending on its relative importance, and the most important criterion is awarded the highest weighting.

- The UHI mitigation methods (k)
- The relative importance of criteria (i) for each of the UHI mitigation methods (S).
- Method 1: k1= Green Roofs (GR)
- Method 2: k2= Permeable Materials (PM)
- Method 3: k3= Cool Roofs (CR)

Secondly, a score is assigned to each of the UHI mitigation methods being considered, as a means of judging the extent to which the particular method achieves each criterion. For example, the impact of Green Roof (GR) method to reduce Initial Investment is considered to be Good and is given a score of 5 (Table 5).

Table 5: Hypothetical scores of criteria for various mitigation methods

Criterion (i)	K1= GR	K2= PM	K3= CR
Initial Investment	5	3	7
Installation Cost	5	5	7
Maintenance/ Disposal Cost	3	5	3
Energy Cost Saving	5	7	7

Replacement Cost	7	1	1
Salvage Value	5	3	7

Outcome shows the Cool Rood (CR) has the highest score and therefore is the preferred UHI mitigation method (Table 6).

Table 6: Weighted score tabulation

Alternative	Criteria						Score
	20%	15%	20%	20%	15%	10%	
	Initial Investment	Installation Cost	Maintenance Cost	Energy Cost Saving	Replacement Cost	Salvage Value	
K1= GR	5 * 0.2	5 * 0.15	3 * 0.2	5 * 0.2	7 * 0.15	5 x 0.10	4.9
K2= PM	3 * 0.2	5 * 0.15	5 * 0.2	7 * 0.2	1 * 0.15	3 x 0.10	4.2
K3= CR	7 * 0.2	7 * 0.15	3 * 0.2	7 * 0.2	1 * 0.15	7 x 0.10	5.3

Comparison of WSM, AHP, ANP, and ANN

Given the characteristics of AHP, WSM, and ANP theories (techniques/methods) (see chapter 2), it is possible to attempt a conceptual and structural comparison.

The mathematical structure that characterizes the mentioned theories is one important technical difference. The hierarchical structure in AHP and the network structure in ANP are interlinked to the decision structures. They are describable in terms of the objective, criteria, sub-criteria/clusters (ANP forces precise definitions of nodes and inter-connections), and alternatives and can be characterized in a system of pairwise comparison. As the result, the elements that are normally non-measurable, become possible to evaluated which is the necessary condition for which the system works. The idea of ANP is to gain deep understanding of a specific problem and its relation to related factors. In both specially in ANP explanation of the concept and process to management is extremely challenging. Therefore, ANP is complex for an implementation as standard tool for practical decision making. Compared to AHP, verification of the result due to feedback loops and interrelations is impossible in ANP.

While WSM evaluates all alternatives against weighted criteria and chooses the alternative with the highest score, in the ANN, on the other hand, the internal structure in no way represents the structure of the problem to be analyzed. ANN is capable of learning from experiences, AHP always necessitates human evaluations.

These methods (AHP, WSM, and ANN) have different systems in the calculation and attribution of the weights, however, all three methods generate a ranking (at any rate) by choice among the alternatives. Also, in case of AHP and WSM aggregate score of each alternative may not remain same even though requirements are same because aggregate score depends on expert's own judgment which may not remain consistent for all the time.

Furthermore, in the final stage of AHP there is the Consistency Ratio (CR) calculation to measure how consistent the judgments have been relative to large samples of purely random judgments. If the CR is much in excess of 0.1 the judgments are untrustworthy because they are too close for comfort to randomness and the exercise is valueless or must be repeated. Despite to AHP, there is no consistency ratio stage in WSM method. So, it is impossible to evaluate the level of trustworthy of judgments in this method.

Regarding qualitative assessment, AHP provides more benefits than WSM. There are some steps in AHP which are ignored in WSM. And this the main reason that qualitative assessment of WSM is not more extensive. While both AHP and the WSM are formalized decision-making methods examine quantitative and qualitative factors, on the other hand, ANN is usually considered a data-processing system that is based on how the human brain works. ANN operates by assigning weights as does a universal function approximator. AHP and ANP however, are based on a goal-criteria-alternatives structure and they operate hierarchically or in networks.

In comparison to other mentioned methods, ANN requires an extensive amount of scientific data (weights and preferences). Another issue in data gathering by questionnaires, WSM requires a smaller number of questions compared with AHP and ANP.

Hypothetical Example

In a hypothetical example to model is validated. According to this, the weights of sustainability and resilience objectives are changed to 70 and 30 percent. With regard to 3Ps of sustainability more weight is allocated to economic sustainability (50%). As the same way, resilience criteria are weighted 60% for vulnerability and 40% for resistance to change. Collectively, Water Feature method with 0.34, Greenery method with 0.30, Reflective and Permeable method with 0.28, and High-Tech method with 0.26 are scored (see Figures 24, 25).

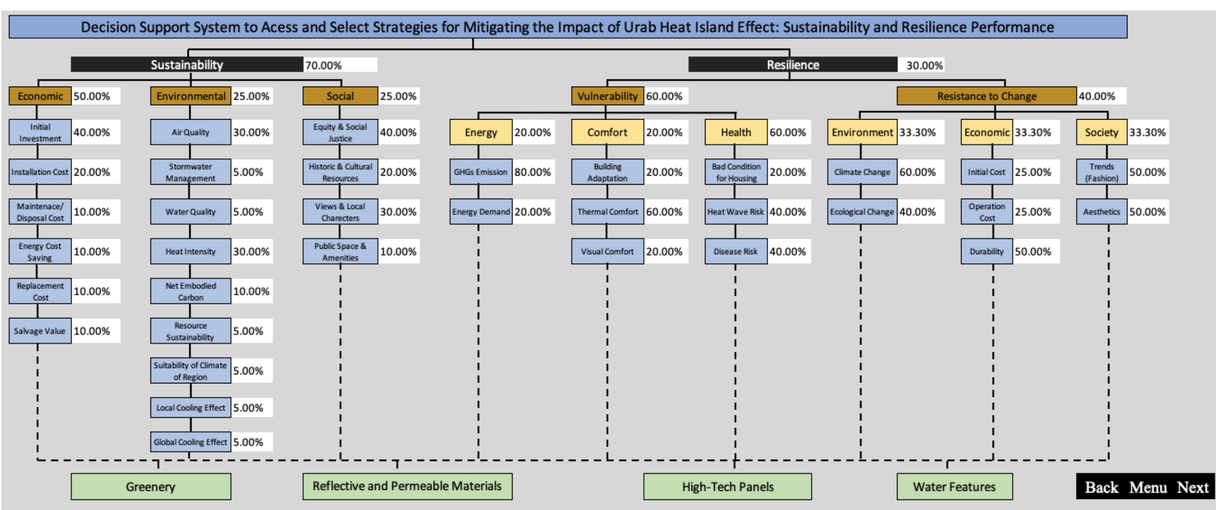

Figure 24: Weights of parameters based on hypothetical example

Final Rank of UHIMSs

	Greenery	Reflective & Permeable Materials	High-Tech Panel	Water Features
Sustainability	0.25	0.23	0.20	0.31
Economic Sustainability	0.17	0.28	0.19	0.36
Environmental Sustainability	0.33	0.20	0.23	0.24
Social Sustainability	0.33	0.19	0.19	0.29
Resilience	0.42	0.38	0.40	0.40
Vulnerability	0.34	0.17	0.17	0.32
Energy	0.41	0.15	0.15	0.30
Comfort	0.28	0.22	0.22	0.28
Health	0.33	0.16	0.17	0.34
Resistance to Change	0.55	0.70	0.75	0.51
Environmental	0.41	0.16	0.23	0.20
Economic	0.89	1.77	1.88	0.98
Society	0.34	0.16	0.15	0.34
Sustainability & Resilience	0.30	0.28	0.26	0.34

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Figure 25: Final ranks of UHIMSs based on hypothetical example

Summary and Conclusion

Although there must be various parameters which have contribution in assessing the strategies of urban heat island mitigation, it is impossible to include all of them. This research aims to identify, classify, and organize the known parameters used for assessing the mitigation strategies to help resolve the UHI effect. To fulfill this purpose, the study proposed a UHIMSs' hierarchy perusing two objectives of Sustainability and Resilience. Each objective and its related criteria and attributes are discussed through the conceptualization of terminologies, examples, and their levels of relationship in the hierarchy. Subsequently, this research proposes a framework to facilitate the application of the UHIMSs' hierarchy. There are three steps in the framework. The first step is hierarchy of objectives, criteria, and attributes. The second one, main engine applies WSM method to carry out all the operations as a part of the evaluation process of alternatives and up till the fulfillment of the objective of the system. Finally, the last step is a user-friendly interface to be built on the extracted data. The proposed framework is envisioned as a knowledge sharing platform supporting stakeholders like urban planners, architects, decision makers and policy makers in the extraction of the most suitable UHI mitigation strategy concerning sustainability and resilience.

Multi-criteria decision-making (MCDM) is an appropriate approach for decision-making problems. Several methods have been proposed for MCDM, among them AHP, WSM, ANP, and ANN (using mathematical modeling to ease the process of decision-making) are described and compared in this research. The AHP and ANP in contrast with WSM, the redundancy of those comparisons in pairs helps in making the analysis more precise in building the knowledge about the elements of a problem. Although WSM, AHP, and ANP are applicable to various problems and their superiority lies exactly in its capacity to attribute a relative weight to all the elements of a problem, either tangible or not, and to build a hierarchy/network of their relative relevance (Russo & Camanho, 2015), however data gathering and manually calculating the eigenvectors could be time-consuming specially in AHP and ANP. Also, depending on how the question is framed, rank reversal may get different results. Furthermore, AHP and ANP are more complex and require an excess amount of question when it comes to developing the questionnaires compared to WSM. In comparison to ANN, AHP and WSM do not have to be too resource intensive. Also, ANN and ANP require additional tools or software, or personnel with technical backgrounds. On the other hand, WSM has simple analysis process, and it is applicable to various problems. In conclusion based on the comparison between these methods as well as limitations and feasibility of this research WSM is applied as the MCDM method for the proposed DSS of this research.

CHAPTER IV

EXPERT ELICITATION & DATA RESULTS

This chapter presents the procedures of developing expert elicitation exercises and participants selection. In addition, the statistical analysis of the collected data from the three expert elicitations are presented in tables and graphs.

Development of the Expert Elicitation Exercises

To qualify the model parameters, it was required to solicit the experts' opinions. Authors designed two expert elicitation exercises in Qualtrics XM to obtain the required data. The main objectives of them are to understand the relative weights of criteria affecting in the assessment of UHIMSs and also find the impact rate of these criteria on each mitigation strategy. The expert elicitation exercises went through multiple rounds of revisions to incorporate comments from experts. They are designed as an educational tool that can be later used by participants with different levels of knowledge.

The respondents selected for this research are LEED/Envision-certified professionals working in green design/contractor firms, scholars with scientific publications in green building, UHI, and LEED. The contact list and respondents' profiles are first generated through Linkedin professional social media. The fit of the possible respondent is analyzed in the following phases: 1) to find LEED or Envision-certified in the Linkedin network, 2) to analyze all selected profiles according to the research protocol profile, 3) to check Linkedin profile information with available data about the respondent's respective organization such as email address and job description, 4) to send through email or Linkedin an invitation for selected professionals about our expert elicitation exercise and ask about interest in participating, 5) to send the questionnaire link for all people that accepted our previous invitation. Moreover, there is no specific geographical link between expert elicitation exercise questions and answers. Any expert in the field of UHI could participate and answer the questions regardless of their spatial and geographical point. There is no factor that affects the variability in the collected data. As far as participants answer the questions completely, it is valid and reliable to be used for the research.

The first part of the expert elicitation exercises consists of 15 questions. The purpose of this part is to find the relative importance (weight) of the objectives, attributes, and criteria affecting the assessment of mitigation strategies of the UHI effect with respect to their levels of resilience and sustainability. This part consists of two sections. In the first section, the personal information of respondents is asked including their name, email address, and their affiliation. In the second section, a total of 14 questions seek information about the relative weights of sustainability and resilience criteria and attributes in the assessment of UHIMSs (see Appendix A and Figure 26). The research questionnaire is developed, with predominantly closed questions, using a percentage scale ranging from 0 to 100. For each criterion of the proposed hierarchy the respondents weight the criterion on a percentage scale (see Figure 26). After several times questionnaire revision, then it is applied online (made available on a web link), using the Qualtrics XM software to collect data, store and perform the statistical analysis. Regarding the first part of expert elicitation, the sample of questions for each level of the hierarchy are as follows:

Second Level: What is the relative importance (weight) of each of the following criteria with respect to Urban Heat Island Mitigation Strategies (UHIMSs)? (Total must be 100%) a) Resilience, b) Sustainability.

Third Level: What is the relative importance (weight) of each of the following criteria with respect to Sustainability? (Total must be 100%) a) Economic, b) Environmental, c) Social.

Fourth Level: What is the relative importance (weight) of each of the following criteria with respect to the Social Sustainability? (Total must be 100%) a) Equity & Social Justice, b) Historic & Cultural Resources, c) Views & Local Characters, d) Public Space & Amenities.

In total, there are 15 questions that demanded an answer, usually in the form of selecting the percentage from 0% to 100%. First question requires respondents to input a text (e.g. name, surname, email address, and affiliation).

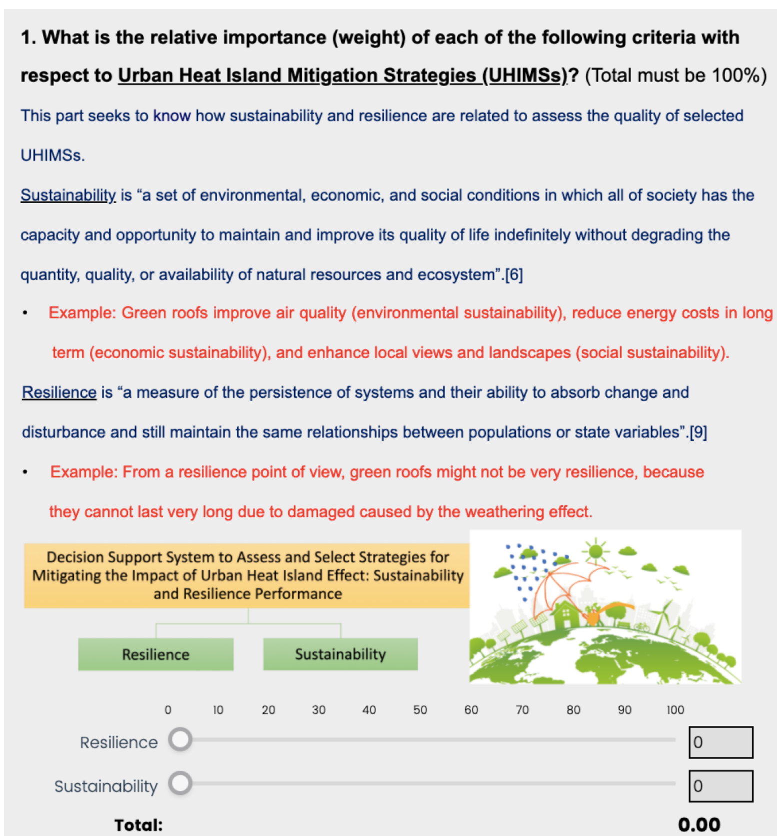

Figure 26: Example question of the 1st part of expert elicitation on Qualtrics XM

Background of the Respondents in the 1st Part

The 1st part of expert elicitation was distributed online through Qualtrics XM on January 19th, 2021, and the provided results are based on data collected over three months, till April 19th. It was distributed to 400 professionals in green building design/contractor firms, as well as researchers and scholars interested in the UHI Effect. The results reported here are based on 45 responses (11.25 percent response rate), with 59 percent coming from academics, 27 percent from industry professionals, 7% from government, and 7% from others (see Figure 27).

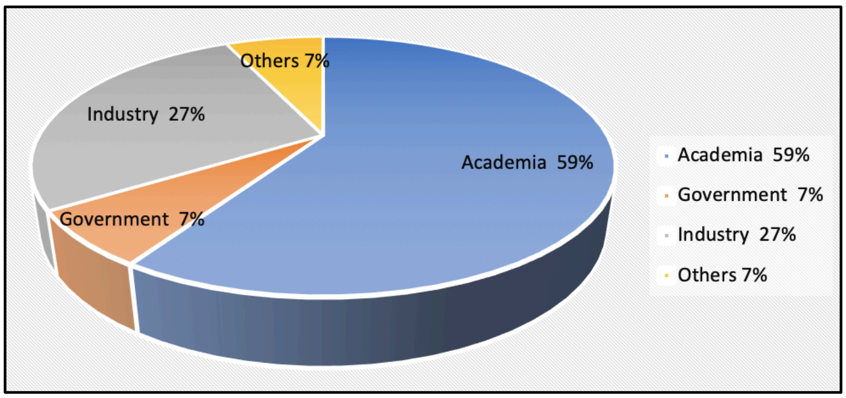

Figure 27: Background of participants in the 1st part

Data Analysis and Results of the 1st Part of the Expert Elicitation

A total of 45 people did the expert elicitation part 1 and answered all of the questions (response rate: about 11.25 percent). Figure 4 shows that the most of the participants (59%) are from academics, with only 27% working in the construction/design business. The findings of descriptive statics analysis on the data collected are shown in the following tables and figures.

The results of this study revealed a wide range of relative weights for attributes and criteria related to the UHI phenomena and UHIMSs. Sustainability and Resilience are the model objectives at the top of the hierarchy. The findings suggest that, in a modest shift, sustainability is more important than resilience, with 55.40 percent and 44.59 percent, respectively (see figure 28 & Table 7).

In the second level of hierarchy, the Vulnerability and Resistance to Change attributes, as well as the Environmental, Economic, and Social sustainability attributes, have no substantial differences in their level of importance (weights) with 48.35, 51.64, 38.72, 30.95, and 30.31 percent, respectively (see figure 29 & Table 8).

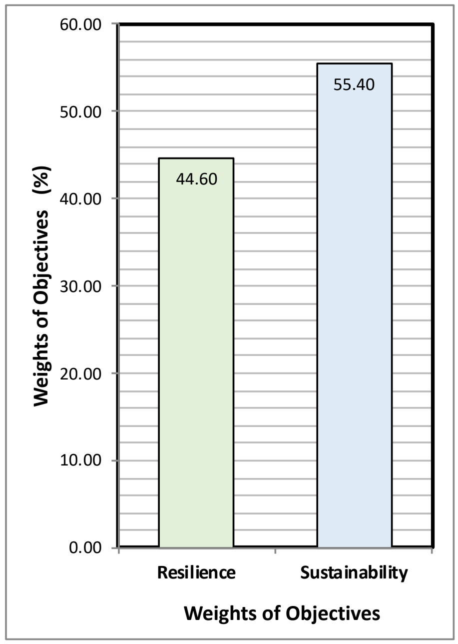

Figure 28: Histogram of objectives' weights

Table 7: Descriptive Statics of Objectives of Hierarchy

	Criterion	Min.	Max.	Mean	Median (2nd Quartile)	1st Quartile	3rd Quartile	Mode	Range	Sample Variance	Standard Deviation
Q1	Sustainability	29.20	80.00	55.40	57.12	46.53	64.00	50.00	50.80	192.83	13.88
	Resilience	20.00	70.80	44.59	42.88	30.00	53.465	50.00	50.80	192.83	13.88

Table 8: Descriptive Statics of Attributes of Hierarchy

	Criterion	Min.	Max.	Mean	Median (2nd Quartile)	1st Quartile	3rd Quartile	Mode	Range	Sample Variance	Standard Deviation
Q2	Vulnerability	0.00	83.95	48.35	50.00	31.25	65.743	50.00	83.95	352.37	18.77
	Resistance to Change	16.05	100.0	51.64	50.00	34.25	68.75	50.00	83.95	352.37	18.77
Q11	Environmental Sustainability	0.00	80.00	38.72	40.00	30.00	42.75	40.00	80.00	243.41	15.60
	Economic Sustainability	0.00	70.00	30.95	30.00	20.00	40.00	30.00	70.00	187.71	13.70
	Social Sustainability	5.00	100.0	30.31	30.00	20.00	33.00	30.00	95.00	247.05	15.71

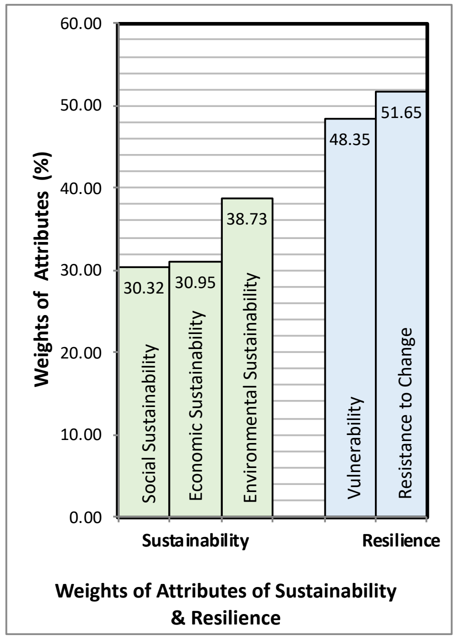

Figure 29: Histogram of attributes' weights

In terms of environmental sustainability, the findings demonstrate a considerable gradient increase in the weight of Air Quality, Water Quality, and Suitability of Climate of Region criteria in UHIMS evaluation, with 13.84, 13.55, and 12.61 percent, respectively. The weights of the remaining criteria in this category ranges from 8.73 to 10.93 percent (see figure 30 & Table 9).

The descriptive statistics findings suggest that economic sustainability criteria are weighted in a range of about 10% to 20% in this study. With weights of 23.50 and 22.18 percent, respectively, the Initial Investment and Energy Cost Saving criteria are the most important (see figure 30 & Table 9).

Surprisingly, when it comes to evaluating UHIMSs, the social sustainability criteria have almost similar weights and level of importance compared to one another. With 28.43, 27.93, 22.65, and 20.97 percent weights, the criteria for Public Spaces & Amenities, Equity and Social Justice, Historic and Cultural Resources, and Views and Local Characters are ranked from high to low in the level of importance (see figure 30 & Table 9).

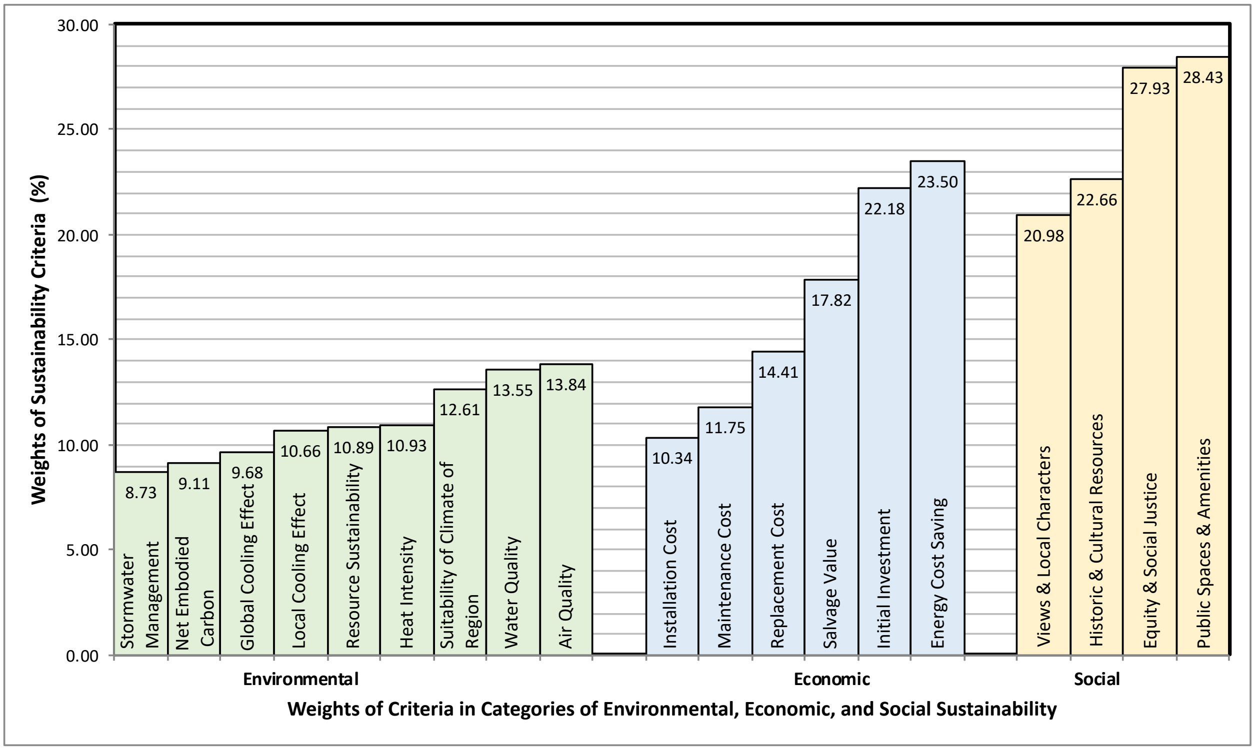

Figure 30: Histogram of Sustainability criteria's weights

Table 9: Descriptive Statics of Sustainability Criteria of Hierarchy

	Criterion	Min.	Max.	Mean	Median (2nd Quartile)	1st Quartile	3rd Quartile	Mode	Range	Sample Variance	Standard Deviation
Q12	Air Quality	0.00	83.95	48.35	50.00	31.25	65.743	50.00	83.95	352.37	18.77
	Stormwater Management	16.05	100.0	51.64	50.00	34.25	68.75	50.00	83.95	352.37	18.77
	Water Quality	0.00	37.00	13.54	13.50	10.00	20.00	20.00	37.00	57.09	7.55
	Heat Intensity	0.00	30.00	10.93	10.00	5.00	15.00	10.00	30.00	54.25	7.36
	Net Embodied Carbon	0.00	21.00	9.11	10.00	5.00	10.75	10.00	21.00	27.40	5.23
	Resource Sustainability	0.00	37.00	10.88	10.00	6.25	15.00	10.00	37.00	46.89	6.84
	Suitability of Climate of Region	0.00	30.00	12.61	10.50	10.00	15.75	10.00	30.00	37.40	6.11
	Local Cooling Effect	0.00	50.00	10.65	10.00	5.00	13.00	5.00	50.00	93.62	9.67
	Global Cooling Effect	0.00	100.0	9.68	8.50	5.00	10.00	10.00	100.0	218.45	14.78
Q13	Initial Investment	0.00	48.00	23.50	20.00	15.75	30.00	20.00	48.00	112.44	10.60
	Installation Cost	0.00	35.00	17.81	20.00	10.50	20.00	20.00	35.00	63.91	7.99
	Maintenance Cost	0.00	40.00	14.41	15.00	8.50	20.00	15.00	40.00	90.66	9.52
	Energy Cost Saving	0.00	60.00	22.18	20.00	13.25	30.00	20.00	60.00	158.43	12.58

	Replacement Cost	0.00	37.00	11.75	10.00	10.00	15.00	10.00	37.00	42.23	6.50
	Salvage Value	0.00	100.0	10.34	10.00	5.00	11.00	10.00	100.0	220.50	14.84
Q14	Equity and Social Justice	0.00	53.00	27.93	26.50	20.00	38.00	35.00	53.00	158.94	12.60
	Historic & Cultural Resources	0.00	40.00	22.65	21.00	18.25	29.75	20.00	40.00	74.41	8.62
	Views & Local Characters	0.00	50.00	20.97	20.00	15.50	25.00	20.00	50.00	74.99	8.66
	Public Spaces & Amenities	10.00	100.0	28.43	26.50	20.00	30.00	20.00	90.00	193.74	13.92

When it comes to criteria related to Vulnerability, Health has the largest weight in evaluating UHI mitigation strategies, at 41.25 percent. With 31.12 and 27.62 percent, respectively, the Energy and Comfort criteria are ranked second and third in importance. The Environmental, Economic, and Social aspects of Resistance to Change, on the other hand, are weighted at 34.52, 35.11, and 30.36 percent, respectively. It is clear that these parameters have no substantial differences in importance while evaluating UHIMSs (see figure 31 & Table 10).

The criteria linked with Energy-Vulnerability (weight of GHGs Emission= 47.93 percent and weight of Energy Demand= 52.06 percent) have comparable levels of importance in assessing the UHIMSs, according to the examined data displayed in figure 9. The Health-Vulnerability criteria (weight of Bad Condition for Housing=31.83 percent, weight of Heat Wave Risk=35.12 percent, and weight of Disease Risk= 32.95 percent) tell the same story.

In the Comfort-Vulnerability category, the Thermal Comfort criterion has the highest weight, with 42.99 percent weight. Building Adaptation and Visual Comfort are ranked second and third in terms of importance when it comes to mitigating UHI effects, with 34.41 and 22.58 percent, respectively (see figure 31 & Table 10).

In the case of the Resistance to Change attribute, the descriptive analysis of the data reveals minor differences in the weights of criteria in each category in relation to one another.

Environmental Resistance to Change criteria (weight of Climate Change= 53.13 percent and weight of Ecological Change= 46.86 percent), Economical Resistance to Change criteria (weight of Initial Cost= 38.75 percent, weight of Operation Cost= 28.68 percent, and weight of Durability= 32.56 percent), and Social Resistance to Change criteria (weight of Trends= 45.95 percent and weight of Durability= 32.56 percent) are just a few examples (see figure 31 & Table 10).

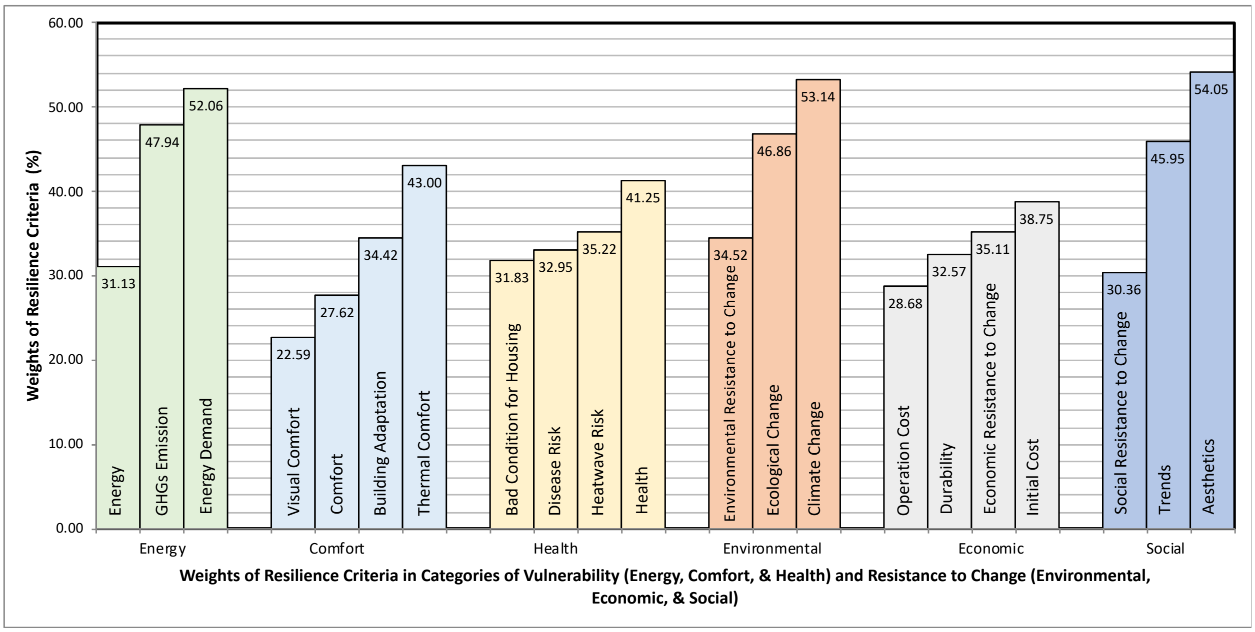

Figure 31: Histogram of Resilience criteria's weights

Table 10: Descriptive Statics of Resilience Criteria of Hierarchy

Question Nr.	Criterion	Min.	Max.	Mean	Median (2nd Quartile)	1st Quartile	3rd Quartile	Mode	Range	Sample Variance	Standard Deviation
Q3	Energy	0.00	70.00	31.12	29.66	20.00	39.01	30.00	70.00	292.06	17.08
	Comfort	0.00	48.85	27.62	29.91	20.00	35.00	20.00	48.85	140.87	11.87
	Health	0.00	100.0	41.25	40.00	30.34	50.00	40.00	100.0	402.78	20.06
Q4	GHGs Emission	0.00	90.00	47.93	47.85	37.52	60.00	18.41	90.00	339.15	18.41
	Energy Demand	10.00	100.0	52.06	52.15	40.00	62.47	50.00	90.00	339.15	18.41
Q5	Building Adaptation	0.00	70.00	34.41	33.76	25.50	40.00	40.00	70.00	191.46	13.83
	Thermal Comfort	0.00	80.00	42.99	41.44	30.74	50.25	50.00	80.00	254.57	15.95
	Visual Comfort	0.00	100.0	22.58	20.00	14.43	29.90	20.00	100.0	263.50	16.23
Q6	Bad Condition for Housing	0.00	80.00	31.83	30.00	20.00	40.00	20.00	80.00	215.55	14.68

	Heat Wave Risk	0.00	80.00	35.12	33.92	27.34	40.09	40.00	80.00	266.63	16.32
	Disease Risk	0.00	100.0	32.95	32.57	20.00	40.25	20.00	100.0	333.14	18.25
Q7	Environmental Resistance to Change	0.00	60.00	34.52	34.50	25.50	50.00	30.00	60.00	261.93	16.18
	Economical Resistance to Change	0.00	80.00	35.11	33.00	26.00	40.00	30.00	80.00	258.61	16.08
	Social Resistance to Change	11.00	100.0	30.36	27.50	20.00	39.25	20.00	89.00	242.75	15.58
Q8	Climate Change	0.00	80.00	53.13	51.00	50.00	65.00	50.00	80.00	240.26	15.50
	Ecological Change	20.00	100.0	46.86	49.00	35.00	50.00	50.00	80.00	240.26	15.50
Q9	Initial Cost	0.00	90.00	38.75	34.50	25.00	50.75	30.00	90.00	397.82	19.94
	Operation Cost	0.00	55.00	28.68	30.00	20.00	34.50	30.00	55.00	115.75	10.76
	Durability	0.00	100.0	32.56	30.00	21.00	42.75	30.00	100.00	316.15	17.78
Q10	Trends	0.00	80.00	45.95	50.00	30.25	60.00	50.00	80.00	328.70	18.13
	Aesthetics	20.00	100.0	54.04	50.00	40.00	69.75	50.00	80.00	328.70	18.13

Background of the Respondents in the 2nd Part

The 2nd part of expert elicitation was distributed online through Qualtrics XM on April 13th, 2021, and the provided results are based on data collected over three months, till Jun 13th. It was distributed to 400 professionals in green building design/contractor firms, as well as researchers and scholars interested in the UHI Effect. The results reported here are based on 28 responses (8.75 percent response rate), with 41% coming from academics, 53% from industry professionals, 0% from government, and 6% from others (see Figure 32).

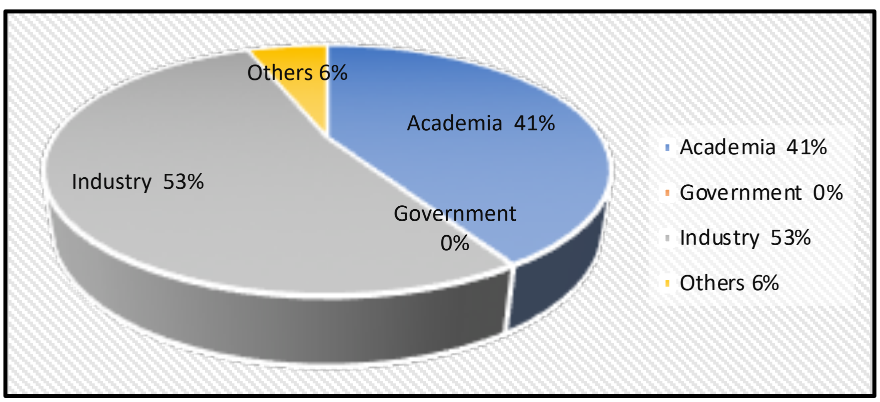

Figure 32: Background of participants in the 2nd part

Data Analysis and Results of the 2nd Part of the Expert Elicitation

A total of 34 people did the expert elicitation part 2 and answered all of the questions (response rate: about 8.75 percent). The findings of descriptive statics analysis on the data collected are shown in the following tables and figures.

Greenery methods provide a nearly high level of sustainability performance, according to the findings. Except for Maintenance Cost (5.00) and Replacement Cost (4.97), the rest of the sustainability parameters indicate that greenery solutions are highly successful. In this regard, the criteria Public Spaces and Amenities (7.97), Heat Intensity (7.93), and Stormwater Management (7.87) demonstrate the greatest contribution of Greenery approaches in decreasing the UHI effect (see Figure 33 & Table 11).

Table 11: Descriptive Statics of Greenery Methods' Scores based of Sustainability Criteria & Attributes

	Criterion	Min.	Max.	Mean	Median (2nd Quartile)	1st Quartile	3rd Quartile	Mode	Range	Sample Variance	Standard Deviation
Q1	Initial Investment	3.00	9.00	6.17	6.00	5.00	7.00	7.00	6.00	2.01	1.42
Q2	Installation Cost	2.00	8.00	5.90	6.00	5.00	7.00	6.00	6.00	1.75	1.32
Q3	Maintenance Cost	1.00	9.00	5.00	5.00	4.00	7.00	5.00	8.00	3.24	1.80
Q4	Energy Cost Saving	0.00	9.00	6.57	7.00	6.00	8.00	8.00	9.00	5.29	2.30
Q5	Replacement Cost	1.00	9.00	4.97	5.00	4.00	6.00	5.00	8.00	3.21	1.79
Q6	Salvage Value	1.00	9.00	6.03	6.00	6.00	8.00	6.00	9.00	5.21	2.28
Q7	Air Quality	4.00	9.00	7.27	8.00	5.75	9.00	9.00	5.00	3.03	1.74
Q8	Stormwater Management	5.00	9.00	7.87	8.00	7.00	9.00	8.00	4.00	0.88	0.94
Q9	Water Quality	4.00	9.00	7.43	7.5	6.00	9.00	9.00	5.00	1.91	1.38
Q10	Heat Intensity	5.00	9.00	7.93	8.00	7.00	9.00	8.00	4.00	0.96	0.98
Q11	Net Embodied Carbon	0.00	9.00	6.00	7.00	6.00	7.00	7.00	9.00	4.69	2.17
Q12	Sustainability of Resources	1.00	9.00	7.23	7.00	6.00	9.00	9.00	8.00	3.15	1.77
Q13	Suitable Condition in a Region	2.00	9.00	7.20	7.00	6.00	9.00	9.00	7.00	3.13	1.77
Q14	Local Cooling Effect	4.00	9.00	7.70	8.00	7.00	9.00	9.00	5.00	1.73	1.32
Q15	Global Cooling Effect	2.00	9.00	5.83	5.00	5.00	7.25	5.00	7.00	4.42	2.10

Q16	Equity & Social Justice	3.00	9.00	7.20	7.50	6.00	8.25	8.00	6.00	2.44	1.56
Q17	Historic & Cultural Resources	2.00	9.00	5.67	5.00	4.75	7.00	5.00	7.00	2.78	1.67
Q18	Views & Local Characters	3.00	9.00	7.43	7.00	7.00	9.00	7.00	6.00	1.98	1.41
Q19	Public Spaces & Amenities	3.00	9.00	7.97	8.00	7.00	9.00	9.00	6.00	1.83	1.35

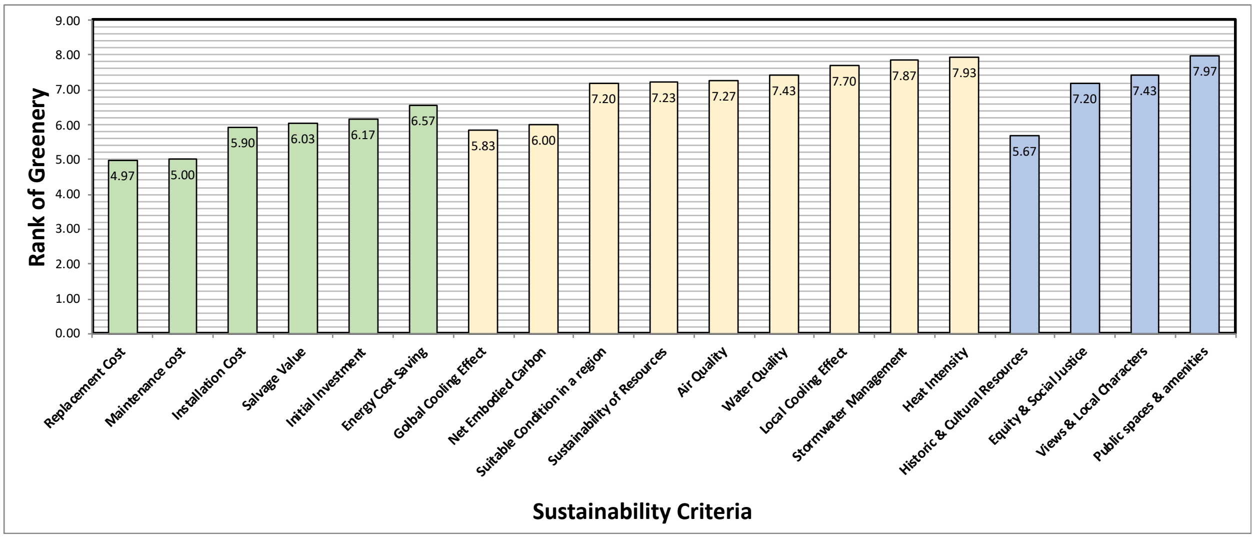

Figure 33: Histogram of Greenery Methods' Scores based of Sustainability Criteria & Attributes

In terms of Environmental Sustainability attributes like Heat Intensity (6.27), Suitable Condition in a Region (6.33), and Global Cooling Effect (6.17), Reflective and Permeable Materials perform better in mitigating anthropogenic heat. Their inefficiency is linked to factors including Equity and Social Justice (4.08), Stormwater Management (4.02), and Water Quality (4.02) (see Figure 34 & Table 12).

Table 12: Descriptive Statics of Reflective & Permeable Materials' Scores based of Sustainability Criteria & Attributes

	Criterion	Min.	Max.	Mean	Median (2nd Quartile)	1st Quartile	3rd Quartile	Mode	Range	Sample Variance	Standard Deviation
Q1	Initial Investment	2.00	8.00	5.40	5.00	4.75	7.00	5.00	6.00	2.87	1.69
Q2	Installation Cost	3.00	8.00	5.70	6.00	4.75	7.00	6.00	5.00	2.29	1.51
Q3	Maintenance Cost	1.00	8.00	4.97	5.00	3.00	6.50	5.00	7.00	4.52	2.13
Q4	Energy Cost Saving	1.00	9.00	5.70	6.00	5.00	7.00	5.00	8.00	4.36	2.09

Q5	Replacement Cost	0.00	8.00	4.77	4.50	3.75	6.00	4.00	8.00	3.84	1.96
Q6	Salvage Value	1.00	9.00	5.30	5.00	4.00	8.00	4.00	8.00	6.24	2.53
Q7	Air Quality	0.00	8.00	4.90	6.50	2.00	7.00	7.00	8.00	7.40	2.72
Q8	Stormwater Management	0.00	9.00	4.00	4.00	1.75	6.00	4.00	9.00	5.45	2.33
Q9	Water Quality	0.00	8.00	4.20	5.00	2.75	6.00	5.00	8.00	5.48	2.34
Q10	Heat Intensity	1.00	9.00	6.27	6.50	5.00	8.00	7.00	8.00	4.20	2.05
Q11	Net Embodied Carbon	0.00	9.00	4.63	4.50	3.75	6.00	4.00	9.00	5.69	2.39
Q12	Sustainability of Resources	0.00	9.00	5.60	7.00	2.00	8.00	8.00	9.00	10.52	3.24
Q13	Suitable Condition in a Region	1.00	9.00	6.23	7.00	4.75	8.00	8.00	8.00	5.56	2.36
Q14	Local Cooling Effect	0.00	9.00	5.70	6.00	4.00	8.00	7.00	9.00	6.29	2.51
Q15	Global Cooling Effect	1.00	9.00	6.17	7.00	5.00	8.00	7.00	8.00	4.42	2.10
Q16	Equity & Social Justice	0.00	8.00	4.00	4.00	3.00	5.00	5.00	8.00	4.07	2.02
Q17	Historic & Cultural Resources	0.00	9.00	4.97	6.00	3.00	7.00	6.00	9.00	6.38	2.53
Q18	Views & Local Characters	1.00	8.00	4.73	5.00	3.00	6.00	5.00	7.00	3.24	1.80
Q19	Public Spaces & Amenities	1.00	9.00	4.73	4.00	3.00	7.00	3.00	8.00	6.57	2.60

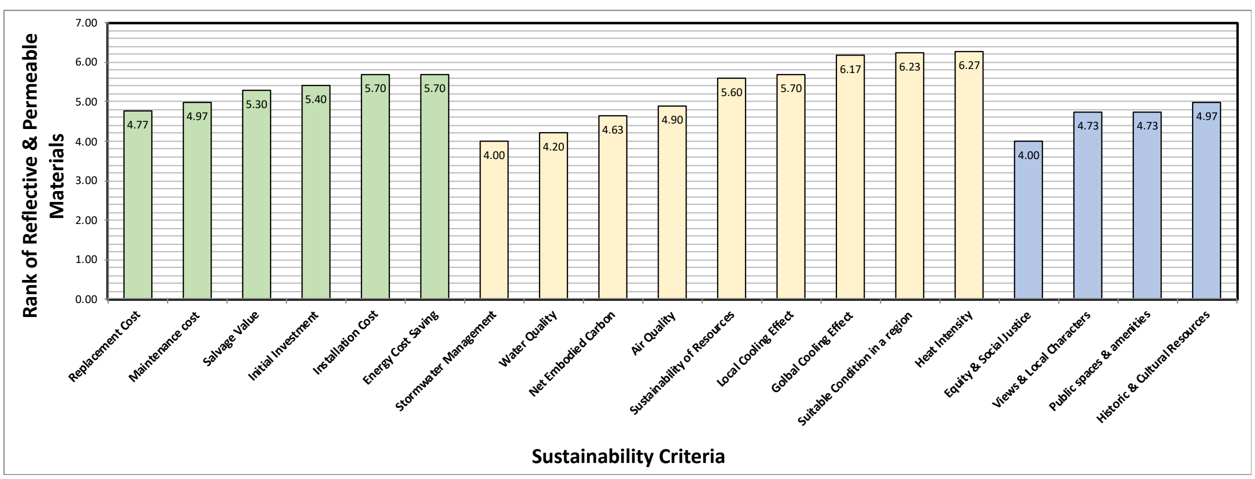

Figure 34: Histogram of Reflective & Permeable Materials' Scores based of Sustainability Criteria & Attributes

High-Tech Panels have a high overall Economic Sustainability score but a lower overall Social Sustainability score. For instance, they are more sustainable in terms of Maintenance Cost (6.67) and Replacement Cost (6.60). Except for Water Quality (2.83), their Environmental Sustainability performance is relatively high (see Figure 35 & Table 13).

Table 13: Descriptive Statics of High-Tech Panels' Scores based of Sustainability Criteria & Attributes

	Criterion	Min.	Max.	Mean	Median (2nd Quartile)	1st Quartile	3rd Quartile	Mode	Range	Sample Variance	Standard Deviation
Q1	Initial Investment	0.00	9.00	5.37	5.00	3.75	8.00	5.00	9.00	6.59	2.57
Q2	Installation Cost	0.00	9.00	5.63	5.00	4.00	8.25	9.00	9.00	6.17	2.48
Q3	Maintenance Cost	3.00	9.00	6.67	7.00	5.00	8.25	9.00	6.00	4.16	2.04
Q4	Energy Cost Saving	2.00	9.00	6.03	6.00	5.00	7.00	7.00	7.00	2.17	1.47
Q5	Replacement Cost	2.00	9.00	6.60	7.00	5.75	8.00	7.00	7.00	2.66	1.63
Q6	Salvage Value	0.00	7.00	4.13	4.50	3.00	6.00	5.00	7.00	3.91	1.98
Q7	Air Quality	0.00	8.00	5.07	6.00	2.00	7.00	6.00	8.00	6.55	2.56
Q8	Stormwater Management	0.00	7.00	3.33	4.00	1.00	5.00	1.00	7.00	5.61	2.37
Q9	Water Quality	0.00	7.00	2.83	3.00	1.00	5.00	3.00	7.00	4.49	2.12
Q10	Heat Intensity	0.00	8.00	5.03	5.00	3.00	7.00	7.00	8.00	6.24	2.50
Q11	Net Embodied Carbon	0.00	9.00	5.10	5.00	3.75	6.25	5.00	9.00	5.96	2.44
Q12	Sustainability of Resources	0.00	8.00	5.07	6.00	1.75	7.00	6.00	8.00	8.20	2.86
Q13	Suitable Condition in a Region	0.00	9.00	5.13	5.00	4.00	7.00	5.00	9.00	5.71	2.39
Q14	Local Cooling Effect	0.00	9.00	4.53	5.00	2.75	6.00	5.00	9.00	5.43	2.33
Q15	Global Cooling Effect	0.00	9.00	5.37	6.00	3.75	7.00	6.00	9.00	5.48	2.34
Q16	Equity & Social Justice	0.00	9.00	4.47	5.00	3.00	6.00	4.00	9.00	5.15	2.27
Q17	Historic & Cultural Resources	0.00	7.00	4.13	4.50	2.00	7.00	7.00	7.00	5.77	2.40
Q18	Views & Local Characters	0.00	8.00	3.87	3.00	3.00	5.25	3.00	8.00	4.53	2.13
Q19	Public Spaces & Amenities	0.00	7.00	3.27	4.00	1.75	4.00	4.00	7.00	3.93	1.98

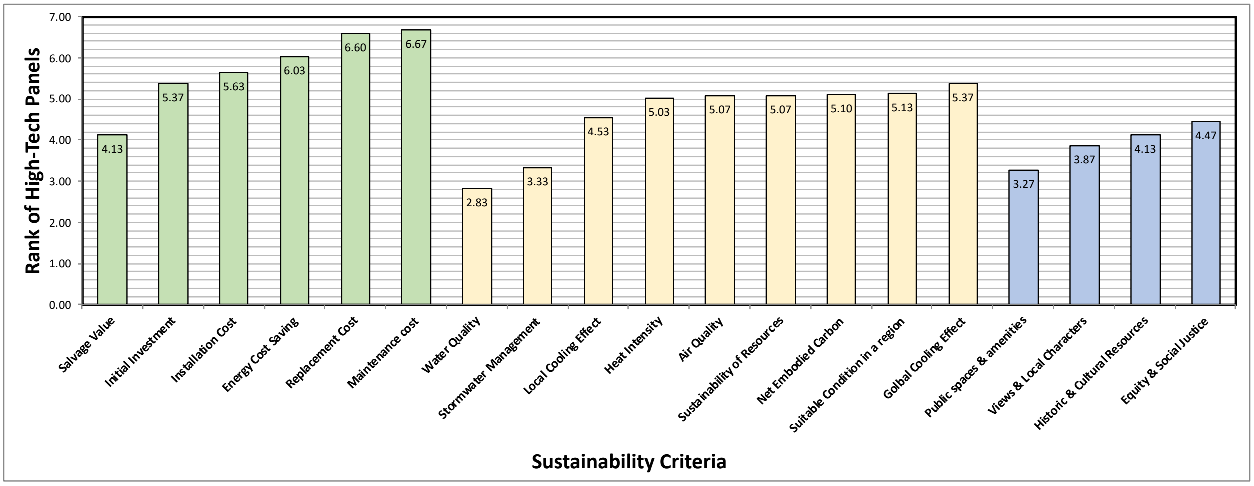

Figure 35: Histogram of High-Tech Panels' Scores based of Sustainability Criteria & Attributes

Water Feature approaches have a pretty high sustainable performance based on expert elicitation exercises, with the exception of some attributes such as Global Cooling Effect (4.57), and Salvage Value (4.53) (see Figure 36 & Table 14).

Table 14: Descriptive Statics of Water Features' Scores based of Sustainability Criteria & Attributes

	Criterion	Min.	Max.	Mean	Median (2nd Quartile)	1st Quartile	3rd Quartile	Mode	Range	Sample Variance	Standard Deviation
Q1	Initial Investment	0.00	9.00	4.77	5.00	3.00	6.25	4.00	9.00	4.46	2.11
Q2	Installation Cost	0.00	9.00	4.53	4.00	2.75	7.00	4.00	9.00	5.71	2.39
Q3	Maintenance Cost	1.00	8.00	4.83	4.00	4.00	6.00	4.00	7.00	2.76	1.66
Q4	Energy Cost Saving	0.00	9.00	5.13	5.00	3.75	7.25	5.00	9.00	6.46	2.54
Q5	Replacement Cost	1.00	8.00	5.10	5.00	3.00	6.25	5.00	7.00	3.20	1.79
Q6	Salvage Value	0.00	8.00	4.53	5.00	4.00	6.00	5.00	8.00	3.43	1.85
Q7	Air Quality	0.00	9.00	5.07	5.00	4.00	7.00	4.00	9.00	6.27	2.50
Q8	Stormwater Management	0.00	9.00	6.17	7.00	4.75	8.00	7.00	9.00	5.52	2.35
Q9	Water Quality	1.00	9.00	6.33	7.00	5.00	7.25	7.00	8.00	3.75	1.94
Q10	Heat Intensity	1.00	9.00	6.77	7.00	6.00	8.25	7.00	8.00	5.15	2.27
Q11	Net Embodied Carbon	0.00	8.00	5.50	6.50	4.00	7.25	7.00	8.00	5.98	2.45
Q12	Sustainability of Resources	0.00	9.00	5.73	6.00	4.00	7.25	7.00	9.00	5.58	2.36
Q13	Suitable Condition in a Region	1.00	9.00	6.37	7.00	5.50	8.00	7.00	8.00	5.48	2.34
Q14	Local Cooling Effect	1.00	9.00	6.63	7.00	6.00	8.00	6.00	8.00	3.48	1.87
Q15	Global Cooling Effect	1.00	9.00	4.57	4.00	3.75	6.00	4.00	8.00	4.53	2.13

Q16	Equity & Social Justice	1.00	9.00	6.30	6.50	4.75	8.00	8.00	8.00	5.39	2.32
Q17	Historic & Cultural Resources	2.00	7.00	5.03	5.00	4.00	6.00	5.00	5.00	1.90	1.38
Q18	Views & Local Characters	2.00	9.00	6.13	6.50	4.75	8.00	8.00	7.00	3.77	1.94
Q19	Public Spaces & Amenities	2.00	9.00	6.57	7.00	5.75	7.25	7.00	7.00	2.94	1.72

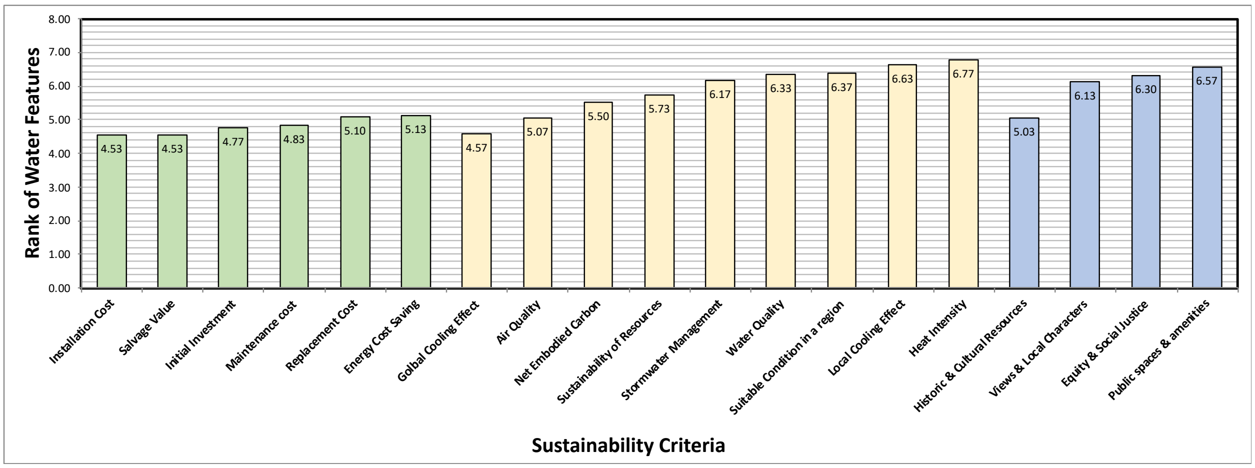

Figure 36: Histogram of Water Features' Scores based of Sustainability Criteria & Attributes

Background of the Respondents in the 3rd Part

The 3rd part of expert elicitation was distributed online through Qualtrics XM on April 13th, 2021, and the provided results are based on data collected over three months, till Jun 13th. It was distributed to 400 professionals in green building design/contractor firms, as well as researchers and scholars interested in the UHI Effect. The results reported here are based on 30 responses (7.50 percent response rate), with 40% coming from academics, 50% from industry professionals, 0% from government, and 0% from others (see Figure 37).

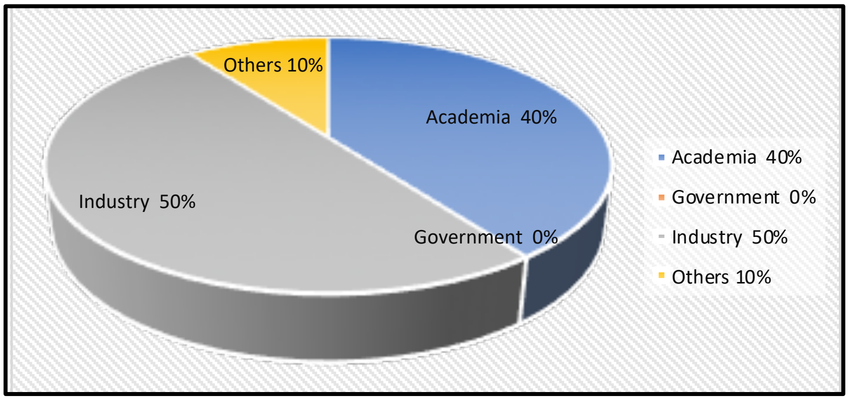

Figure 37: Background of participants in the 3rd part

Data Analysis and Results of the 3rd Part of the Expert Elicitation

A total of 30 people did the expert elicitation part 3 and answered all of the questions (response rate: about 7.5 percent). The findings of descriptive statics analysis on the data collected are shown in the following tables and figures.

Greenery approaches have the highest performance score in terms of Aesthetics, Visual Comfort, and Trends, with scores of 8.30, 7.70, and 7.67, respectively, based on statistical analysis of the collected data. Disease Risk and Durability have the lowest performance of the Greenery approaches, according to experts, with 5.07 and 5.37, respectively (see Figure 38 & Table 15).

Table 15: Descriptive Statics of Greenery Methods' Scores based of Resilience Criteria & Attributes

	Criterion	Min.	Max.	Mean	Median (2nd Quartile)	1st Quartile	3rd Quartile	Mode	Range	Sample Variance	Standard Deviation
Q1	GHG Emission	1.00	9.00	6.80	7.00	5.75	8.25	7.00	8.00	2.17	4.72
Q2	Energy Demand	1.00	9.00	5.70	6.00	5.00	7.00	7.00	8.00	1.93	3.73
Q3	Building Adaptation	1.00	9.00	6.07	6.00	5.75	7.00	6.00	8.00	1.80	3.24
Q4	Thermal Comfort	1.00	9.00	7.03	7.00	6.00	8.00	7.00	8.00	1.59	2.52
Q5	Visual Comfort	2.00	9.00	7.70	8.00	7.00	9.00	9.00	7.00	1.49	2.22
Q6	Bad Condition of Housing	0.00	9.00	5.53	6.00	4.50	7.00	6.00	9.00	2.49	6.19
Q7	Heatwave Risk	1.00	9.00	7.10	8.00	6.50	9.00	9.00	8.00	2.55	6.51
Q8	Disease Risk	2.00	9.00	5.07	5.00	4.00	6.00	5.00	7.00	1.46	2.13
Q9	Climate Change	4.00	9.00	7.17	8.00	6.00	8.00	8.00	5.00	1.56	2.42

Q10	Ecological Change	3.00	9.00	7.27	8.00	6.00	9.00	9.00	6.00	1.78	3.17
Q11	Initial Cost	2.00	9.00	6.67	7.50	5.75	8.00	8.00	7.00	2.04	4.16
Q12	Cost of Operation	1.00	9.00	6.73	8.00	5.50	8.25	8.00	8.00	2.33	5.44
Q13	Durability	4.00	8.00	5.37	5.00	4.75	5.50	5.00	4.00	1.33	1.76
Q14	Trends	2.00	9.00	7.67	8.00	7.00	9.00	9.00	7.00	1.71	2.92
Q15	Aesthetics	7.00	9.00	8.30	9.00	7.75	9.00	9.00	2.00	0.84	0.70

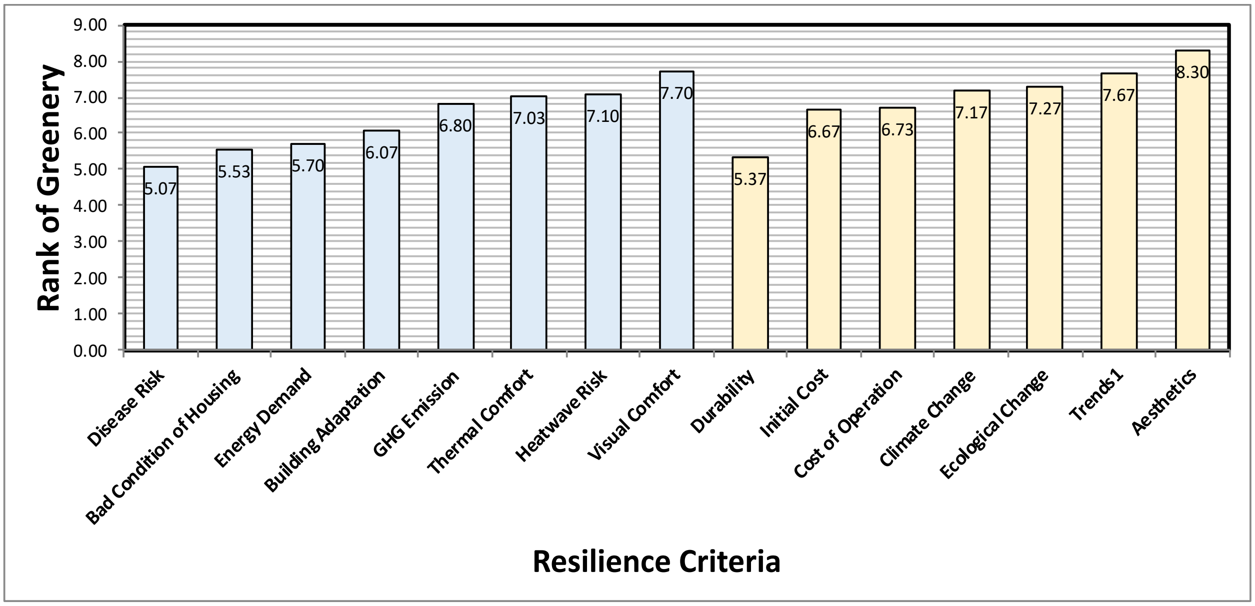

Figure 38: Histogram of Greenery Methods' Scores based of Resilience Criteria & Attributes

The findings show that Reflective and Permeable Materials outperform others in terms of Building Adaptation (7.00) and Durability (6.30). These mitigation strategies, on the other hand, are ineffective in terms of Ecological Change (2.73), Initial Cost (3.07), Cost of Operation (5.13), and Visual Comfort (3.47) (see Figure 39 & Table 16).

Table 16: Descriptive Statics of Reflective & Permeable Materials' Scores based of Resilience Criteria & Attributes

	Criterion	Min.	Max.	Mean	Median (2nd Quartile)	1st Quartile	3rd Quartile	Mode	Range	Sample Variance	Standard Deviation
Q1	GHG Emission	1.00	9.00	3.80	3.00	2.00	5.00	2.00	8.00	1.94	3.57
Q2	Energy Demand	1.00	8.00	5.10	5.50	4.00	6.00	6.00	7.00	1.84	3.40
Q3	Building Adaptation	3.00	9.00	7.00	7.50	5.75	8.25	8.00	6.00	1.89	3.59
Q4	Thermal Comfort	3.00	8.00	5.30	5.00	4.00	7.00	5.00	5.00	1.51	2.29
Q5	Visual Comfort	1.00	9.00	3.47	3.00	2.00	4.25	2.00	8.00	1.91	3.64
Q6	Bad Condition of Housing	0.00	9.00	5.80	5.00	4.00	8.00	8.00	9.00	2.62	6.86

Q7	Heatwave Risk	2.00	9.00	4.87	5.00	4.00	5.25	5.00	7.00	1.78	3.15
Q8	Disease Risk	0.00	9.00	5.60	6.00	4.00	8.00	8.00	9.00	2.42	5.83
Q9	Climate Change	2.00	9.00	4.13	4.00	3.00	4.25	4.00	7.00	1.55	2.40
Q10	Ecological Change	3.00	8.00	2.73	2.00	1.00	4.00	2.00	8.00	2.16	4.69
Q11	Initial Cost	1.00	9.00	3.07	2.00	1.00	5.00	1.00	8.00	2.43	5.93
Q12	Cost of Operation	0.00	8.00	3.13	2.00	2.00	5.25	2.00	8.00	2.16	4.67
Q13	Durability	2.00	9.00	6.30	7.00	4.75	8.00	8.00	7.00	2.44	5.94
Q14	Trends	1.00	9.00	5.03	5.00	5.00	6.00	6.00	8.00	1.79	3.21
Q15	Aesthetics	1.00	8.00	3.67	3.00	3.00	4.25	3.00	7.00	1.65	2.71

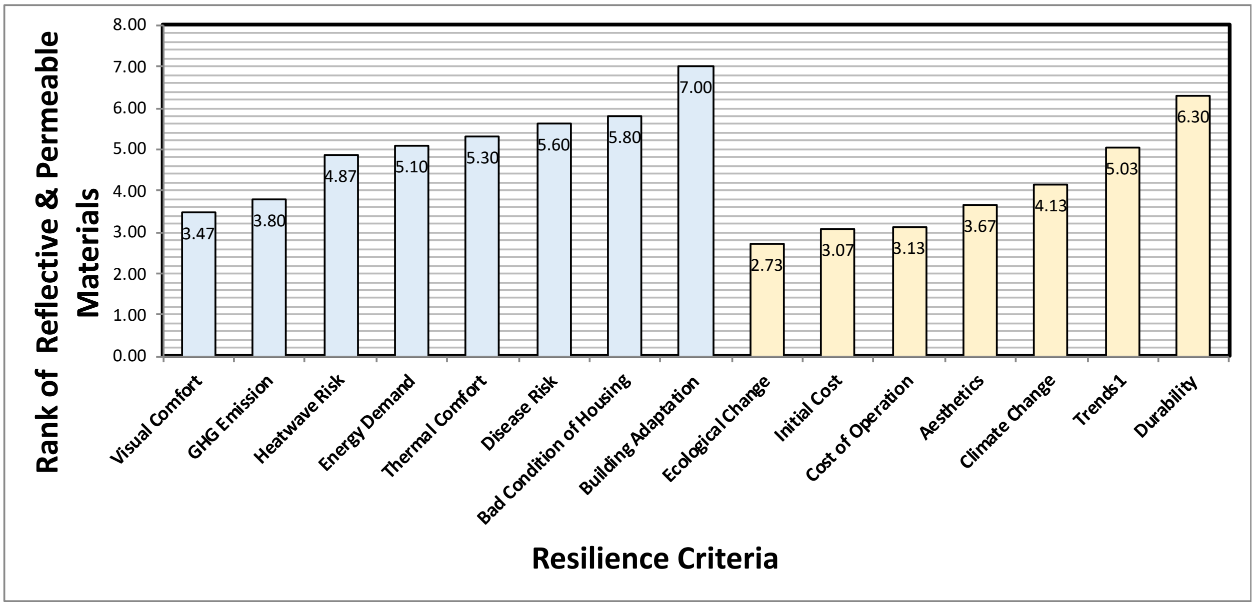

Figure 39: Histogram of Reflective & Permeable Materials' Scores based of Resilience Criteria & Attributes

According to expert elicitation exercises, High-Tech Panels' resilience is low in terms of Heatwave Risk (2.67), and Ecological Change (2.67). They score higher in the following categories: Building Adaptation (7.13), Durability (6.67), GHG Emission (6.53), and Climate Change (6.50) (Figure 40 & Table 17).

Table 17: Descriptive Statics of High-Tech Panels' Scores based of Resilience Criteria & Attributes

	Criterion	Min.	Max.	Mean	Median (2nd Quartile)	1st Quartile	3rd Quartile	Mode	Range	Sample Variance	Standard Deviation
Q1	GHG Emission	2.00	9.00	6.53	7.00	5.00	8.00	8.00	7.00	1.98	3.91
Q2	Energy Demand	0.00	9.00	4.80	4.00	4.00	6.25	4.00	9.00	2.01	4.03
Q3	Building Adaptation	3.00	9.00	7.13	8.00	5.75	8.25	8.00	6.00	1.87	3.50

Q4	Thermal Comfort	0.00	7.00	4.33	5.00	3.75	5.00	5.00	7.00	1.58	2.51
Q5	Visual Comfort	1.00	9.00	3.40	3.00	2.00	4.00	3.00	8.00	2.08	4.32
Q6	Bad Condition of Housing	0.00	8.00	3.60	4.00	3.00	4.00	4.00	8.00	1.50	2.25
Q7	Heatwave Risk	0.00	7.00	2.67	2.00	1.00	4.00	1.00	7.00	2.02	4.09
Q8	Disease Risk	0.00	8.00	5.10	6.00	4.00	7.00	7.00	8.00	2.19	4.78
Q9	Climate Change	2.00	9.00	6.50	7.00	5.00	8.00	8.00	7.00	2.11	4.47
Q10	Ecological Change	0.00	8.00	2.67	2.00	1.00	3.50	1.00	8.00	2.14	4.57
Q11	Initial Cost	1.00	9.00	3.23	2.00	1.00	5.25	1.00	8.00	2.66	7.08
Q12	Cost of Operation	0.00	9.00	3.43	3.00	1.00	6.00	1.00	9.00	2.73	7.43
Q13	Durability	3.00	9.00	6.67	7.00	5.00	9.00	9.00	6.00	2.09	4.37
Q14	Trends	1.00	9.00	3.93	3.00	3.00	5.00	3.00	8.00	2.10	4.41
Q15	Aesthetics	1.00	9.00	4.10	3.00	3.00	4.25	3.00	8.00	2.26	5.13

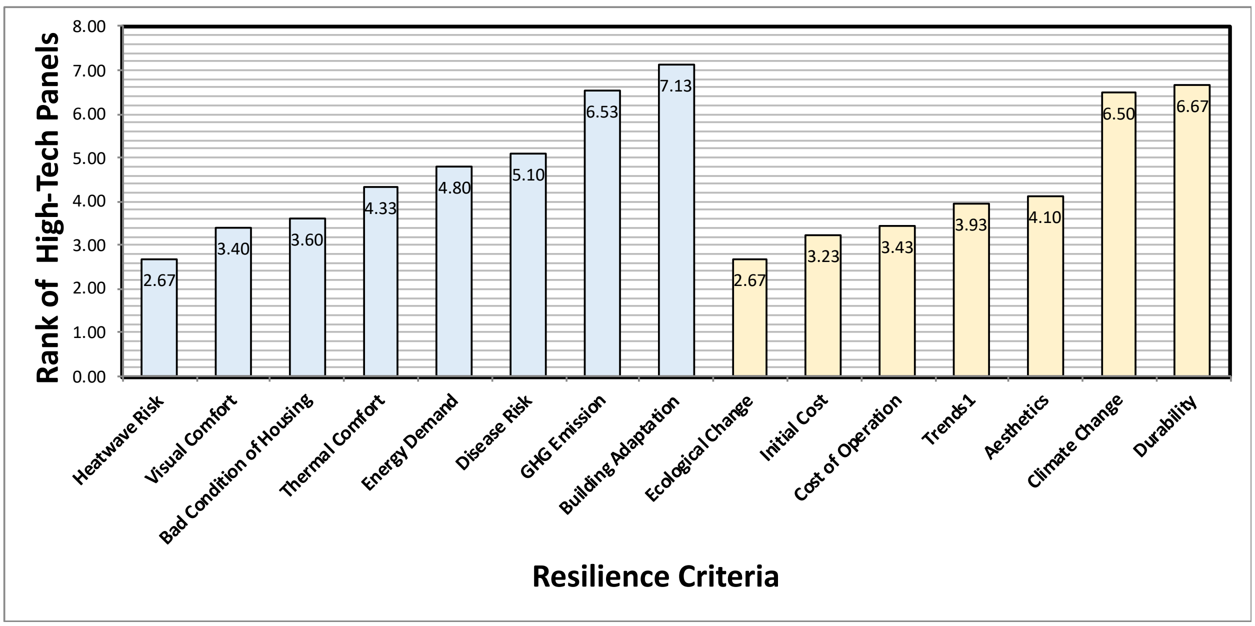

Figure 40: Histogram of High-Tech Panels' Scores based of Resilience Criteria & Attributes

Water features approaches, according to experts, have higher resilience performance with attributes like Building Adaptation (7.13), Durability (6.67), GHG Emission (6.53), and Climate Change (6.50). Ecological Change (2.67), Initial Cost (5.23), and Cost of Operation are all factors that contribute to their poor performance (3.43) (Figure 41 & Table 18).

Table 18: Descriptive Statics of Water Features' Scores based of Resilience Criteria & Attributes

	Criterion	Min.	Max.	Mean	Median (2nd Quartile)	1st Quartile	3rd Quartile	Mode	Range	Sample Variance	Standard Deviation
Q1	GHG Emission	1.00	8.00	2.90	1.00	1.00	5.25	1.00	7.00	2.5	6.23

Q2	Energy Demand	0.00	9.00	3.83	3.50	2.00	5.00	2.00	9.00	2.13	4.56
Q3	Building Adaptation	1.00	8.00	2.77	2.00	1.00	5.00	1.00	7.00	2.22	4.94
Q4	Thermal Comfort	1.00	9.00	6.77	7.00	5.00	8.00	8.00	8.00	2.06	4.25
Q5	Visual Comfort	1.00	9.00	7.20	7.50	7.00	8.25	7.00	8.00	1.79	3.20
Q6	Bad Condition of Housing	0.00	9.00	5.40	7.00	4.00	7.00	7.00	9.00	2.47	6.11
Q7	Heatwave Risk	1.00	9.00	5.47	6.00	5.00	7.00	6.00	8.00	2.03	4.12
Q8	Disease Risk	1.00	9.00	4.87	5.00	4.00	6.00	6.00	8.00	1.80	3.22
Q9	Climate Change	1.00	9.00	2.90	2.50	1.75	4.00	2.00	8.00	1.81	3.27
Q10	Ecological Change	1.00	8.00	3.77	3.00	2.75	5.00	3.00	7.00	1.91	3.63
Q11	Initial Cost	1.00	9.00	6.30	7.00	4.00	8.00	7.00	8.00	2.42	5.87
Q12	Cost of Operation	1.00	9.00	6.43	7.00	5.00	8.25	9.00	8.00	2.21	4.87
Q13	Durability	1.00	6.00	2.93	2.00	2.00	4.25	2.00	5.00	1.44	2.06
Q14	Trends	2.00	9.00	6.20	6.50	5.00	7.00	7.00	7.00	1.49	2.23
Q15	Aesthetics	4.00	9.00	7.93	8.00	7.75	9.00	8.00	5.00	1.17	1.37

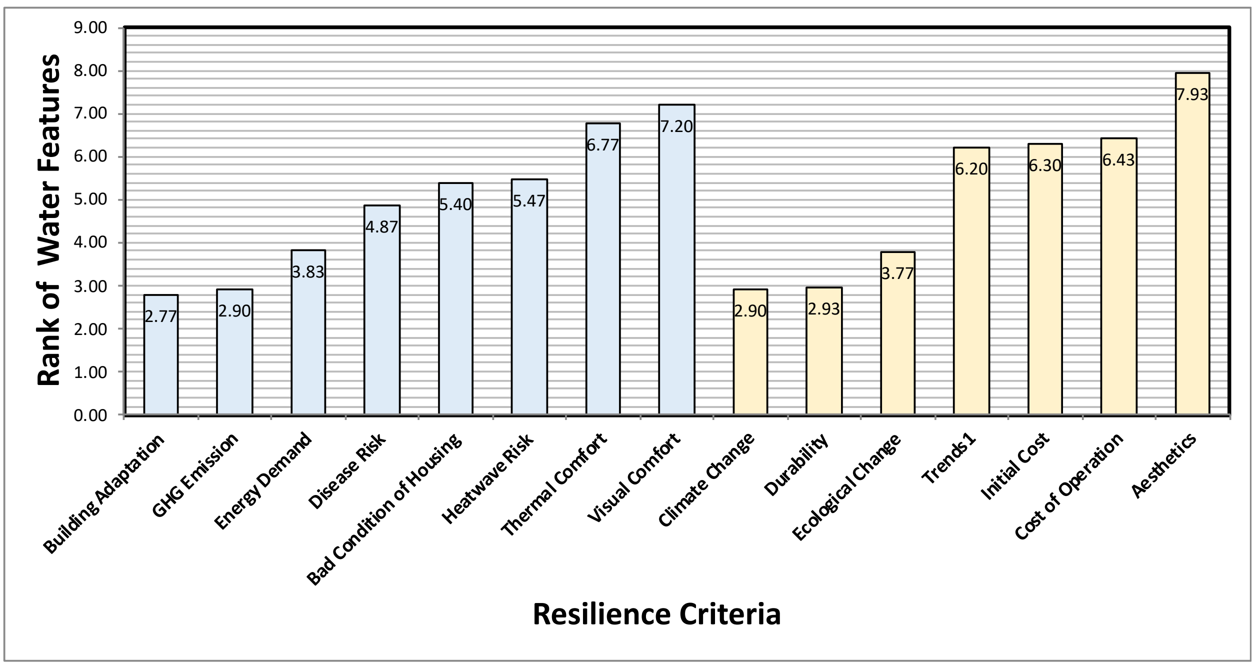

Figure 41: Histogram of Water Features' Scores based of Resilience Criteria & Attributes

Summary and Conclusion

This chapter explains how to create expert elicitation exercises and how to choose participants. In addition, tables and graphs depict the statistical analysis of the data gathered from the three expert elicitations. The results of the statistical analysis will be discussed in the next chapter.

CHAPTER V

DISCUSSION

Introduction

The UHI effect has been a dominating characteristic of urban climates as urbanization has progressed, and it has had a considerable impact on inhabitants' quality of life (Imran et al., 2018; Meerow et al., 2016; J. Qi et al., 2020; Santamouris et al., 2018). As a result, urban planning and management has been focusing on measures to reduce the impact of UHIs and promote sustainable and resilient urban growth. As previously stated, this research 1) identified, classified, and organized the various parameters that play a significant role in qualifying the selected strategies as suitable candidates to mitigate the effects of the heat island in a comprehensive framework with respect to sustainability and resilience; and 2) determined the relative weights of these parameters using data from expert elicitation exercises. In terms of increasing the quality of the natural environment and attaining sustainable development, the findings are critical for urban planning and land-use management. As a result, this chapter tries to connect the findings of the three-part expert elicitation activities to other research in the field.

Discussion of the Results of Objectives

Because of the rising intensity and frequency of natural disasters, resilience thinking has emerged, requiring buildings to be not just sustainable but also resilient (Phillips et al., 2017; L. Xu et al., 2015). As a result, the concepts of sustainability and resilience have become inextricably linked, with the latter considered as necessary if the former is to adhere to a more sustainable future. Cities' resilience has been recognized as a major priority for the city of the future, and defined as a response to environmental disturbance, how ecosystems can reorganize rapidly after a disturbance, or as vulnerability of a system to alteration (Pearson et al., 2014; Zoomers et al., 2017). Similarly, the findings of this study show that the sustainability and resilience objectives are almost equal in value when evaluating UHIMSs.

Discussion of the Results of Criteria

Discussion of Sustainability Criteria

Sustainability has three purposes, according to the literature: environmental, economic, and social (Sustainable Infrastructure Framework Guidance Manual, 2018). The present green building knowledge system and researches mostly focus on environmental elements; however, other components of sustainability, such as social sustainability, are often ignored (Zuo & Zhao, 2014). The descriptive statistics findings suggest that the environmental aspect of sustainability still has a larger weight than the others in this study, although there is no significant difference in their importance levels.

Since the literature about sustainability is widespread, this research aims to focuses mainly on the literature related to the impact of green building on the different aspects of sustainability which they are Social, Environmental and Economic sustainability. The four greenest building rating systems and most well-known assessment tools in the world are LEED, CASBEE, BREEAM, and the GB Tool. They give complete criteria for their areas, evaluate the entire building rather than a single design feature, employ quantifiable methods to show how much the building incorporates sustainability principles.

These four green rating systems have certain similar issues, such as prioritizing energy usage in the buildings, water efficiency, interior and outdoor environmental quality, resources and materials, service quality, and site strategy. BREEAM, on the one hand, views transportation and pollution as independent elements in the evaluation categories and awards them high credits; on the other hand, LEED did not give them this priority and included them among the major aspects of its evaluation. Despite the fact that all mentioned rating systems value energy efficiency so highly that it accounts for even more than 20percent of each system's total certification, each system rates assessment criteria differently depending on its country's local circumstances. These rating tools employ a point system (numerical value) to determine how green a building is, but each system has its own measurement method. Sustainable sites (14), water efficiency (05), energy and atmosphere (17), materials and resources (13), indoor environmental quality (15), and LEED innovation credits (05) are the primary categories on LEED. The following categories make up the CASBEE rating system: energy efficiency, resource efficiency, local environment, and indoor environment. Energy (21.42), transportation (8.56), pollution (14.99), materials (14.98), water (10), health and well-being (15.04), and land use and ecology (15.01) are the BREEAM categories. Finally, GB Tool has the following weighted categories: site selection, project planning and development (7.8), energy and resource consumption (25.9), environmental loadings (21.6), indoor environmental quality (15.5), service quality (5.2), cultural and perceptual aspects (21.6), social and economic aspects (21.6), and cultural and perceptual aspects (2.6). In general, these rating systems have the weights of criteria in descending order from energy and, environmental quality, site/land use/ ecology, resources/materials, water, and social/economic issues.

Discussion of Resilience Criteria

Based on the literatures, cities' resilience, and the need for future cities to be resilient, has been recognized as a major priority. It has been defined as a reaction to environmental, economic, and social disturbances, how ecosystems can restructure after a disruption, or as a system's vulnerability to alteration (Folke, 2016; Holling, 1973b; D. Zhao et al., 2015). This study looks at resilience in terms of two primary sub-categories: "vulnerability" and "Resistance to Change". The importance of the research contribution is nearly equal for both of them, with Resistance to Change having a higher weight.

Discussion of the Results of Attributes

Discussion of Economic Sustainability Attributes

In terms of economic sustainability, the categories of Energy Cost Savings and Initial Investment criteria with the highest weights, Salvage Value and Replacement Cost criteria with medium weights, and Maintenance Cost and Installation Cost with the lowest weights are listed in the proposed framework of economic sustainability criteria. Because the mentioned rating systems are primarily focused on environmental factors, their conclusions are not comparable to findings of this research. Despite the fact that energy efficiency and resource use are the most important factors in them, none of them mention energy in terms of cost savings. Economic factors are not a major factor in these rating systems.

Discussion of Environmental Sustainability Attributes

According to the proposed environmental sustainability criteria of this study, the main findings of this research reveal that the Air/Water Quality and Suitability of Climate of Region criteria have the highest weights when it comes to assessment of UHIMSs. Similarly, Heat Intensity, Resource Sustainability, and Local Cooling Effect have the medium weights. And

Global Cooling Effect, Net Embodied Carbon, and Stormwater Management criteria have the lowest level of importance. These conclusions are similar to those of the previously described rating system.

Discussion of Social Sustainability Attributes

Social sustainability factors are not covered in the rating systems, with the exception of the GB Tool, which includes cultural and perceptual factors among others. As a result, this research focus on the ISI Envision grading system's social sustainability criteria. The criterion of "Public Spaces & Amenities" and "Equity & Social Justice" account for 56.36 percent of the total, while "Historic & Cultural Resources" and "Views & Local Characters" account for 43.64 percent.

Discussion of Vulnerability Attributes

Vulnerability and Resistance to Change are implied in the definitions of Resilience. Short- and long-term risks, large fixed costs, and a strong dependency on resources are all decreased by using a resilience strategy. Life-cycle concerns, comfort, health, energy consumption, and durability to extend the useful life of constructed works are all considered in this strategy (Sustainable Infrastructure Framework Guidance Manual, 2018). According to IPCC report, in the context of global warming and UHI, the ongoing expansion of vulnerability is particularly important. It addresses vulnerability in three components of exposure, sensitivity and adaptive capacity. Exposure describes the amount to which users or systems are located in areas threatened by climate changes and their consequences. Sensitivity is the degree to which users or systems react to climate changes and their effects. Adaptive capacity refers to the ability to deal with the negative consequences of climate change by seizing opportunities as they come and mitigating the consequences through proactive and preventative measures (IPCC, 2007).

This research addresses vulnerability in three categories of Energy, Comfort, and Health. They are all representing the consequences of climate change and global warming. Among them the Health category obtained a higher weight based on experts' opinion. Similarly, the literatures reveal that heat waves have a detrimental health impact on cities, which is only projected to worsen as global warming continues (Klein Rosenthal et al., 2014; Knowlton et al., 2007). This is in line with several previous researches that associate physical exposure to heat stress with social vulnerability (Harlan et al., 2006).

Discussion of Resistance to Change Attributes

By referring to resilience as resistance to change, a dominant area of focus in the literature is referred to disturbances due to climate change (Leichenko, 2011) or hazards and disasters (Burby et al., 2000; Godschalk, 2003; Pelling, 2003). Surprisingly few definitions of urban resilience precisely address resistance to change. As per literature reviews show urban systems as complex physical and social networks with equal priorities (Godschalk, 2003), the findings of expert elicitation exercises address three aspect of environmental, economic, and social resistance to change in almost equal level of importance.

Discussion of UHIMSs

Discussion of Greenery Methods

Based on the results of the expert elicitation exercises, greenery methods represent their level of performance in assessment with economic sustainability attributes of Energy Cost Saving with the highest score; Initial Investment, Installation Cost, and Salvage Value with the medium scores. It can be discussed by this example that some vegetation such "regional flora", may not be affected by the changes in the economy over time. The price of local flora usually stays within a reasonable margin of the price. The Maintenance and Replacement Cost attributes have the lowest scores. This is well explained by this example that in cramped, congested urban environments, maintaining trees is costly and time consuming due to limited access for maintenance teams and machinery (Hoverter, 2012).

In general greenery methods demonstrate their high level of performance in assessment with environmental sustainability attributes. Among these attributes Heat Intensity, Stormwater Management, and Local Cooling Effect have the highest scores which is compatible with other studies (Ebrahimian et al., 2019; He & Zhu, 2018). Global Cooling Effect attribute has the lowest level of performance. Greeneries may provide less global cooling effect than cool materials. They absorb water from their soil and emit it back into the air, where ambient heat converts the water into vapor, a process known as evapotranspiration. While it cools both individual buildings and surrounding areas, the heat can be trapped near the earth by greenhouse gases (Hoverter, 2012).

Similarly, in social sustainability attributes, greenery methods have an effective level of performance except Historic and Cultural Resources. Although greenery methods such as green roofs and vertical gardens (green walls) provide a natural appealing view, however, their roots and dampness have the potential to harm cultural and historical sites.

With regard to resilience-vulnerability, these mitigation methods show a noticeable performance scores in attributes such as Visual Comfort, Heatwave Risk, Thermal Comfort, GHG Emission. Some scholars believe that green roofs reduce vulnerability by lessening pollution, and capturing greenhouse gases and particulate matter (Alexandri & Jones, 2008; Herrera-Gomez et al., 2017). Their lowest performance score shows itself in Disease Risk attribute which can be discussed by their potential in exacerbating allergies and respiratory disease (Hoverter, 2012). These type of UHI effect mitigation methods have a medium level of performance in attributes such as Bad Condition of Housing, Building Adaptation, and Energy Demand.

Greenery methods' performance with regard to resistance to change aspect of resilience attributes has its highest score in Aesthetics and Trends. Since the UHIMSs involve dealing with people, it is unavoidable not to consider the taste of people/society in them. If two or more methods are similar or close in the scoring system, it is preferable to choose one which is leaning more toward the fashion trends of the area of application. For instance, greenery techniques are more appreciated. Their lowest performance is allocated to Durability attribute because they cannot last very long due to damaged caused by the weathering effect.

Discussion of Reflective and Permeable Materials

Based on the results of the expert elicitation exercises, Reflective and Permeable methods represent an average level of performance scores with respect to economic sustainability attributes. Their lowest level of performance is associated with attributes such as Maintenance and Replacement Cost. Unlike the effectiveness of them to mitigate the UHI effect, an urban area with a cold climate must take care that water does not freeze within porous pavements which causes cracking.

Generally Reflective and Permeable methods demonstrate their high level of environmental sustainability performance in attributes such as Heat Intensity, Suitable Condition in a Region, and Global Cooling Effect. It can be discussed by this fact that they reflect the sun's energy into the upper atmosphere, thus cooling not only the surrounding area but the planet as a whole through the albedo effect (global cooling).

Surprisingly results of expert elicitations reveal a medium score of effectiveness to these mitigation strategies with respect to Stormwater Management and Water Quality. It can be discussed by this fact that although the main objective of permeable materials is managing runoffs and increasing the quality of water, however reflective materials don't show any efficiency in terms of stormwater management and water quality.

As per social sustainability attributes, Reflective and Permeable methods have an average level of performance which is compatible with the belief of some scholars about social sustainability in construction (Abdel-Raheem & Ramsbottom, 2016).

With respect to resilience-vulnerability, these mitigation methods show a medium performance scores in attributes such as Disease and Heatwave Risk, Bad Condition of Housing, Thermal Comfort, and Energy demand. It is mainly because reflective panels can reflect the sun light and causing some thermal and health issues for other users in the surrounding area. Moreover, in the process of their manufacturing, they demand high level of energy. These mitigation strategies shows their high performance score in Building Adaptation attribute which is compatible with the reviewed literatures (Santamouris, 2014). Their lowest efficiency is associated with attributes of GHG Emission and Visual Comfort. It can be discussed by this fact that reflective materials can cause unwanted glare which violates the visual comfort for the users. Similarly, while permeable materials are known as a very effective technique for reducing run-offs and stormwater, their production are associated with high emissions of GHGs. The production process of them involves asphalt/concrete, also a high consumption of energy and high emission of GHGs in the area.

Reflective and Permeable methods' performance with regard to resistance to change aspect of resilience attribute has its highest score in Durability which is in the same vein with the literatures (Xie et al., 2019). The rest of attributes represent a low level of efficiency because they highly rely on resources in process of manufacturing. In addition, they are not resilience when it comes to changes in the initial and operation costs.

Discussion of High-Tech Panels

The results of collected data demonstrate that High-Tech Panels represent a high level of performance scores with respect to economic sustainability attributes such as Maintenance Cost, Energy Cost Saving and Replacement Cost. Their lowest level of performance is associated with Salvage Value attribute. It is discussed due to the fact that the salvage value of these panels might decrease due to the fact that they might lose performance levels and power warranties over years.

Generally High-Tech Panels demonstrate a medium level of environmental sustainability performance in attributes such as Global Cooling Effect, Suitable Condition in a Region, Sustainability of Resources, Net Embodied Carbon, Heat Intensity, and Air Quality. Their lowest efficiency is associated with Water Quality and Stormwater Management.

The results of expert elicitations reveal a low score of effectiveness to these mitigation strategies with respect to social sustainability criteria and attributes such as Public Spaces and Amenities with the lowest efficiency.

With respect to resilience-vulnerability, these strategies show a significant performance scores in attributes such as Building Adaptation and GHG Emission attributes. Their medium level of performance shows itself in Energy Demand, Thermal Comfort, and Disease Risk. As it is expected the have very low effectiveness in Visual Comfort, Bad Condition for Housing, and Heatwave Risk. It is discussed that installing the photovoltaic panels might exert a significant load on the structural of building (Brito, 2020). On the other hand, retroreflective materials can cause glare which causes discomfort to other species. In addition, the development of these methods in the urban area with the risk of heatwave risk could pose a threat to users' bodies and health (Tian et al., 2007).

High-Tech Panels performance with regard to resistance to change aspect of resilience attribute has its highest score in Climate Change and Durability. They represent low performance score in the rest of attributes associated with resistance to change such as Initial/Operation Cost, Ecological Change, Trends, and Aesthetics. The built environment should foster a connection to people's senses and not reflect alienation from them. The mitigation methods used in residential and urban areas might be different from industrial areas as the integrity of beauty in design is an important factor to consider while choosing one method over another. For instance, photovoltaic panels might be very suitable in industrial areas, but not be aesthetically appealing in residential areas.

Discussion of Water Features

The results of obtained data demonstrate that Water Features methods reveal a medium level of performance scores with respect to economic sustainability attributes. This result can be discussed by this fact that all of these techniques rely on power and energy to function.

Generally, Water Features methods demonstrate an average high level of environmental sustainability performance in attributes such as Heat Intensity, Local Cooling Effect, Suitable Condition in a Region, Water Quality, and Stormwater Management. It is compatible with other work of studies mentioning the efficiency of water features in reducing UHI effect in urban area (Nishimura et al., 1998; J. Xu et al., 2010). Their medium performance scores are demonstrated in Global Cooling Effect that shows their effectiveness in locally cooling the environment.

Similar to previous strategies, Water Features mitigation methods show a high-performance score in social sustainability attributes except when they are adjacent to Historical and Cultural Resources. The installation of them nearby the historic monuments can pose a threat to the structure of buildings due to an increase in the level of humidity.

Regarding to resilience-vulnerability, these mitigation methods represent a high-performance score in attributes such as GHG Emission and Building Adaptation. They show the medium and low efficiency in the rest of attributes such as Energy Demand and Bad Condition of Housing. It is discussed due to increase the demand for electricity usage to operate the pump.

Water Features' performance with regard to resistance to change aspect of resilience has its highest score in Climate Change and Durability. They have an average efficiency in terms of Aesthetics and Trends. Finally, these methods have their lowest level of performance in Ecological Change, Initial and Operation Costs. Use of fountains and sprinklers might not be economically efficient over time because of reliance on electricity and changes in the prices of electricity.

Summary and Conclusion

As urbanization has evolved, the UHI effect has become a dominant feature of metropolitan climates, having a significant impact on residents' quality of life. As a result, strategies to mitigate the impact of UHIs and promote sustainable and resilient urban expansion have been prioritized in urban planning and management. The findings of researches in this area are critical for urban planning and land-use management in terms of improving the quality of the natural environment and achieving sustainable development. As a result, the findings of the three-part expert elicitation exercises are linked to additional field studies in this chapter.

CHAPTER VI

SUMMARY AND CONCLUSION

Introduction

This chapter presents a summary of the work accomplished throughout this research along with the final conclusion and recommendations. The aim is to provide a quick review of the thesis and highlight some of the outputs to help future studies in the area of UHI effect.

Summary

This research has proposed a framework, and Decision Support System (DSS) using Weighted Scoring Method (WSM) for assessing the mitigation strategies of UHI effect. Multi Criteria Decision Making (MCDM) methods are widely used in decision making problems. According to this WSM has been used throughout the research. The three methods of WSM, AHP, and ANP has been compared and the shortcoming and benefits of each method has been reviewed. The developed framework/system is composed of a list of objectives (sustainability and resilience), criteria (economic, environmental, social, vulnerability, and resistance to change), attributes, and the most commonly used mitigation methods for UHI effect. The system's second component is the main engine (using WSM as the decision support system), which is responsible for determining the best mitigation strategies - the system's predefined goal. The Weighted Scoring Method (WSM) has been used in this study to develop matrices to do pairwise comparison of criteria, assign a relative weight to each criterion, score each strategy against each criterion, and calculate the weighted scores based on experts' opinion and information gathered through sets of expert elicitation exercises. Therefore, three expert elicitation exercises have been designed in Qualtrics XM to obtain the required data. The main objectives of them are to understand the relative weights of criteria affecting in the assessment of UHIMSs and find the impact rate of these criteria on each mitigation strategy. The expert elicitation exercises have gone through multiple rounds of revisions to incorporate comments from experts. They have been designed as an educational tool that can be later used by participants with different levels of knowledge. Decision-makers can analyze the UHIMSs after the matrix has been set up with weighted scores to find the best method that fit their needs (system objective). The third key component is the user-friendly interface, which combines the previous two components of the system and applies spreadsheets to present the best feasible mitigation strategy. The contribution this study has sought is to develop a DSS resembling a knowledge sharing platform to support stakeholders like urban planners, architects, decision makers and policy makers in the extraction of UHIMSs based on their sustainability and resilience performance. In addition, this study has been developed to serve as a foundation for the establishment of a dynamic computer-based decision support system (DSS) for selecting the most efficient UHIMSs.

Conclusion

The effect of UHI has been investigated for years. Various mitigation measures are now being used to create resiliency by lowering the vulnerability of metropolitan areas in the face of increasing heat. Greenery, Cool Material, Green Roofs, and Evaporative Techniques are the most noticeable of the several ways used to reduce UHI intensity. When it comes to choosing between the most effective mitigation method(s) in terms of their sustainability and resilience achievement, the concern is the lack of clear performance metrics. As a result, a comprehensive performance measuring tool or DSS in the form of an integrated computer-based system is required to assist people in solving issues and making choices using computer communications, data, documents, knowledge, and models. As a consequence, this research proposes three expert elicitation exercises to elicit expert opinions and gather data for the DSS development. Throughout the process of developing this research the following hypotheses have been proposed. The results of them are discussed and concluded in the following paragraphs.

Earlier in the first chapter, the two concepts of sustainability and resilience are postulated to be independent yet complementary conceptual aims. Therefore, the weights of parameters in the user interface spreadsheets are modified in two different efforts to obtain new outcomes (the performance scores of UHIMSs based on sustainability and resilience parameters). The weights of the resilience objective, criteria, and attributes are set to 0.00 percent in the initial try. Similarly, the weight of the sustainability objective, criteria, and attributes is reduced to 0.00 percent in the second attempt. The following are the findings of the investigation:

It is hypothesized that if resilience objective is given a 0.00 percent weight, the final performance score of UHIMSs will alter. The Paired Two-Sample T-Test analysis reveals that the mean scores of UHIMSs' performance decreases from M= 0.25 (SD= 0.042) to M= 0.24 (SD= 0.052). However, this change was not statistically significant $t(3)= -0.39$, $p= 0.35$.

It is hypothesized that if sustainability objective is given a 0.00 percent weight, the final performance score of UHIMSs will alter. The Paired Two-Sample T-Test analysis reveals that the mean scores of UHIMSs' performance decreases from M= 0.25 (SD= 0.042) to M= 0.24 (SD= 0.038). However, this change was not statistically significant $t(3)= 0.52$, $p= 0.32$.

As a result, this theory is disproved. This shows that the experts couldn't differentiate between the roles of sustainability and resilience. So, these two concepts are pretty much the same for experts.

Furthermore, the 3Ps of sustainability (economic, environmental, and social) are all equally important, according to the findings of the literature review. As a result, it is predicted that the criteria for the two primary objectives (Sustainability and Resilience) should be given equal weights, i.e., the three pillars of sustainability (Environmental, Economic, and Social), as well as the two key criteria of resilience (Vulnerability and Resistance to change), should be given equal weights. The findings of expert elicitation experiments reveal that a small number of experts give equal weight to three pillars of sustainability and two resilience criteria (Vulnerability and Resistance to Change) (see Figures 42 and 43).

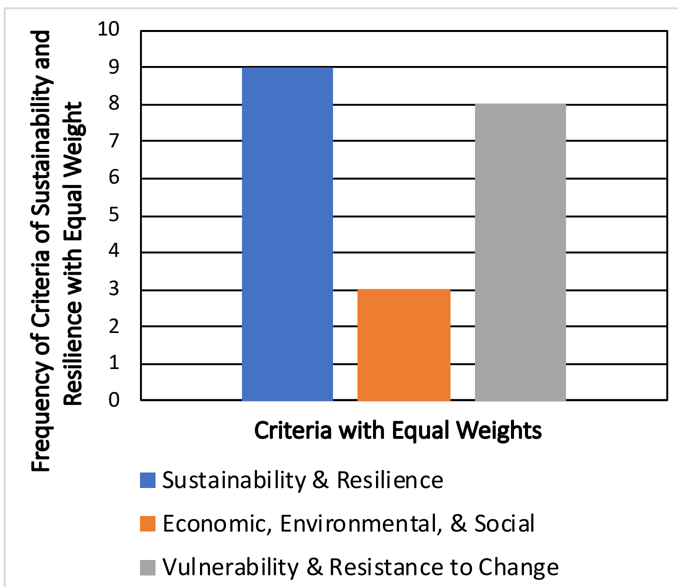

Figure 42: Histogram of Frequency of Sustainability and Resilience Criteria with Equal Weight

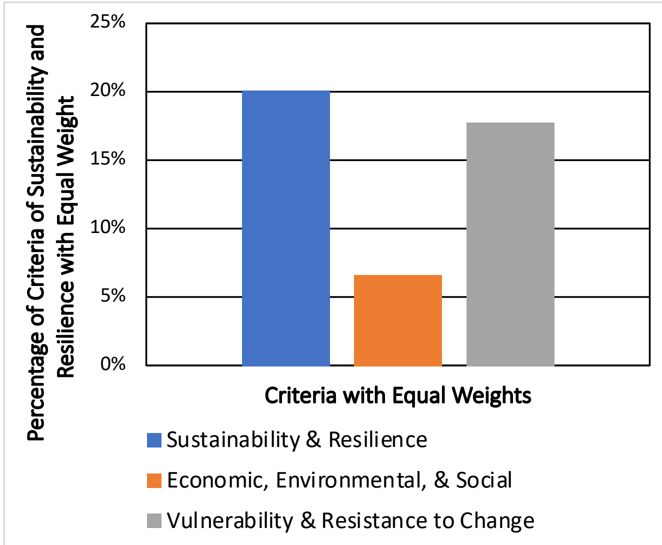

Figure 43: Histogram of Percentage of Sustainability and Resilience Criteria with Equal Weight

Since the greenery approach is emphasized more in the examined literatures. The final hypothesis of this study is that most experts will favor Greenery techniques as the most effective/efficient UHIMSs. The findings of the expert elicitation exercises demonstrate that the specialists appear to be more inclined toward greenery approaches than the others (see Figures 44 and 45). As a result, if one makes changes to the user interface, most of the time, the final output will be the greenery technique.

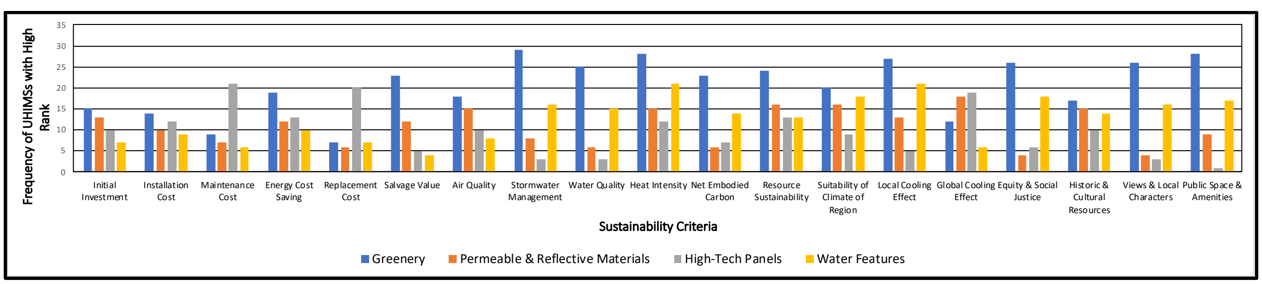

Figure 44: Histogram of Frequency of UHIMSs with High Rank based on Sustainability Criteria

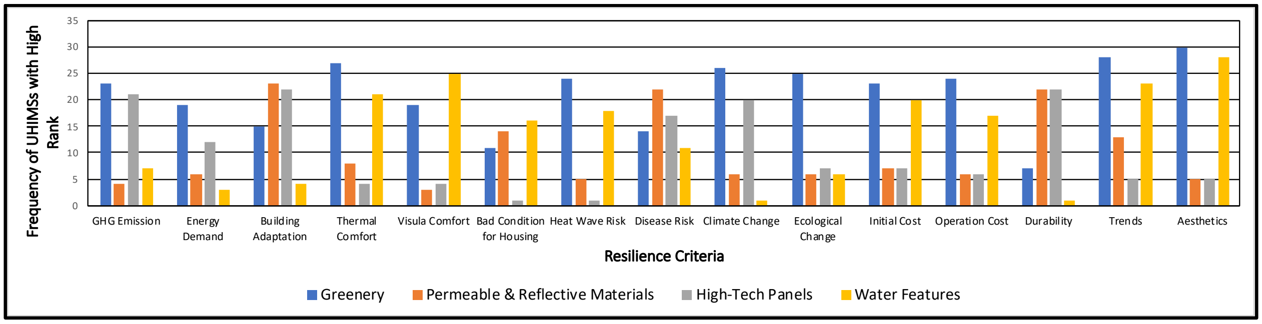

Figure 45: Histogram of Frequency of UHIMSs with High Rank based on Resilience Criteria

Recommendation and Future Extensions

Although the developed framework/system is designed to help decision makers in extracting the UHIMSs based on their sustainability and resilience performance, it still could be enhanced taking the following points in considerations: -1. It has been noticed that because the respondents selected for this research are only the professionals with LEED/Envision-certified working in green design/contractor firms, scholars with scientific publications in green building, UHI, and LEED, the response rates were not high enough. Thus, that would be great if the expert elicitation exercises can be distributed between many of them without any time limitation to acquire more data and eventually obtain more precise results. -2. Based on the limitation of this research, WSM was the most appropriate and feasible decision-making method proposed by this research. However, there are more accurate and precise methods such as AHP appropriate to be used as the main engine for the proposed decision support system by this research. -3. Although this research has put too much effort to identify, organize, and categorize the most relevant parameters in evaluating UHIMSs in terms of sustainability and resilience, however, there must be other parameters specially with the future expansion of the topic. Thus, the future work of this research will be allocated to updating the proposed framework and DSS with the most relevant and new affecting parameters in assessing UHIMSs. -4. The developed framework and decision support system of this research can be adapted for use with various socio-ecological issues. To accomplish so, further expert elicitations are needed to collect relevant data on the chosen study field. -5. As for the topic of UHI effect and its mitigation strategies are widely studied by various number of researchers and scholars. There is a lack in literatures when it comes to assessing UHIMSs in terms of sustainability and resilience. Therefore, it is recommended to conduct more researched in this area focusing on sustainability and resilience performance of UHIMSs.

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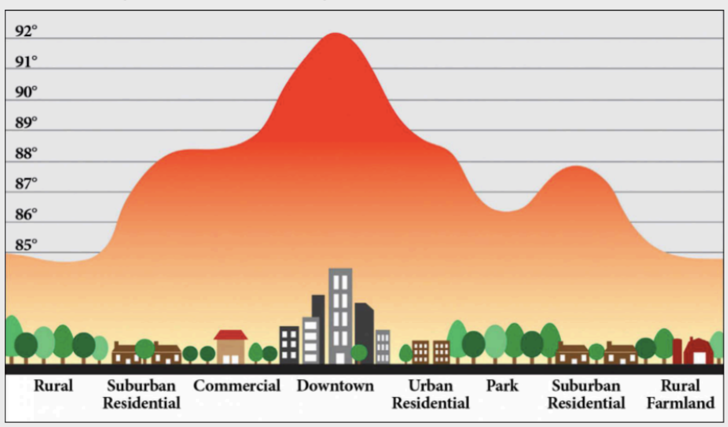
APPENDIX A

APPENDIX A

EXPERT ELICITATION EXERCISE PART 1

This survey is conducted by Bahareh Bathaei, a research Assistant, at the Civil Engineering Department, University of Texas Rio Grande Valley (UTRGV). The work is conducted under the supervision of Dr. Mohamed Abdel-Raheem.

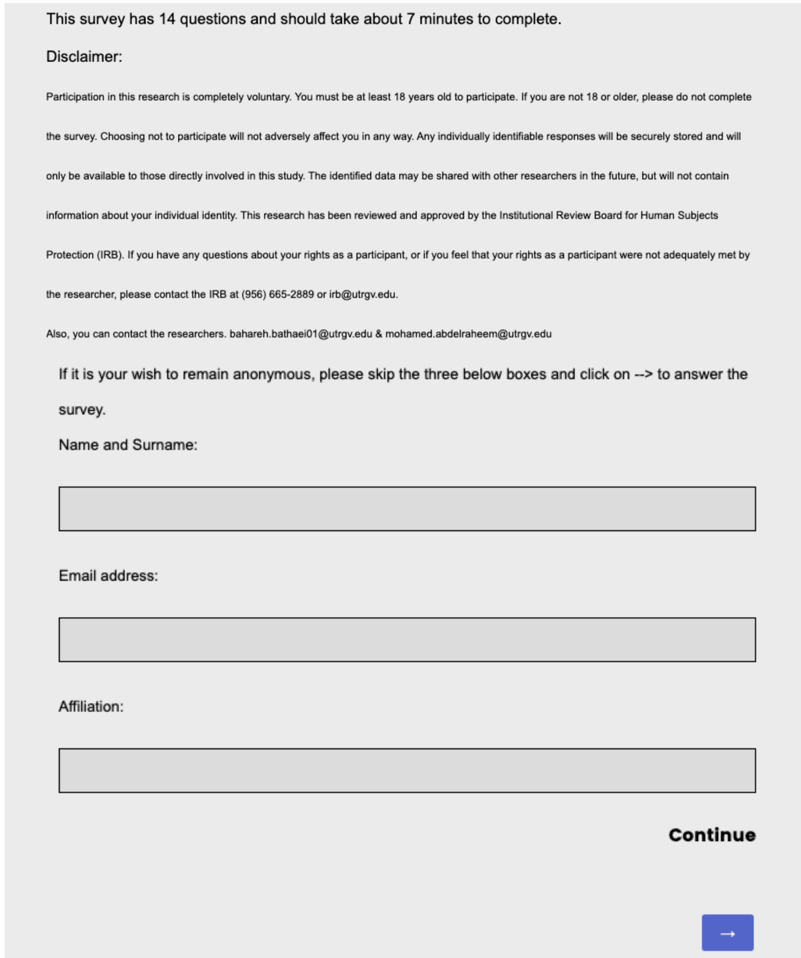
This study focuses on the Urban Heat Island (UHI) Effect. The purpose of this study is to find the relative importance (weight) of the different criteria affecting the assessment of mitigation strategies of the UHI effect. The effect of UHI is defined as relative air temperature increase in developed areas (cities) compared to undeveloped ones (rural). Some previous studies raise concerns about the impact of the UHI on the society, environment, and economy.



Currently, there are different strategies that are used to mitigate the impact of these effects. However, these approaches vary with respect to their levels of resilience and sustainability. Some examples of these methods are Greenery, Cool Material Usage in Construction, Green Roofs, and Evaporative Techniques.

The survey is composed of 3 parts. This survey (part 1) focuses on the assessment of the relative importance of criteria that are used to assess the Urban Heat Island Mitigation Strategies (UHIMSs) with respect to their levels of resilience and sustainability. Parts 2 and 3 will come in the future at different studies.

Figure 1: Introduction slide of the 1st part of expert elicitation on Qualtrics XM



This survey has 14 questions and should take about 7 minutes to complete.

Disclaimer:

Participation in this research is completely voluntary. You must be at least 18 years old to participate. If you are not 18 or older, please do not complete the survey. Choosing not to participate will not adversely affect you in any way. Any individually identifiable responses will be securely stored and will only be available to those directly involved in this study. The identified data may be shared with other researchers in the future, but will not contain information about your individual identity. This research has been reviewed and approved by the Institutional Review Board for Human Subjects Protection (IRB). If you have any questions about your rights as a participant, or if you feel that your rights as a participant were not adequately met by the researcher, please contact the IRB at (956) 665-2889 or irb@utrgv.edu.

Also, you can contact the researchers. bahareh.bathaei01@utrgv.edu & mohamed.abdelraheem@utrgv.edu

If it is your wish to remain anonymous, please skip the three below boxes and click on --> to answer the survey.

Name and Surname:

Email address:

Affiliation:

Continue

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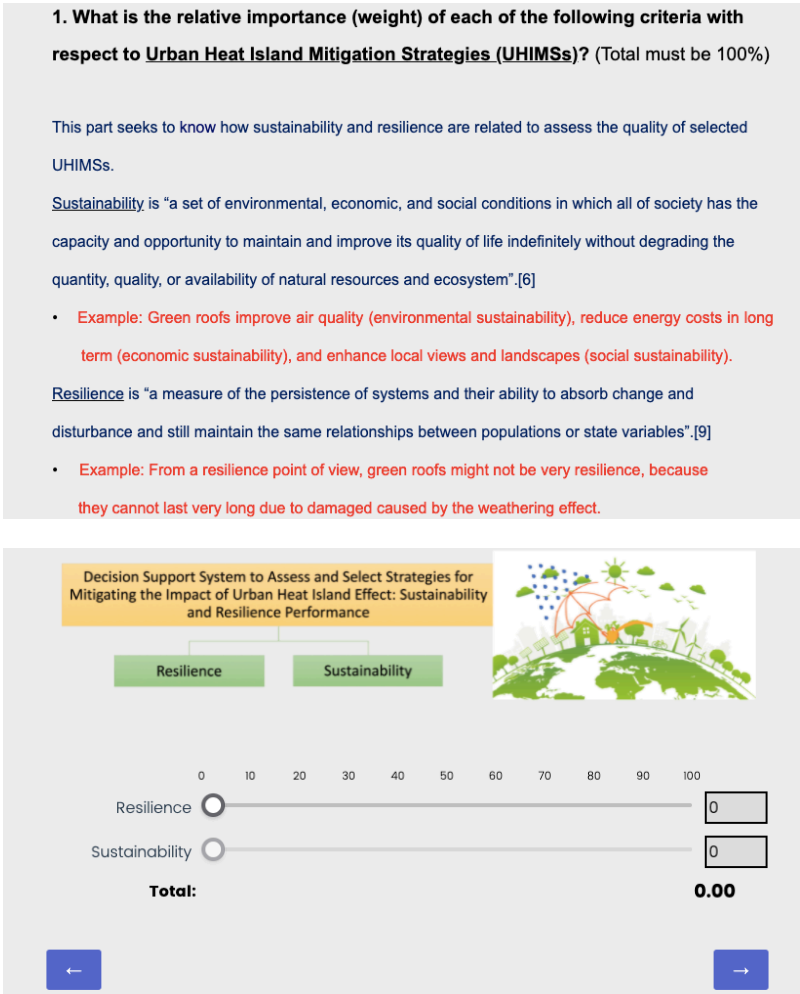
Figure 2: Descriptive question of the 1st part of expert elicitation on Qualtrics XM



1. What is the relative importance (weight) of each of the following criteria with respect to <u>Urban Heat Island Mitigation Strategies (UHIMSs)</u>? (Total must be 100%)

This part seeks to know how sustainability and resilience are related to assess the quality of selected UHIMSs.

<u>Sustainability</u> is "a set of environmental, economic, and social conditions in which all of society has the capacity and opportunity to maintain and improve its quality of life indefinitely without degrading the quantity, quality, or availability of natural resources and ecosystem".[6]

- Example: Green roofs improve air quality (environmental sustainability), reduce energy costs in long term (economic sustainability), and enhance local views and landscapes (social sustainability).

<u>Resilience</u> is "a measure of the persistence of systems and their ability to absorb change and disturbance and still maintain the same relationships between populations or state variables".[9]

- Example: From a resilience point of view, green roofs might not be very resilience, because they cannot last very long due to damaged caused by the weathering effect.

	0	10	20	30	40	50	60	70	80	90	100	
Resilience												0
Sustainability												0
Total:												**0.00**

← →

Figure 3: Question 1 of the 1st part of expert elicitation on Qualtrics XM

2. What is the relative importance (weight) of each of the following criteria with respect to Resilience? (Total must be 100%)

This part seeks to know how vulnerability and resistance to change are related to assess the quality of selected UHIMSs.

Vulnerability from a resilience point of view is the ability of the system to mitigate possible/probable impacts on users due to the presence of the selected system.

- Example: Air conditioning systems are used to cool down the temperature, but they might have negative impacts on users due to the noises associated with operating the systems or the higher electricity built due to electricity consumption.

Resistance to change is defined as "the ability of an urban system and all its constituent socio-ecological and socio-technical networks across temporal and spatial scales to maintain or rapidly return to desired functions in the face of a disturbance, to adapt to change, and to quickly transform systems that limit current or future adaptive capacity." [4]

	0	10	20	30	40	50	60	70	80	90	100	
Vulnerability												0
Resistance to Change												0
Total:												**0.00**

← →

Figure 4: Question 2 of the 1st part of expert elicitation on Qualtrics XM

3. What is the relative importance (weight) of each of the following criteria with respect to Vulnerability? (Total must be 100%)

This part seeks to know how energy, comfort, and health aspects of vulnerability are related to assess the quality of selected UHIMSs.

Energy is an aspect of vulnerability that refers to the ability of the proposed system to protect from the anticipated impact of the system on the users due to energy consumption or demands consequences.

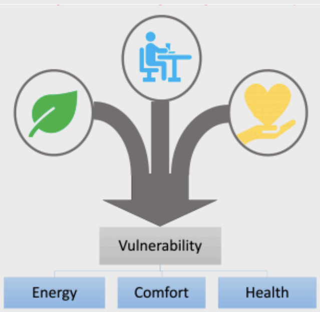
- Example: Fountain is one of the UHI mitigation methods. However, they need a pump which consumes electricity to operate. Although electricity can be green still it will be costly in money over time.

Comfort is an aspect of vulnerability that refers to the ability of the proposed system to protect from the anticipated impact of the system on the users due to comfort violations such as violated visual or thermal comfort.

- Example: Evaporative techniques in dry climates can significantly enhance the comfort by balancing the moisture level hence lowering the real feel temperature.
- Example: Although, evaporative methods are effective in enhancing the comfort level especially in dry climate, but some of the humidity-related health issues generated by evaporative techniques.
- Example: Although, light color materials rely on enhancing a natural heat-shedding effect known as passive radiative cooling but, they can cause unwanted glare which violates the visual comfort for the users.

Health is an aspect of vulnerability that refers to the ability of the proposed system to protect the users from the anticipated impact of the system due to health risk conditions and its consequences.

- Example: Green roofs or vertical gardens can mitigate the UHI effect. However, they can increase pollen production which potentially exacerbating allergies and respiratory disease.[1]



	0 10 20 30 40 50 60 70 80 90 100	
Energy		0
Comfort		0
Health		0
Total:		**0.00**

← →

Figure 5: Question 3 of the 1st part of expert elicitation on Qualtrics XM

4. What is the relative importance (weight) of each of the following criteria with respect to the Energy aspect of Vulnerability? (Total must be 100%)

In layman's terms, we want to assess the selected UHIMS with respect to its impact on users in terms of greenhouse gases (GHGs) emission and energy demand.

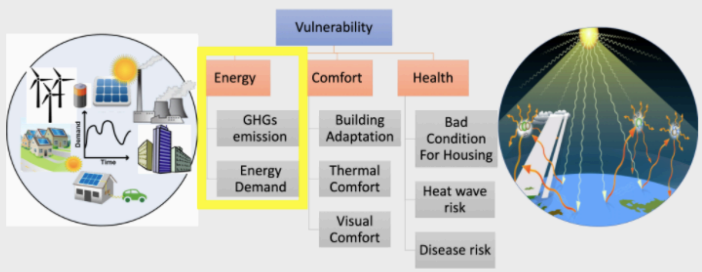
This part seeks to know how the energy aspect of vulnerability is related to assess the quality of selected UHIMSs.

Greenhouse gases (GHGs) are "chemical compounds in the earth's atmosphere that absorb and emit radiation, which causes the greenhouse effect that affects the regulation of the earth's temperature. Water vapor (H2O), carbon dioxide (CO2), nitrous oxide (N2O), methane (CH2), and fluorinated gases" are examples of these compounds.[6]

- Example: While mitigation methods like light color materials do not generate GHGs, others like water sprinklers or fountains indirectly generate GHGs due to their dependency on electricity for running and their electricity is supplied from generating plants that might use fossil fuels.

Energy Demand: The UHIMSs being installed should protect the users from changes in the needs of energy, such as an increase in the energy cost.

- Example: Although the fountains/sprinklers can reduce the heatwave, they increase the demand for electricity usage to operate the pump. Alternatively, reflective materials do not demand any energy for operation.



	0 10 20 30 40 50 60 70 80 90 100	
GHGs Emission		0
Energy Demand		0
Total:		**0.00**

← →

Figure 6: Question 4 of the 1st part of expert elicitation on Qualtrics XM

5. What is the relative importance (weight) of each of the following criteria with respect to the Comfort aspect of Vulnerability? (Total must be 100%)

This part seeks to know how the comfort aspect of vulnerability is related to assess the quality of selected UHIMSs.

Comfort incorporates the creation of spaces of physical and mental wellbeing, ambient qualities, and a sense of security. A lack of comfort is likely to be experienced by habitants of urban areas due to heat retention.

Building Adaptation is the ability of the building or the users to adapt to the impact of systems UHMISs being installed.

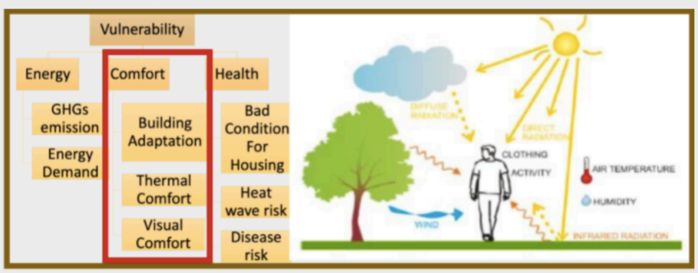
- Example: Installing the photovoltaic panels or green roofs might exert a significant load on built the structure might be a real concern from a structural point of view.

Thermal Comfort refers to the ability of UHIMSs to provide users the satisfaction with the thermal conditions of the environment.

- Example: Although air conditioning systems achieve thermal comfort inside the building, they might compromise the exterior comfort of the users. While green roofs or vertical gardens can maintain thermal comfort externally and internally.

Visual Comfort is the ability of the selected UHIMSs to minimize visual discomfort due to the lack of natural light or glare.

- Example: Green roofs provide a natural appealing view. Yet, if they are not carefully designed, they can block sunlight. On the other hand, retroreflective materials can cause glare which causes discomfort to other species.



	0	10	20	30	40	50	60	70	80	90	100	
Building Adaptaion												0
Thermal Comfort												0
Visual Comfort												0
Total:												**0.00**

← →

Figure 7: Question 5 of the 1st part of expert elicitation on Qualtrics XM

6. What is the relative importance (weight) of each of the following criteria with respect to the Health aspect of Vulnerability? (Total must be 100%)

This part seeks to know how the health aspect of vulnerability is related to assess the quality of selected UHIMSs.

According to IPCC (Intergovernmental Panel on Climate Change) (2007), another impact from an increase of heatwave concerns is the health risk.

- Example: Cool pavements lead to reduce the temperature of stormwater runoff into local water bodies. Minimizing overheated runoff can preserve aquatic ecosystems and especially protect wildlife vulnerable to temperature increases.[1]

The bad condition of housing is the unsuitable condition of building due to impacts of UHIMSs. Here we are talking about the ability of the system to mitigate the impact resulting from installing the system itself.

- Example: Unlike the effectiveness of cool roofs, the installation of them in a building that is surrounded by high buildings can cause unwanted glare. As Stuart Gaffin, a scientist at Columbia University's Earth Institute, point out, cool roofs reflect sunlight away from themselves, but they can bounce the light onto taller neighboring buildings, warming those buildings instead. They can also cause unwanted glare.[1]

A heatwave is considered extreme weather that can be a natural disaster, and a danger because heat and sunlight may overheat the human body.

- Example: Although retroreflective materials could reduce the UHI effect, the development of them in the urban area with the risk of heatwave risk could pose a threat to users' bodies and health.

Disease risk is something that enhances a person's vulnerability in developing a disease.

- Example: Although greenery techniques are effective in mitigating the effects of heat island, their plants could generate pollen or aggravating forms of pollen which might consider as a risk of developing allergies or asthma diseases for some users.

0 10 20 30 40 50 60 70 80 90 100

Bad Condition For Housing 0

Heat Wave Risk 0

Disease Risk 0

Total: **0.00**

← →

Figure 8: Question 6 of the 1st part of expert elicitation on Qualtrics XM

7. What is the relative importance (weight) of each of the following criteria with respect to Resistance to Change? (Total must be 100%)

This part seeks to know how environmental, economic, and social aspects of resistance to change are related to assess the quality of selected UHIMSs.

Environmental Resistance to Change means the ability of UHIMSs to recover from disturbances and to tolerate or adapt to changing environments.

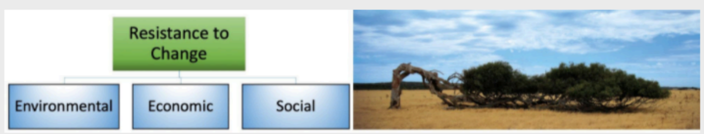
- Example: Cool roofs can be a feasible alternative to mitigate the impact of the heat island effect, however they might not have a high level of resistance to change. For instance, cool roofs generally have high reflectance, but weathering and dirt accumulation can lower the solar reflectance of them over time.[1]

Economic Resistance to Change addresses the degree of resistance of UHIMSs to changes in the economy.

- Example: Use of fountains might not be economically efficient over time because of reliance on electricity and changes in the prices of electricity, whereas using greeneries for example "regional flora", may not be affected by the changes in the economy over time. The price of local flora usually stays within a reasonable margin of the price.

Social Resistance to Change is the ability of UHIMSs to resist the change in society such as trends and aesthetics.

- Example: Since the UHIMSs involve dealing with people, it is unavoidable not to consider the taste of people/society in them. If two or more methods are similar or close in the scoring system, it is preferable to choose one which is leaning more toward the fashion trends of the area of application. For instance, greenery techniques are more appreciated.



	0	10	20	30	40	50	60	70	80	90	100	
Environmental												0
Economic												0
Social												0
Total:												**0**

← →

Figure 9: Question 7 of the 1st part of expert elicitation on Qualtrics XM

8. What is the relative importance (weight) of each of the following criteria with respect to Environmental Resistance to Change? (Total must be 100%)

This part seeks to know how environmental resistance to change is related to assess the quality of selected UHIMSs.

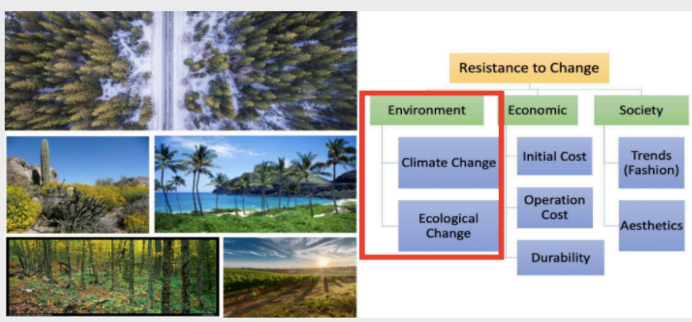
Environmental Resistance to Change is defined as recovering from disturbances and to tolerate or adapt to changing climate.

NASA addresses Climate Change as a long-term change in the average weather patterns that have come to define earth's local, regional, and global climates.

- Example: The photovoltaic panels can be a feasible alternative to mitigate the impact of the heat island effect, however, the installation of them is vulnerable and they might not be suitable in the tropical climate prone to hurricanes or severe weather conditions.
- Example: Evaporative techniques can be very efficient as long as a constant and reliable source of water supply, however, changes in weather conditions leading to drought might cause these systems to be ineffective. So, if the systems go through a state of drought, then these systems need to be replaced.
- Example: Unlike the effectiveness of porous pavements to mitigate the UHI effect, an urban area with a cold climate must take care that water does not freeze within porous pavements which causes cracking.

According to MA (Millennium Ecosystem Assessment), Ecological Change is any variation in the state, outputs, or structure of an ecosystem.

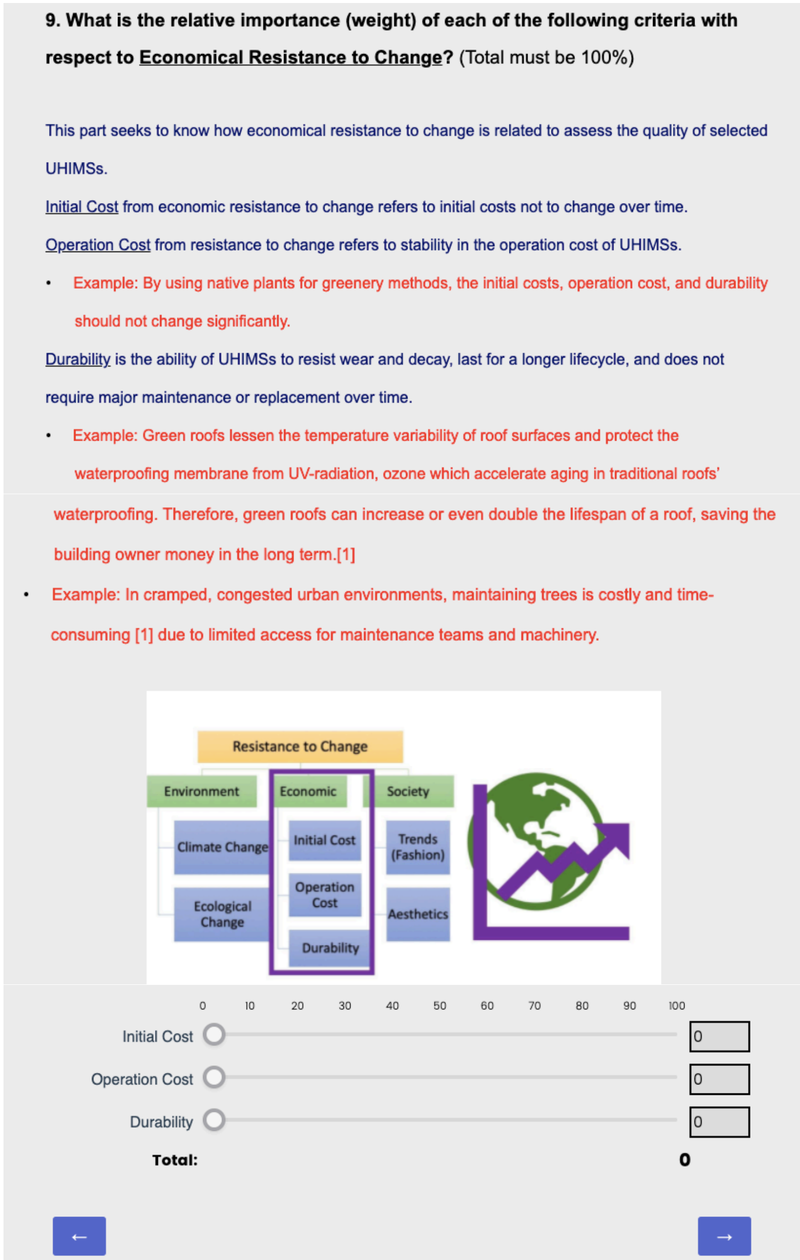
- Example: Although evaporative techniques have a high level of effectiveness especially in dry climates, they increase the demands of water supply (increase its ecological footprint). So, if there is curtsy of water (drought), they might not be the best solution.



	0	10	20	30	40	50	60	70	80	90	100	
Climate Change												0
Ecological Change												0
Total:												**0**

← →

Figure 10: Question 8 of the 1st part of expert elicitation on Qualtrics XM



9. What is the relative importance (weight) of each of the following criteria with respect to Economical Resistance to Change? (Total must be 100%)

This part seeks to know how economical resistance to change is related to assess the quality of selected UHIMSs.

Initial Cost from economic resistance to change refers to initial costs not to change over time.

Operation Cost from resistance to change refers to stability in the operation cost of UHIMSs.

- Example: By using native plants for greenery methods, the initial costs, operation cost, and durability should not change significantly.

Durability is the ability of UHIMSs to resist wear and decay, last for a longer lifecycle, and does not require major maintenance or replacement over time.

- Example: Green roofs lessen the temperature variability of roof surfaces and protect the waterproofing membrane from UV-radiation, ozone which accelerate aging in traditional roofs' waterproofing. Therefore, green roofs can increase or even double the lifespan of a roof, saving the building owner money in the long term.[1]
- Example: In cramped, congested urban environments, maintaining trees is costly and time-consuming [1] due to limited access for maintenance teams and machinery.

	0	10	20	30	40	50	60	70	80	90	100	
Initial Cost												0
Operation Cost												0
Durability												0
Total:												**0**

← →

Figure 11: Question 9 of the 1st part of expert elicitation on Qualtrics XM

10. What is the relative importance (weight) of each of the following criteria with respect to Social Resistance to Change? (Total must be 100%)

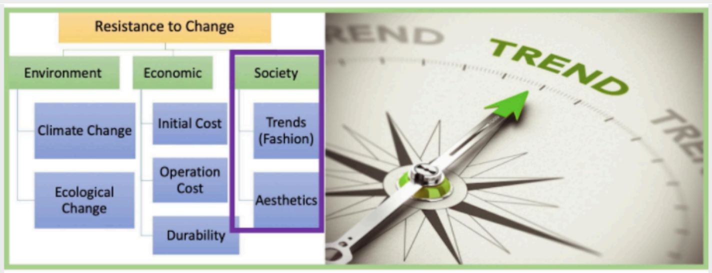
This part seeks to know how social resistance to change is related to assess the quality of selected UHIMSs.

Trend refers to a general direction in which something is developing or changing. It means that something is an indicator of whether it is in style/fashion in society. This criterion seeks to measure the degree of resistance of UHIMSs to change in the trends of society.

- Example: As mitigation methods used in UHI are dealing with people, it is unavoidable not to consider the taste of people in them. If two or more methods are similar or close in the scoring system, it is preferable to choose one which is leaning more toward the fashion trends of the area of application. For instance, when two methods of vertical gardens and light color materials have the same or close ranks in the scoring system, light color materials might be selected by users who follow minimalist design trends.

Aesthetics is the ability of UHIMSs to have resistance to change in the level of attractiveness.

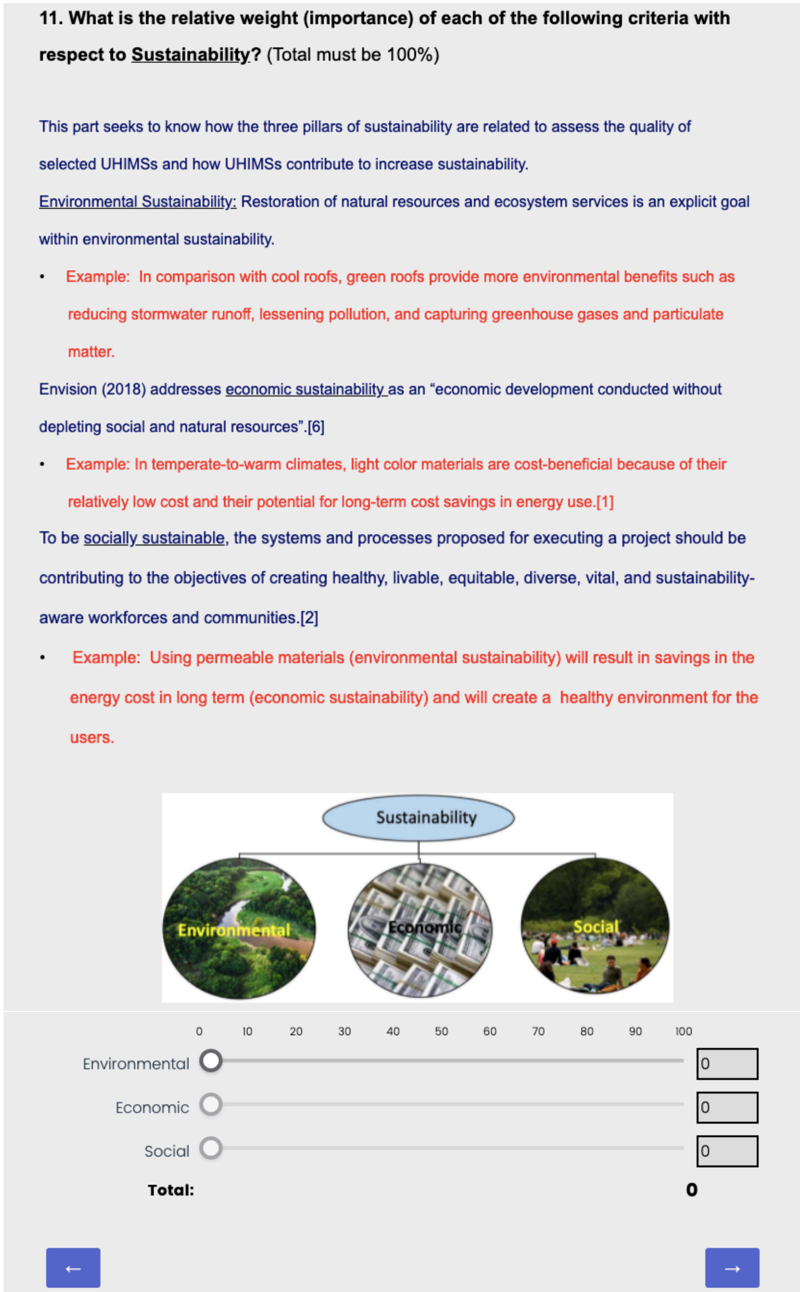
- Example: The built environment should foster a connection to people's senses and not reflect alienation from them. The mitigation methods used in residential and urban areas might be different from industrial areas as the integrity of beauty in design is an important factor to consider while choosing one method over another. For instance, photovoltaic panels might be very suitable in industrial areas, but not be aesthetically appealing in residential areas.



	0	10	20	30	40	50	60	70	80	90	100	
Trends (Fashion)												0
Aesthetics												0
Total:												**0**

← →

Figure 12: Question 10 of the 1st part of expert elicitation on Qualtrics XM



11. What is the relative weight (importance) of each of the following criteria with respect to Sustainability? (Total must be 100%)

This part seeks to know how the three pillars of sustainability are related to assess the quality of selected UHIMSs and how UHIMSs contribute to increase sustainability.

Environmental Sustainability: Restoration of natural resources and ecosystem services is an explicit goal within environmental sustainability.

- Example: In comparison with cool roofs, green roofs provide more environmental benefits such as reducing stormwater runoff, lessening pollution, and capturing greenhouse gases and particulate matter.

Envision (2018) addresses economic sustainability as an "economic development conducted without depleting social and natural resources".[6]

- Example: In temperate-to-warm climates, light color materials are cost-beneficial because of their relatively low cost and their potential for long-term cost savings in energy use.[1]

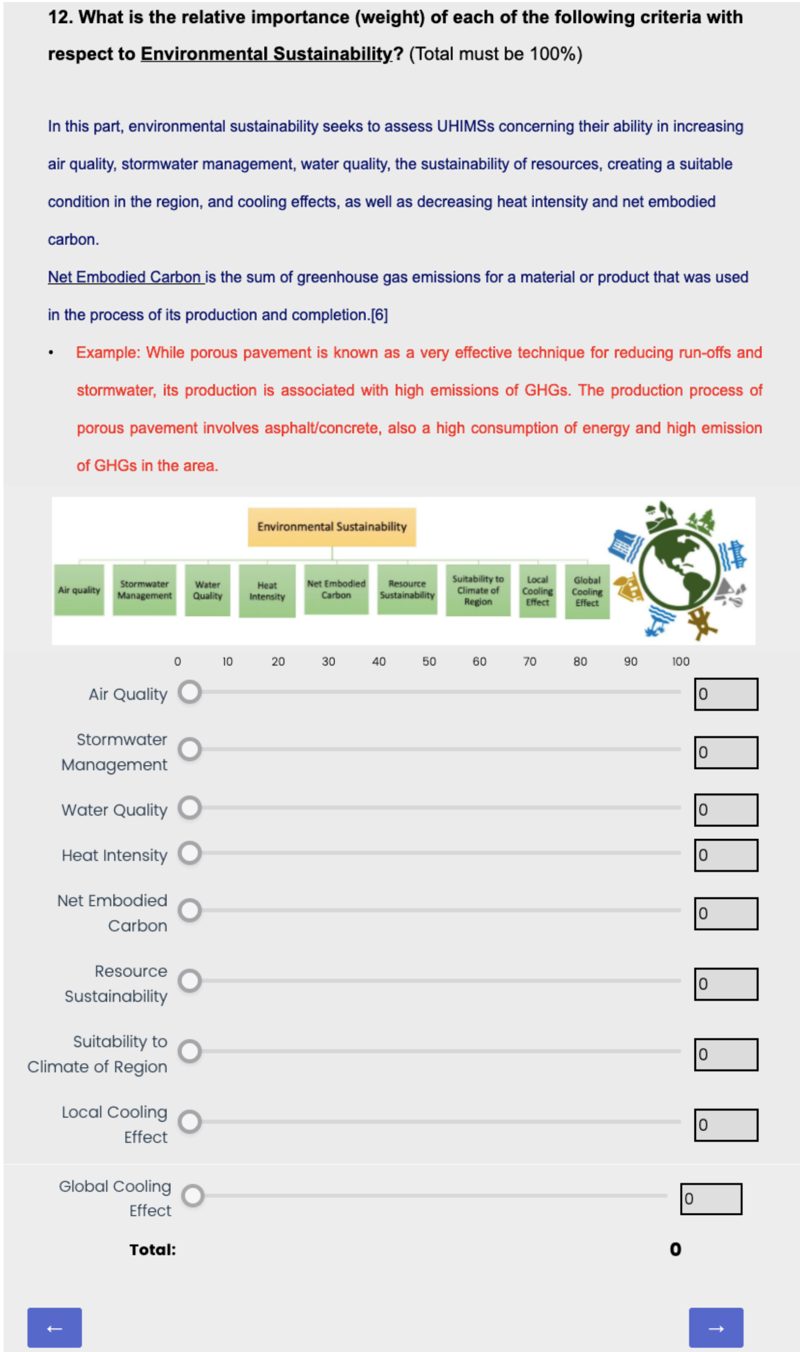
To be socially sustainable, the systems and processes proposed for executing a project should be contributing to the objectives of creating healthy, livable, equitable, diverse, vital, and sustainability-aware workforces and communities.[2]

- Example: Using permeable materials (environmental sustainability) will result in savings in the energy cost in long term (economic sustainability) and will create a healthy environment for the users.

	0	10	20	30	40	50	60	70	80	90	100	
Environmental												0
Economic												0
Social												0
Total:												**0**

← →

Figure 13: Question 11 of the 1st part of expert elicitation on Qualtrics XM



12. What is the relative importance (weight) of each of the following criteria with respect to <u>Environmental Sustainability</u>? (Total must be 100%)

In this part, environmental sustainability seeks to assess UHIMSs concerning their ability in increasing air quality, stormwater management, water quality, the sustainability of resources, creating a suitable condition in the region, and cooling effects, as well as decreasing heat intensity and net embodied carbon.

Net Embodied Carbon is the sum of greenhouse gas emissions for a material or product that was used in the process of its production and completion.[6]

- Example: While porous pavement is known as a very effective technique for reducing run-offs and stormwater, its production is associated with high emissions of GHGs. The production process of porous pavement involves asphalt/concrete, also a high consumption of energy and high emission of GHGs in the area.

Environmental Sustainability

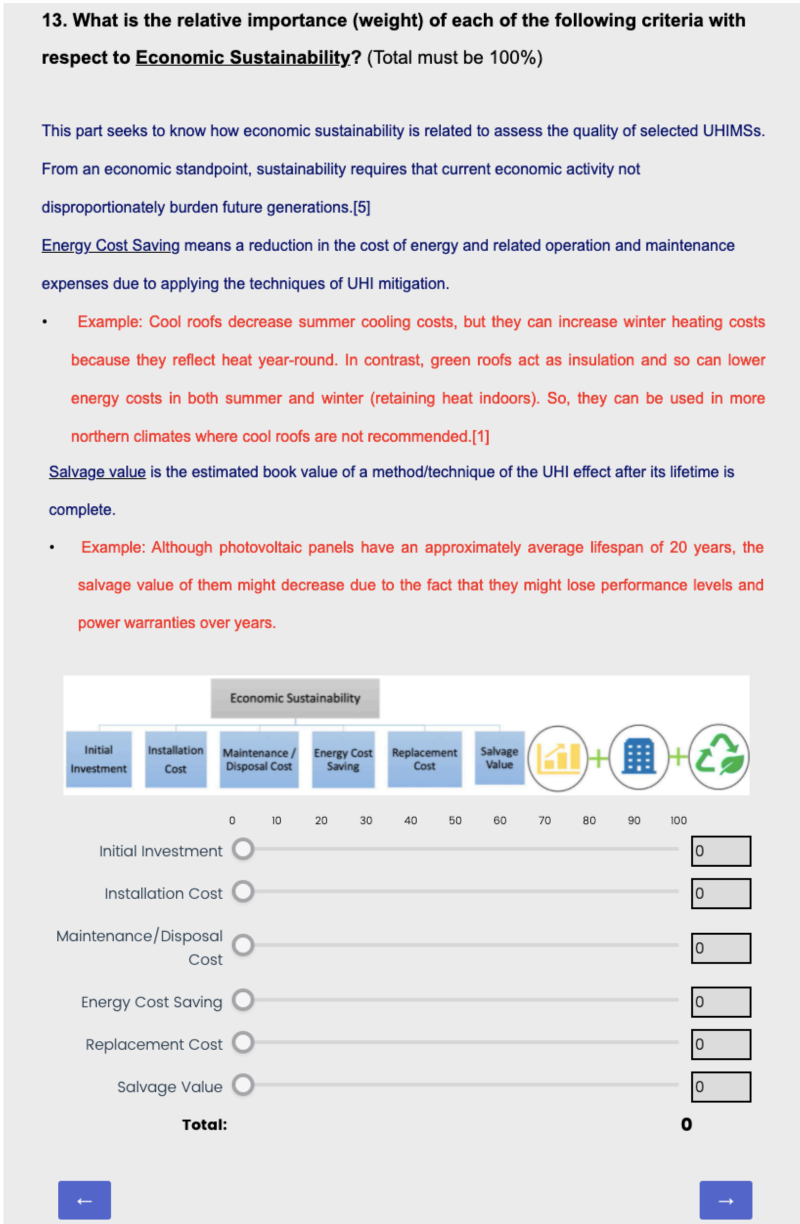
Air quality | Stormwater Management | Water Quality | Heat Intensity | Net Embodied Carbon | Resource Sustainability | Suitability to Climate of Region | Local Cooling Effect | Global Cooling Effect

0 10 20 30 40 50 60 70 80 90 100

Air Quality	0
Stormwater Management	0
Water Quality	0
Heat Intensity	0
Net Embodied Carbon	0
Resource Sustainability	0
Suitability to Climate of Region	0
Local Cooling Effect	0
Global Cooling Effect	0
Total:	**0**

← →

Figure 14: Question 12 of the 1st part of expert elicitation on Qualtrics XM



13. What is the relative importance (weight) of each of the following criteria with respect to Economic Sustainability? (Total must be 100%)

This part seeks to know how economic sustainability is related to assess the quality of selected UHIMSs. From an economic standpoint, sustainability requires that current economic activity not disproportionately burden future generations.[5]

Energy Cost Saving means a reduction in the cost of energy and related operation and maintenance expenses due to applying the techniques of UHI mitigation.

- Example: Cool roofs decrease summer cooling costs, but they can increase winter heating costs because they reflect heat year-round. In contrast, green roofs act as insulation and so can lower energy costs in both summer and winter (retaining heat indoors). So, they can be used in more northern climates where cool roofs are not recommended.[1]

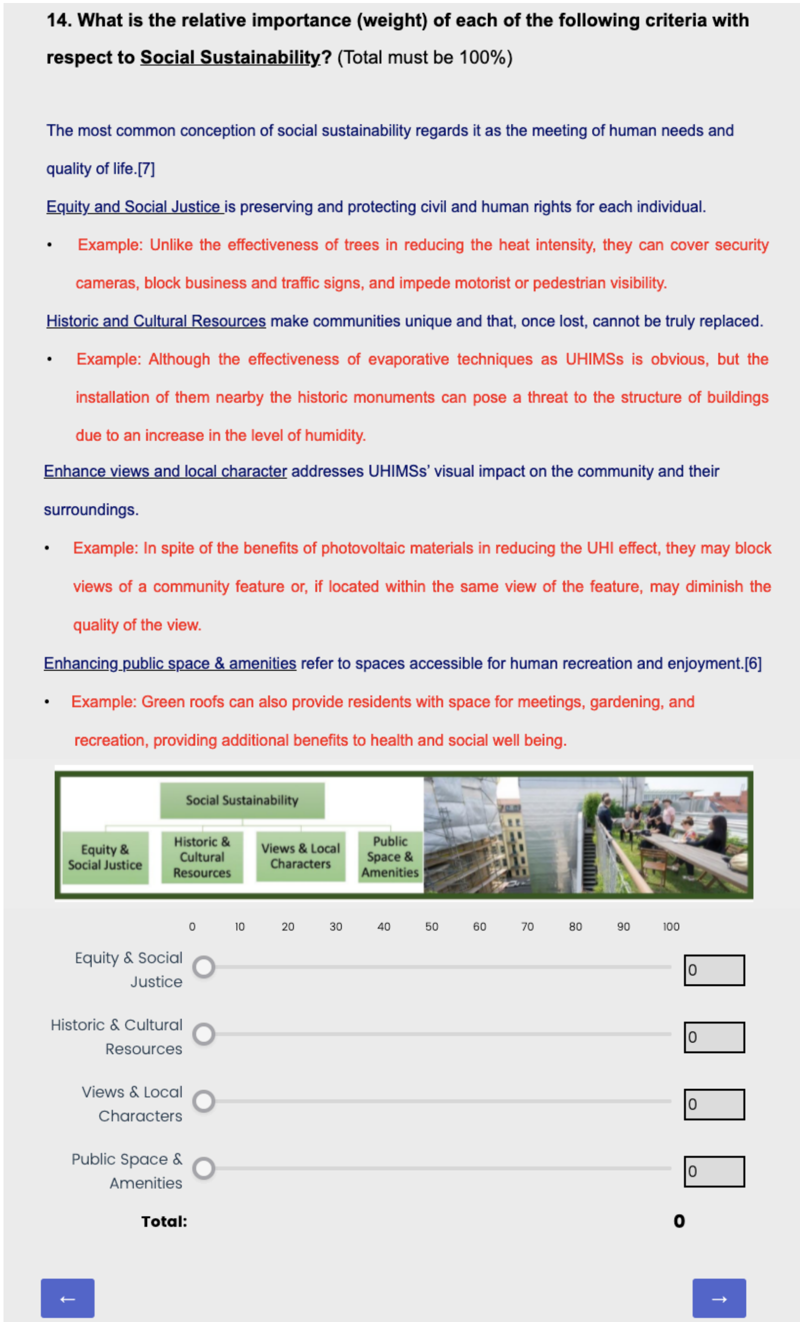
Salvage value is the estimated book value of a method/technique of the UHI effect after its lifetime is complete.

- Example: Although photovoltaic panels have an approximately average lifespan of 20 years, the salvage value of them might decrease due to the fact that they might lose performance levels and power warranties over years.

	0 10 20 30 40 50 60 70 80 90 100	
Initial Investment		0
Installation Cost		0
Maintenance/Disposal Cost		0
Energy Cost Saving		0
Replacement Cost		0
Salvage Value		0
Total:		**0**

← →

Figure 15: Question 13 of the 1st part of expert elicitation on Qualtrics XM



14. What is the relative importance (weight) of each of the following criteria with respect to Social Sustainability? (Total must be 100%)

The most common conception of social sustainability regards it as the meeting of human needs and quality of life.[7]

Equity and Social Justice is preserving and protecting civil and human rights for each individual.

- Example: Unlike the effectiveness of trees in reducing the heat intensity, they can cover security cameras, block business and traffic signs, and impede motorist or pedestrian visibility.

Historic and Cultural Resources make communities unique and that, once lost, cannot be truly replaced.

- Example: Although the effectiveness of evaporative techniques as UHIMSs is obvious, but the installation of them nearby the historic monuments can pose a threat to the structure of buildings due to an increase in the level of humidity.

Enhance views and local character addresses UHIMSs' visual impact on the community and their surroundings.

- Example: In spite of the benefits of photovoltaic materials in reducing the UHI effect, they may block views of a community feature or, if located within the same view of the feature, may diminish the quality of the view.

Enhancing public space & amenities refer to spaces accessible for human recreation and enjoyment.[6]

- Example: Green roofs can also provide residents with space for meetings, gardening, and recreation, providing additional benefits to health and social well being.

	0 10 20 30 40 50 60 70 80 90 100	
Equity & Social Justice		0
Historic & Cultural Resources		0
Views & Local Characters		0
Public Space & Amenities		0
Total:		**0**

← →

Figure 16: Question 14 of the 1st part of expert elicitation on Qualtrics XM

APPENDIX B

APPENDIX B

EXPERT ELICITATION EXERCISE PART 2

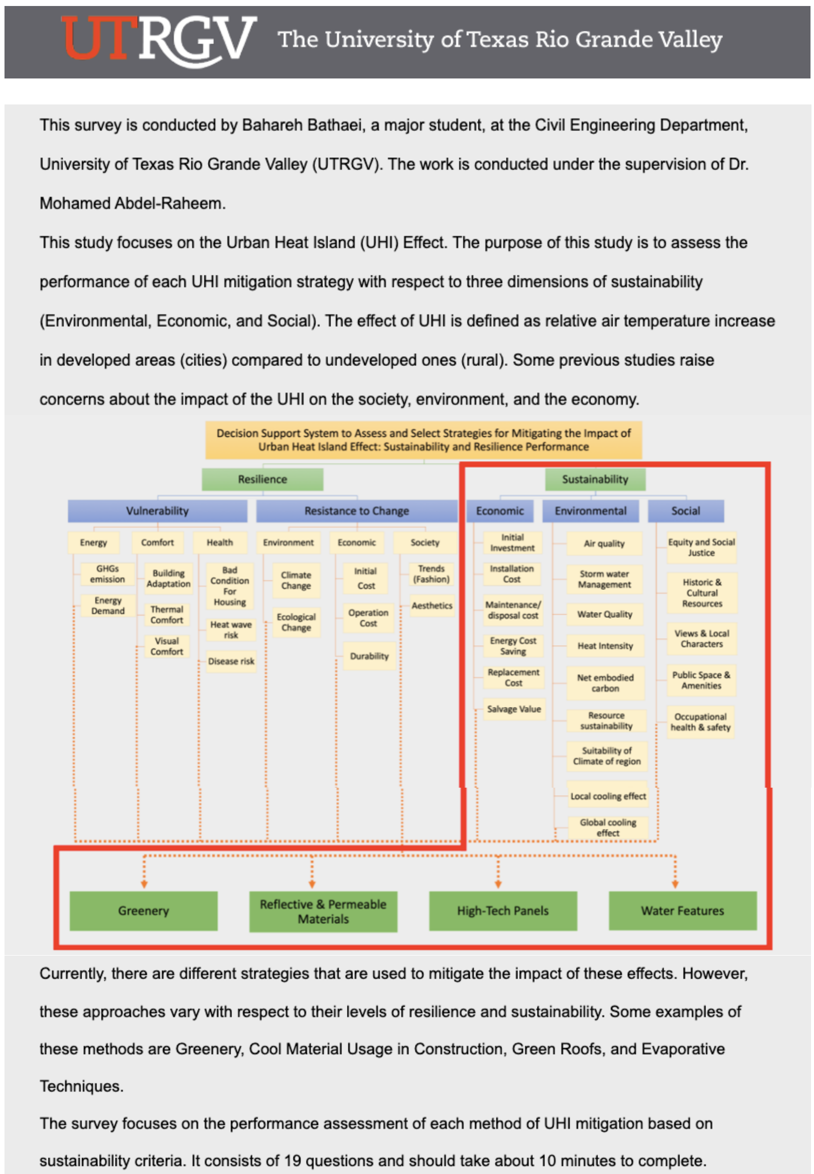
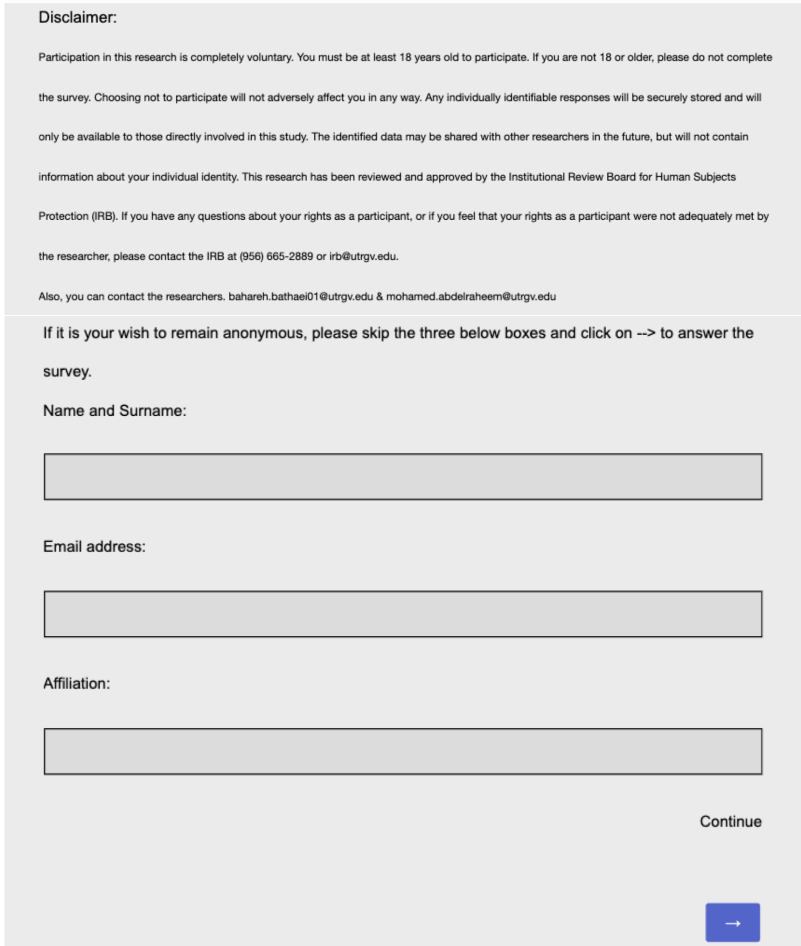


Figure 17: Introduction slide of the 2nd part of expert elicitation on Qualtrics XM



Disclaimer:

Participation in this research is completely voluntary. You must be at least 18 years old to participate. If you are not 18 or older, please do not complete the survey. Choosing not to participate will not adversely affect you in any way. Any individually identifiable responses will be securely stored and will only be available to those directly involved in this study. The identified data may be shared with other researchers in the future, but will not contain information about your individual identity. This research has been reviewed and approved by the Institutional Review Board for Human Subjects Protection (IRB). If you have any questions about your rights as a participant, or if you feel that your rights as a participant were not adequately met by the researcher, please contact the IRB at (956) 665-2889 or irb@utrgv.edu.

Also, you can contact the researchers. bahareh.bathaei01@utrgv.edu & mohamed.abdelraheem@utrgv.edu

If it is your wish to remain anonymous, please skip the three below boxes and click on --> to answer the survey.

Name and Surname:

Email address:

Affiliation:

Continue

→

Figure 18: Descriptive question of the 2nd part of expert elicitation on Qualtrics XM

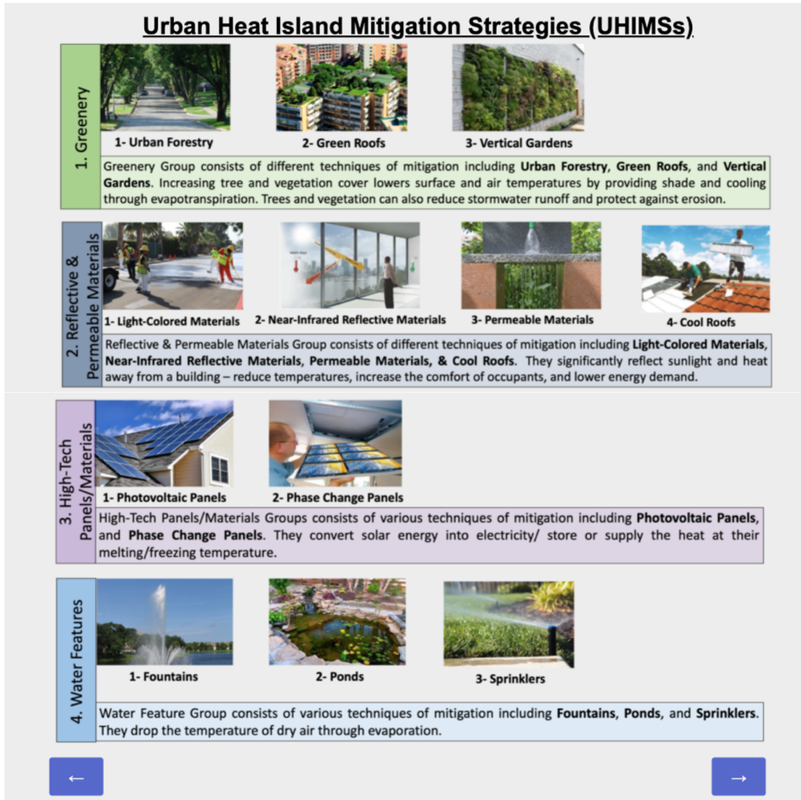


Figure 19: UHIMSs introduction slide of the 2nd part of expert elicitation on Qualtrics XM

Figure 20: Economic sustainability introduction slide of the 2nd part of expert elicitation on Qualtrics XM

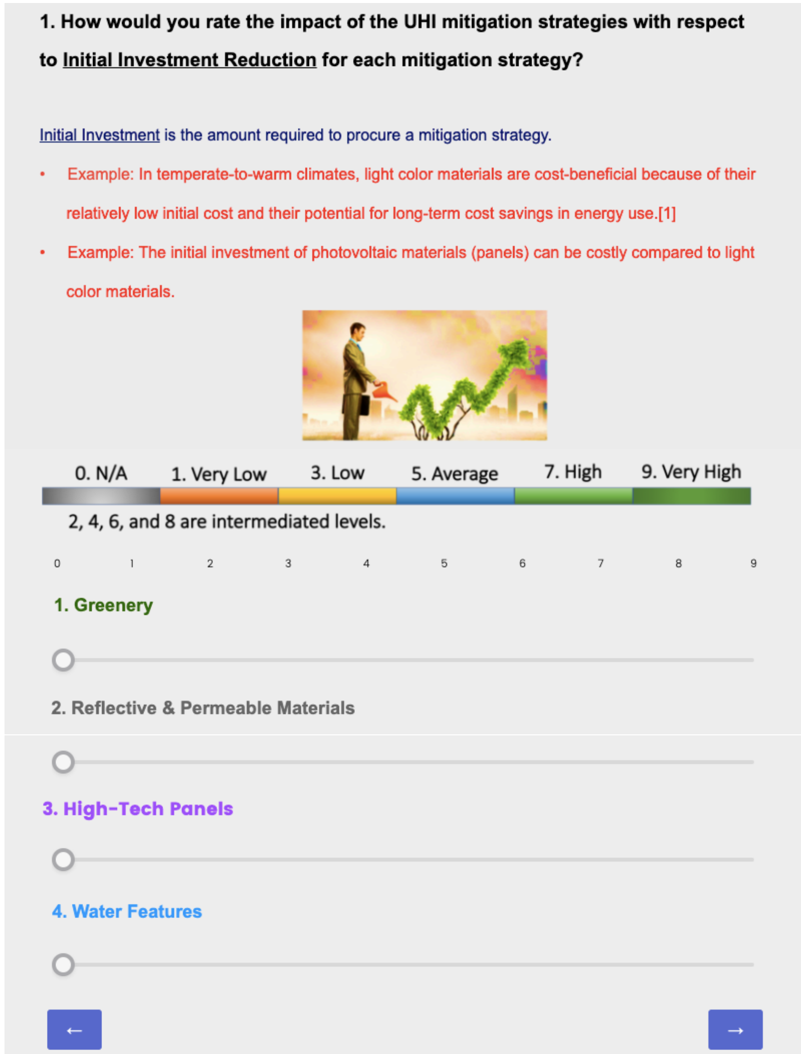
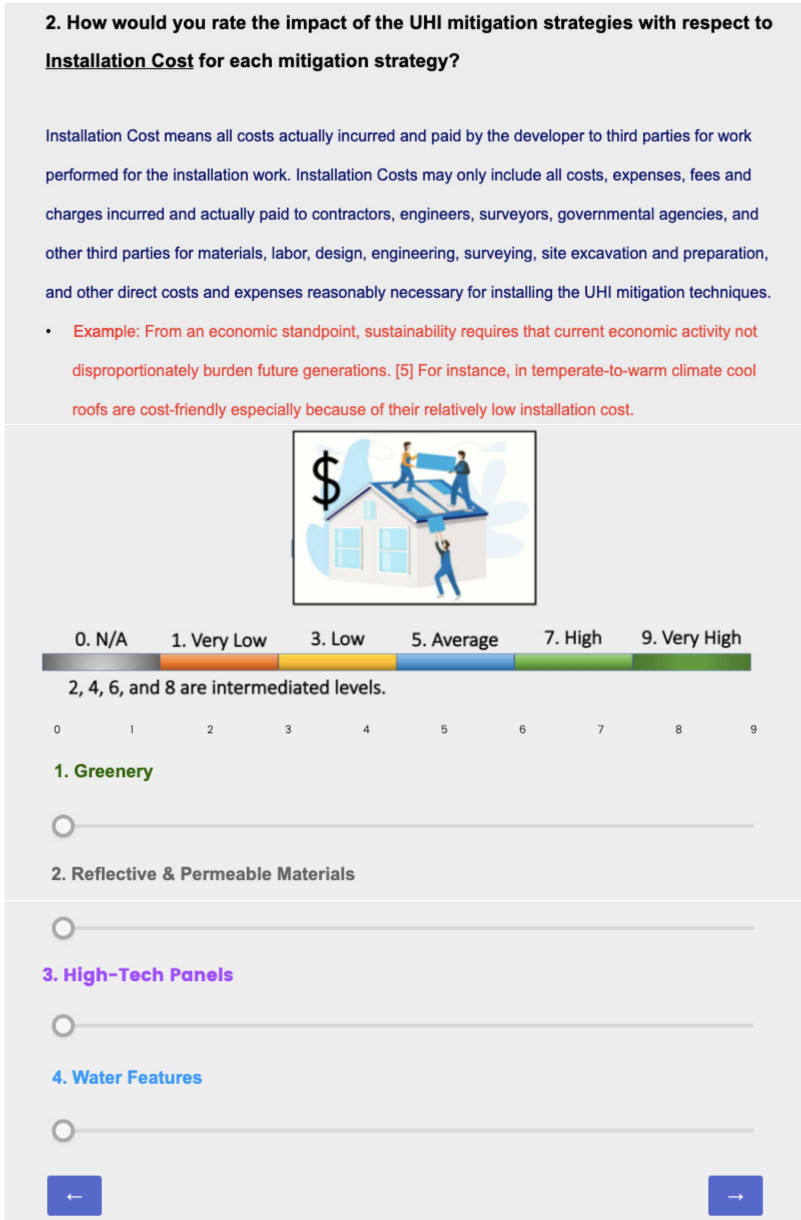


Figure 21: Question 1 of the 2nd part of expert elicitation on Qualtrics XM



2. How would you rate the impact of the UHI mitigation strategies with respect to Installation Cost for each mitigation strategy?

Installation Cost means all costs actually incurred and paid by the developer to third parties for work performed for the installation work. Installation Costs may only include all costs, expenses, fees and charges incurred and actually paid to contractors, engineers, surveyors, governmental agencies, and other third parties for materials, labor, design, engineering, surveying, site excavation and preparation, and other direct costs and expenses reasonably necessary for installing the UHI mitigation techniques.

- Example: From an economic standpoint, sustainability requires that current economic activity not disproportionately burden future generations. [5] For instance, in temperate-to-warm climate cool roofs are cost-friendly especially because of their relatively low installation cost.

1. Greenery

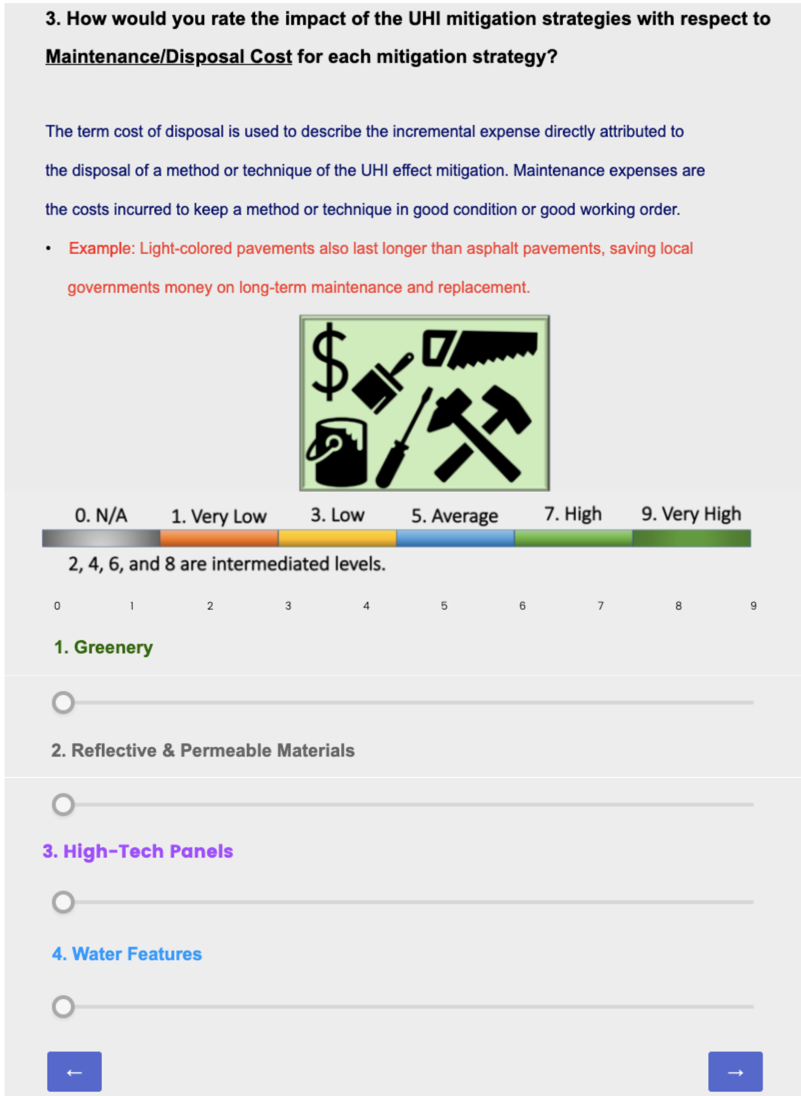
2. Reflective & Permeable Materials

3. High-Tech Panels

4. Water Features

← →

Figure 22: Question 2 of the 2nd part of expert elicitation on Qualtrics XM



3. How would you rate the impact of the UHI mitigation strategies with respect to Maintenance/Disposal Cost for each mitigation strategy?

The term cost of disposal is used to describe the incremental expense directly attributed to the disposal of a method or technique of the UHI effect mitigation. Maintenance expenses are the costs incurred to keep a method or technique in good condition or good working order.

- Example: Light-colored pavements also last longer than asphalt pavements, saving local governments money on long-term maintenance and replacement.

0. N/A 1. Very Low 3. Low 5. Average 7. High 9. Very High

2, 4, 6, and 8 are intermediated levels.

0 1 2 3 4 5 6 7 8 9

1. Greenery

2. Reflective & Permeable Materials

3. High-Tech Panels

4. Water Features

← →

Figure 23: Question 3 of the 2nd part of expert elicitation on Qualtrics XM


4. How would you rate the impact of the UHI mitigation strategies with respect to Energy Cost Saving for each mitigation strategy?

Energy Cost Saving means a reduction in the cost of energy and related operation and maintenance expenses due to applying the techniques of UHI mitigation.

- Example: Cool roofs decrease summer cooling costs, but they can increase winter heating costs because they reflect heat year-round. In contrast, green roofs act as insulation and so can lower energy costs in both summer and winter (retaining heat indoors). So, they can be used in more northern climates where cool roofs are not recommended.[1]

0. N/A 1. Very Low 3. Low 5. Average 7. High 9. Very High

2, 4, 6, and 8 are intermediated levels.

0 1 2 3 4 5 6 7 8 9

1. Greenery

2. Reflective & Permeable Materials

3. High-Tech Panels

4. Water Features

← →

Figure 24: Question 4 of the 2nd part of expert elicitation on Qualtrics XM

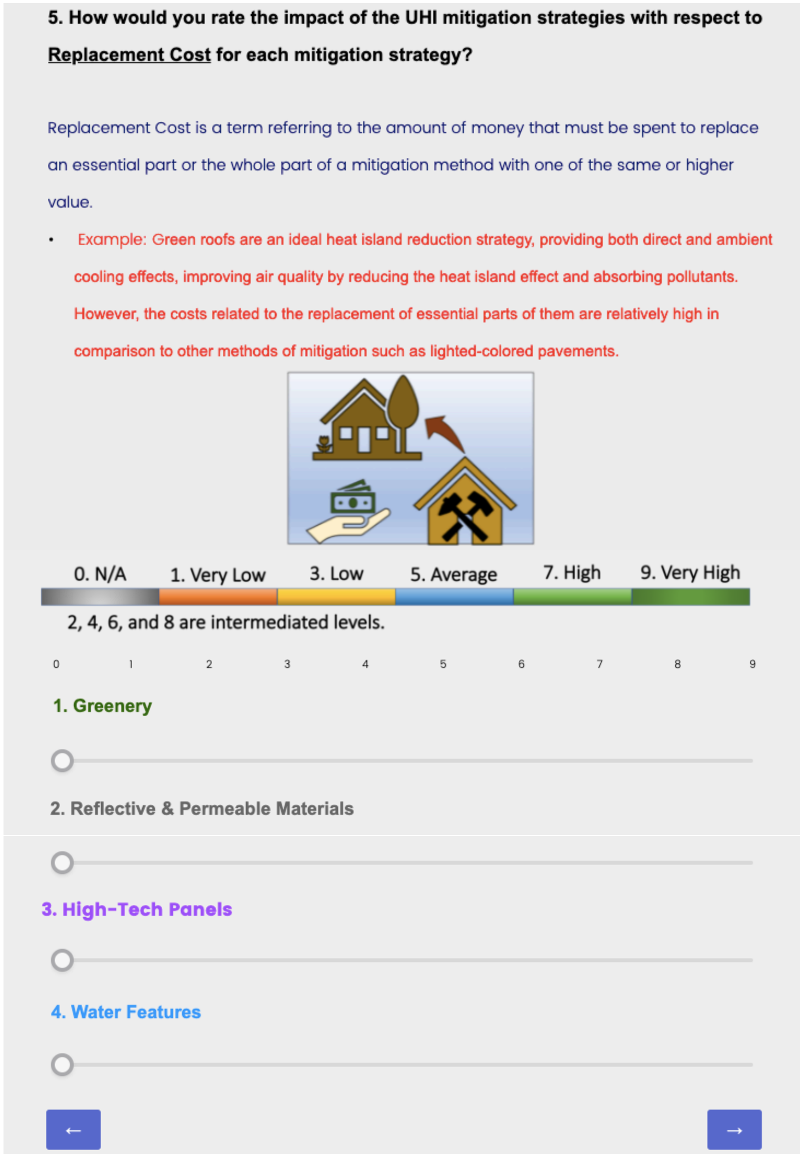


Figure 25: Question 5 of the 2nd part of expert elicitation on Qualtrics XM

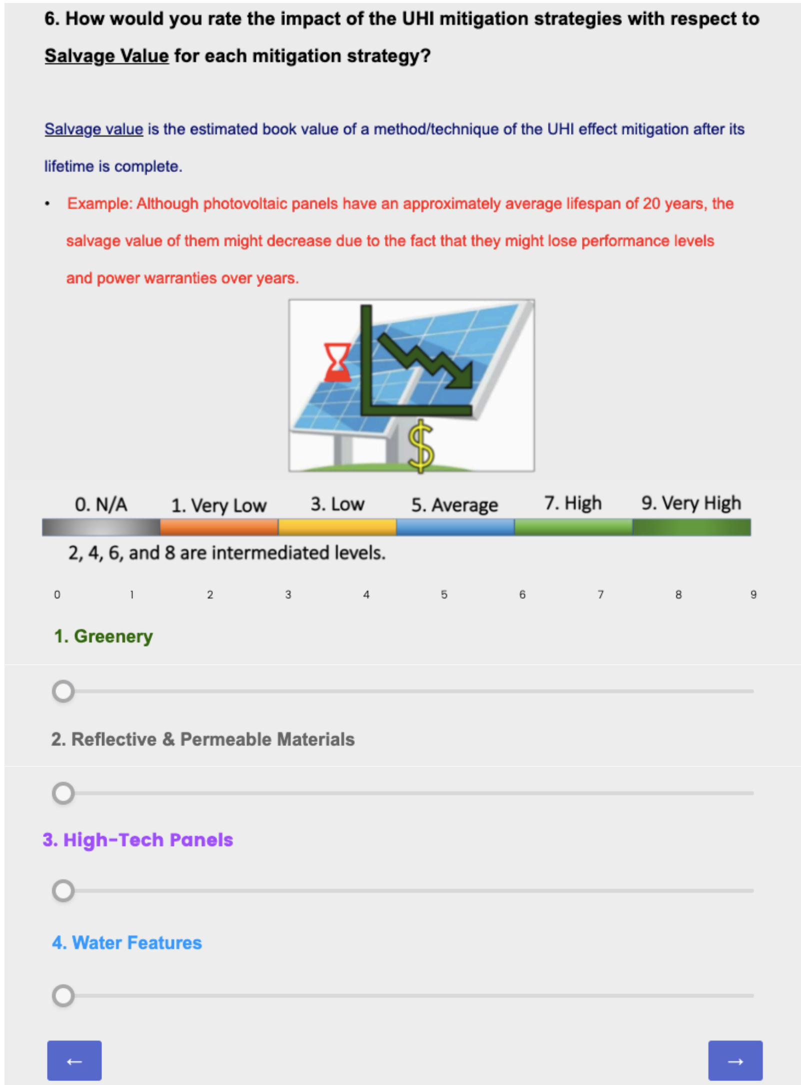


Figure 26: Question 6 of the 2nd part of expert elicitation on Qualtrics XM

Figure 27: Environmental sustainability introduction slide of the 2nd part of expert elicitation on Qualtrics XM

7. How would you rate the impact of the UHI mitigation strategies with respect to Air Quality for each mitigation strategy?

Air Quality: It is the degree to which the ambient air is pollution-free assessed by measuring a number of indicators of pollution.

- Example: Greenery techniques improve air quality and reduce greenhouse gas emissions.

0. N/A 1. Very Low 3. Low 5. Average 7. High 9. Very High

2, 4, 6, and 8 are intermediated levels.

0 1 2 3 4 5 6 7 8 9

1. Greenery

2. Reflective & Permeable Materials

3. High-Tech Panels

4. Water Features

Figure 28: Question 7 of the 2nd part of expert elicitation on Qualtrics XM


8. How would you rate the impact of the UHI mitigation strategies with respect to Stormwater Management for each mitigation strategy?

Stormwater Management is reducing runoff of rainwater or melted snow into streets, lawns, and other sites and the improvement of water quality.

- Example: Unlike cool roofs, green roofs, and urban forestry techniques also reduce stormwater runoff because, depending on the vegetation and time of year, they retain up to 90 percent of rainfall.

Stormwater Management

0. N/A | 1. Very Low | 3. Low | 5. Average | 7. High | 9. Very High

2, 4, 6, and 8 are intermediated levels.

0 1 2 3 4 5 6 7 8 9

1. Greenery

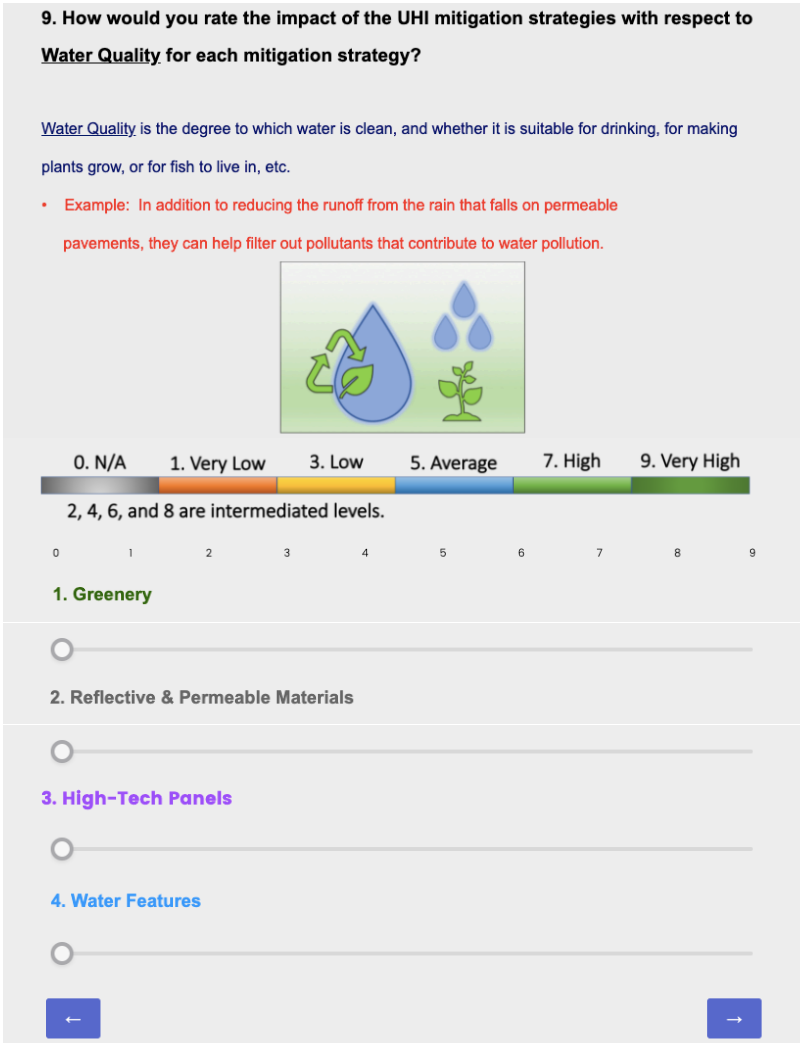
2. Reflective & Permeable Materials

3. High-Tech Panels

4. Water Features

← →

Figure 29: Question 8 of the 2nd part of expert elicitation on Qualtrics XM


9. How would you rate the impact of the UHI mitigation strategies with respect to Water Quality for each mitigation strategy?

Water Quality is the degree to which water is clean, and whether it is suitable for drinking, for making plants grow, or for fish to live in, etc.

- Example: In addition to reducing the runoff from the rain that falls on permeable pavements, they can help filter out pollutants that contribute to water pollution.

0. N/A 1. Very Low 3. Low 5. Average 7. High 9. Very High

2, 4, 6, and 8 are intermediated levels.

0 1 2 3 4 5 6 7 8 9

1. Greenery

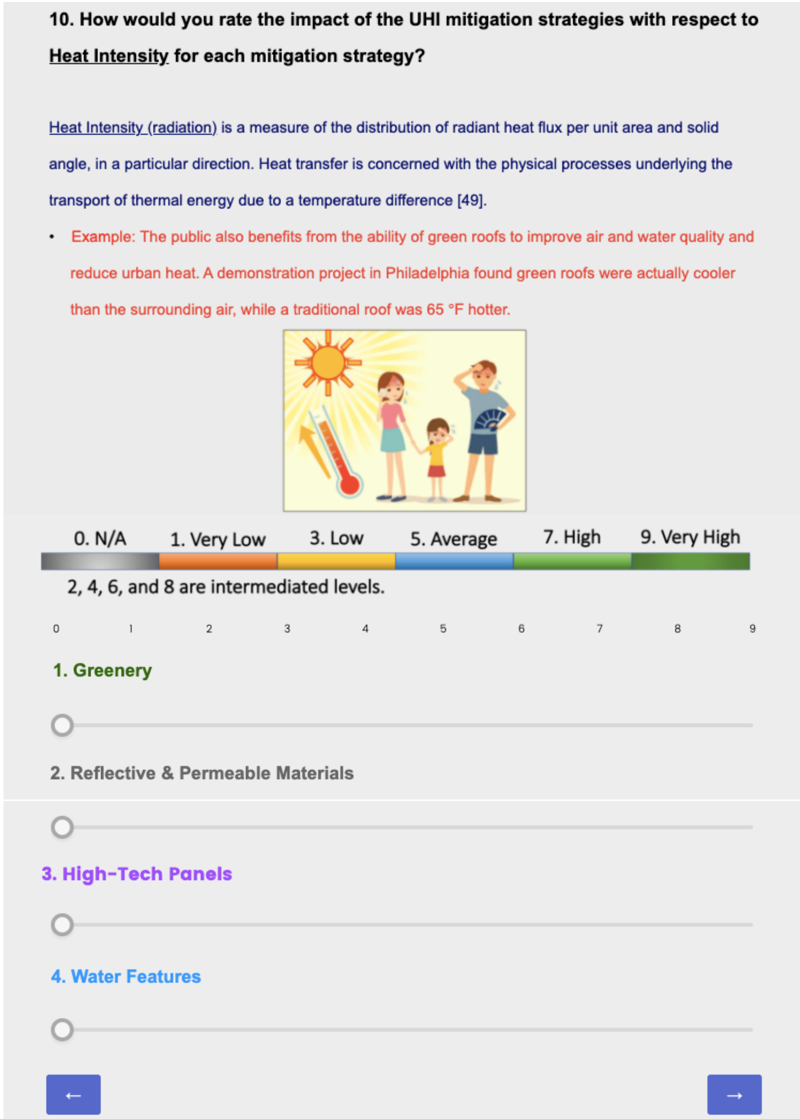
2. Reflective & Permeable Materials

3. High-Tech Panels

4. Water Features

← →

Figure 30: Question 9 of the 2nd part of expert elicitation on Qualtrics XM



10. How would you rate the impact of the UHI mitigation strategies with respect to Heat Intensity for each mitigation strategy?

Heat Intensity (radiation) is a measure of the distribution of radiant heat flux per unit area and solid angle, in a particular direction. Heat transfer is concerned with the physical processes underlying the transport of thermal energy due to a temperature difference [49].

- Example: The public also benefits from the ability of green roofs to improve air and water quality and reduce urban heat. A demonstration project in Philadelphia found green roofs were actually cooler than the surrounding air, while a traditional roof was 65 °F hotter.

0. N/A | 1. Very Low | 3. Low | 5. Average | 7. High | 9. Very High

2, 4, 6, and 8 are intermediated levels.

0 1 2 3 4 5 6 7 8 9

1. Greenery

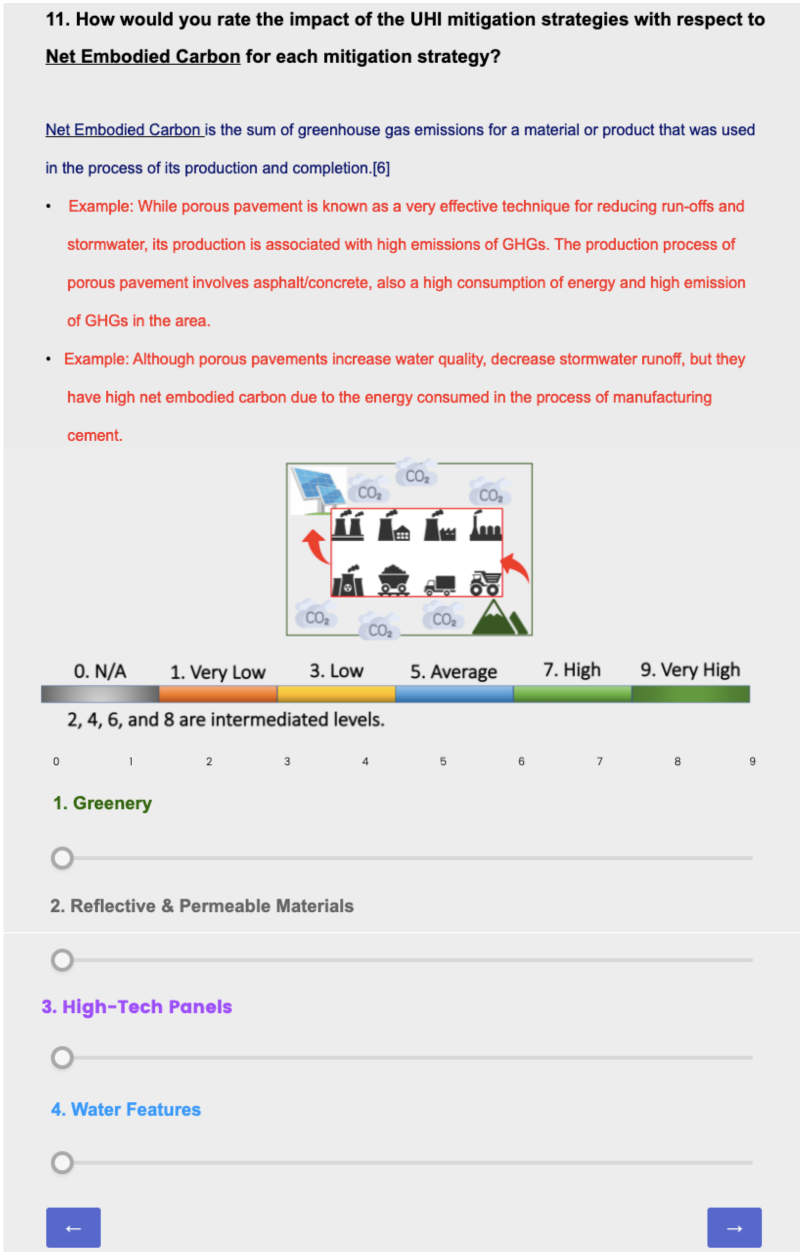
2. Reflective & Permeable Materials

3. High-Tech Panels

4. Water Features

← →

Figure 31: Question 10 of the 2nd part of expert elicitation on Qualtrics XM



11. How would you rate the impact of the UHI mitigation strategies with respect to Net Embodied Carbon for each mitigation strategy?

Net Embodied Carbon is the sum of greenhouse gas emissions for a material or product that was used in the process of its production and completion.[6]

- Example: While porous pavement is known as a very effective technique for reducing run-offs and stormwater, its production is associated with high emissions of GHGs. The production process of porous pavement involves asphalt/concrete, also a high consumption of energy and high emission of GHGs in the area.
- Example: Although porous pavements increase water quality, decrease stormwater runoff, but they have high net embodied carbon due to the energy consumed in the process of manufacturing cement.

0. N/A | 1. Very Low | 3. Low | 5. Average | 7. High | 9. Very High

2, 4, 6, and 8 are intermediated levels.

0 1 2 3 4 5 6 7 8 9

1. Greenery

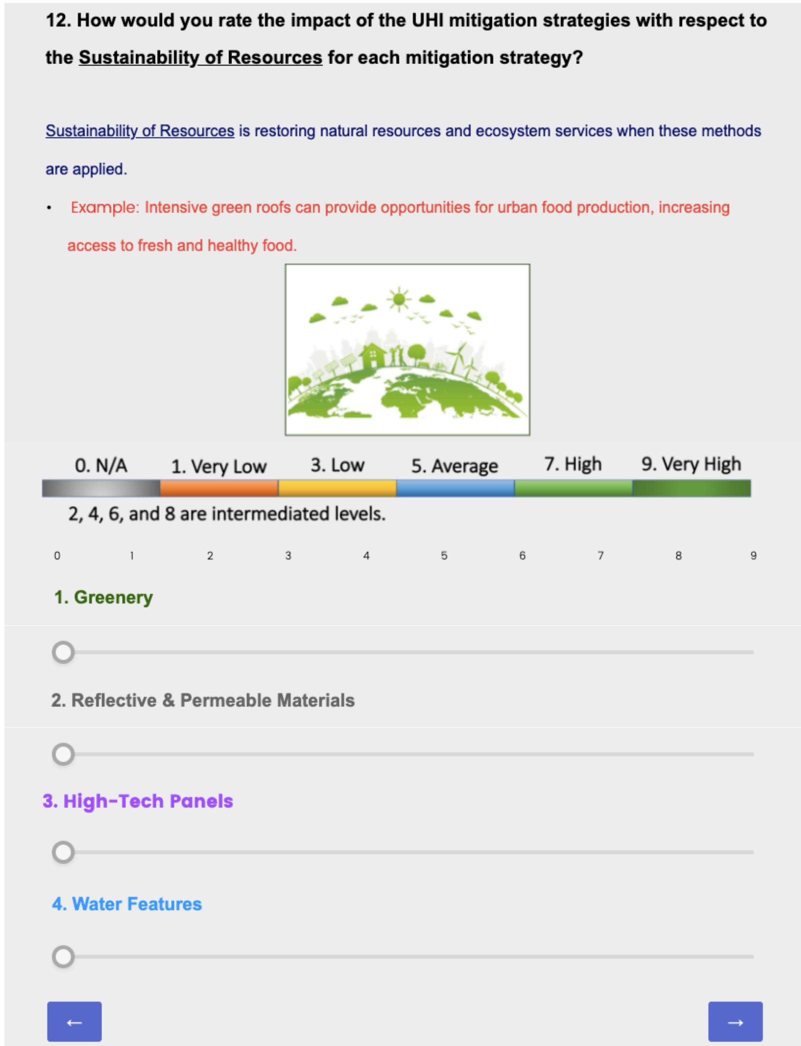
2. Reflective & Permeable Materials

3. High-Tech Panels

4. Water Features

← →

Figure 32: Question 11 of the 2nd part of expert elicitation on Qualtrics XM



12. How would you rate the impact of the UHI mitigation strategies with respect to the Sustainability of Resources for each mitigation strategy?

Sustainability of Resources is restoring natural resources and ecosystem services when these methods are applied.

- Example: Intensive green roofs can provide opportunities for urban food production, increasing access to fresh and healthy food.

0. N/A | 1. Very Low | 3. Low | 5. Average | 7. High | 9. Very High

2, 4, 6, and 8 are intermediated levels.

0 1 2 3 4 5 6 7 8 9

1. Greenery

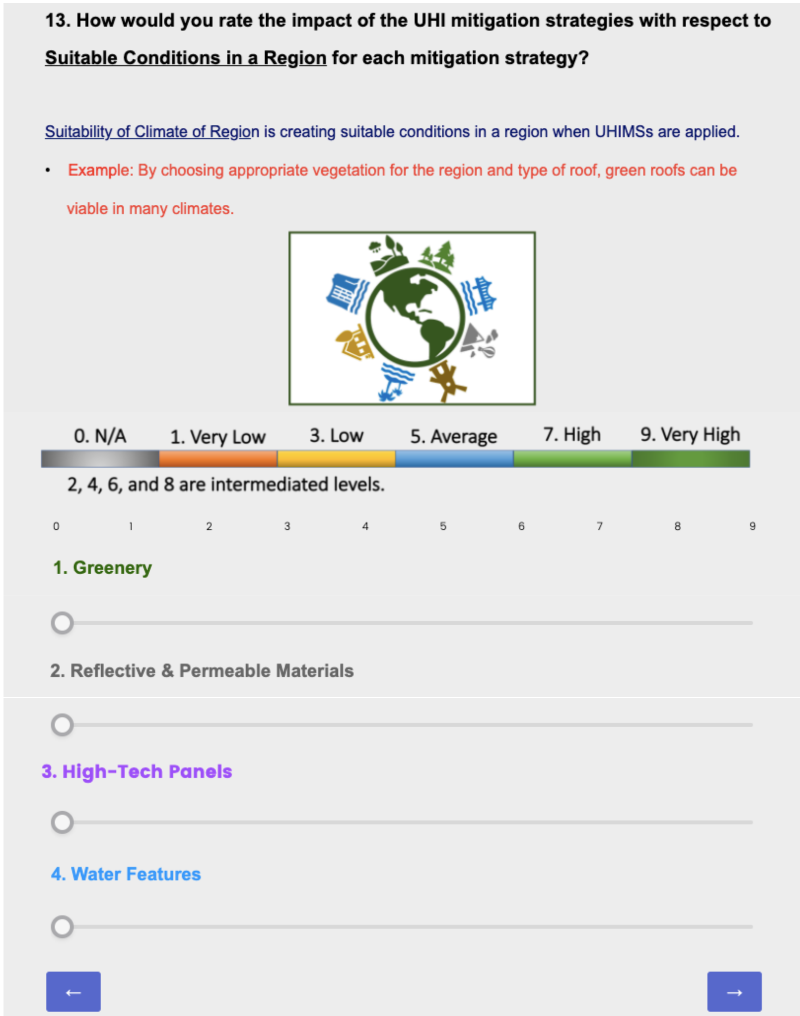
2. Reflective & Permeable Materials

3. High-Tech Panels

4. Water Features

← →

Figure 33: Question 12 of the 2nd part of expert elicitation on Qualtrics XM



13. How would you rate the impact of the UHI mitigation strategies with respect to Suitable Conditions in a Region for each mitigation strategy?

Suitability of Climate of Region is creating suitable conditions in a region when UHIMSs are applied.

- Example: By choosing appropriate vegetation for the region and type of roof, green roofs can be viable in many climates.

0. N/A | 1. Very Low | 3. Low | 5. Average | 7. High | 9. Very High

2, 4, 6, and 8 are intermediated levels.

0 1 2 3 4 5 6 7 8 9

1. Greenery

2. Reflective & Permeable Materials

3. High-Tech Panels

4. Water Features

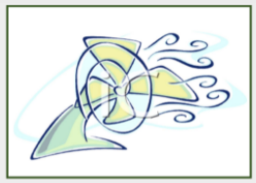
← →

Figure 34: Question 13 of the 2nd part of expert elicitation on Qualtrics XM

14. How would you rate the impact of the UHI mitigation strategies with respect to the Local Cooling Effect for each mitigation strategy?

The local Cooling effect is the most common type of cooling. It is referring to some UHIMSs that provide cooling only for the building and its surrounding area but the heat will be trapped near the earth by greenhouse gases.

- Example: Green roofs may provide the local cooling effect. They absorb water from their soil and emit it back into the air, where ambient heat converts the water into vapor, a process known as evapotranspiration. While this cools both individual buildings and surrounding areas, the heat can be trapped near the earth by greenhouse gases.



0. N/A 1. Very Low 3. Low 5. Average 7. High 9. Very High

2, 4, 6, and 8 are intermediated levels.

0 1 2 3 4 5 6 7 8 9

1. Greenery

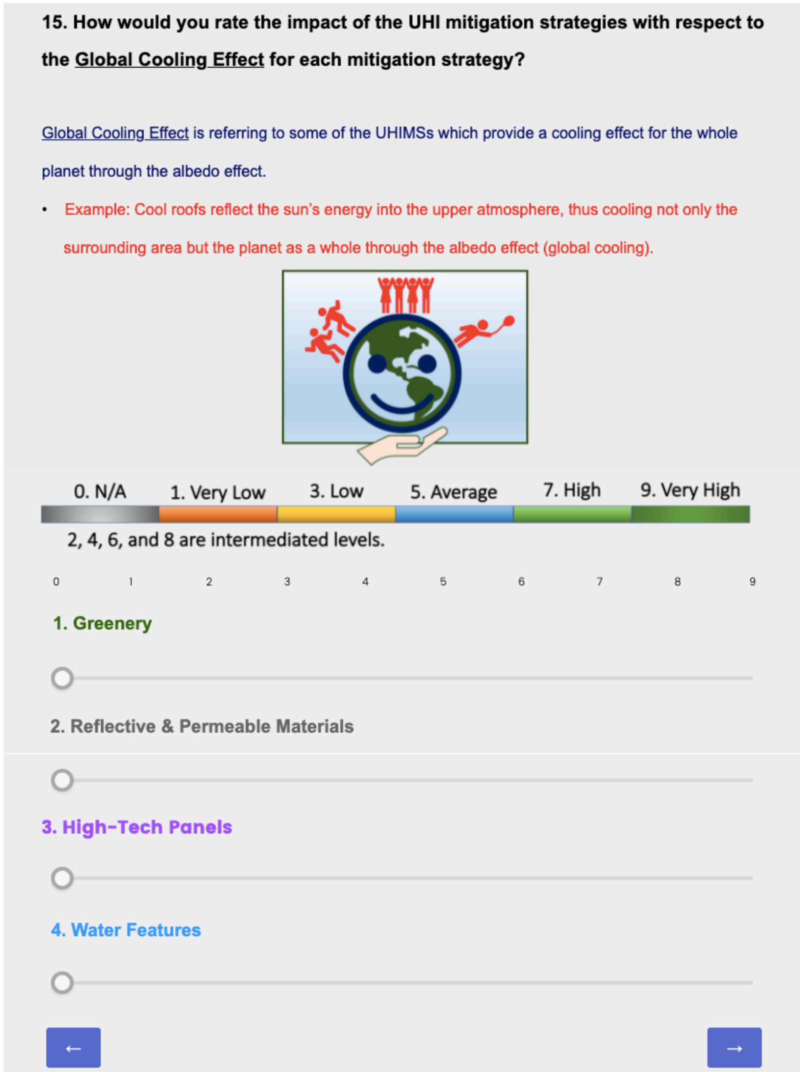
2. Reflective & Permeable Materials

3. High-Tech Panels

4. Water Features

← →

Figure 35: Question 14 of the 2nd part of expert elicitation on Qualtrics XM



15. How would you rate the impact of the UHI mitigation strategies with respect to the Global Cooling Effect for each mitigation strategy?

Global Cooling Effect is referring to some of the UHIMSs which provide a cooling effect for the whole planet through the albedo effect.

- Example: Cool roofs reflect the sun's energy into the upper atmosphere, thus cooling not only the surrounding area but the planet as a whole through the albedo effect (global cooling).

0. N/A 1. Very Low 3. Low 5. Average 7. High 9. Very High

2, 4, 6, and 8 are intermediated levels.

0 1 2 3 4 5 6 7 8 9

1. Greenery

2. Reflective & Permeable Materials

3. High-Tech Panels

4. Water Features

← →

Figure 36: Question 15 of the 2nd part of expert elicitation on Qualtrics XM

Figure 37: Social sustainability introduction slide of the 2nd part of expert elicitation on Qualtrics XM

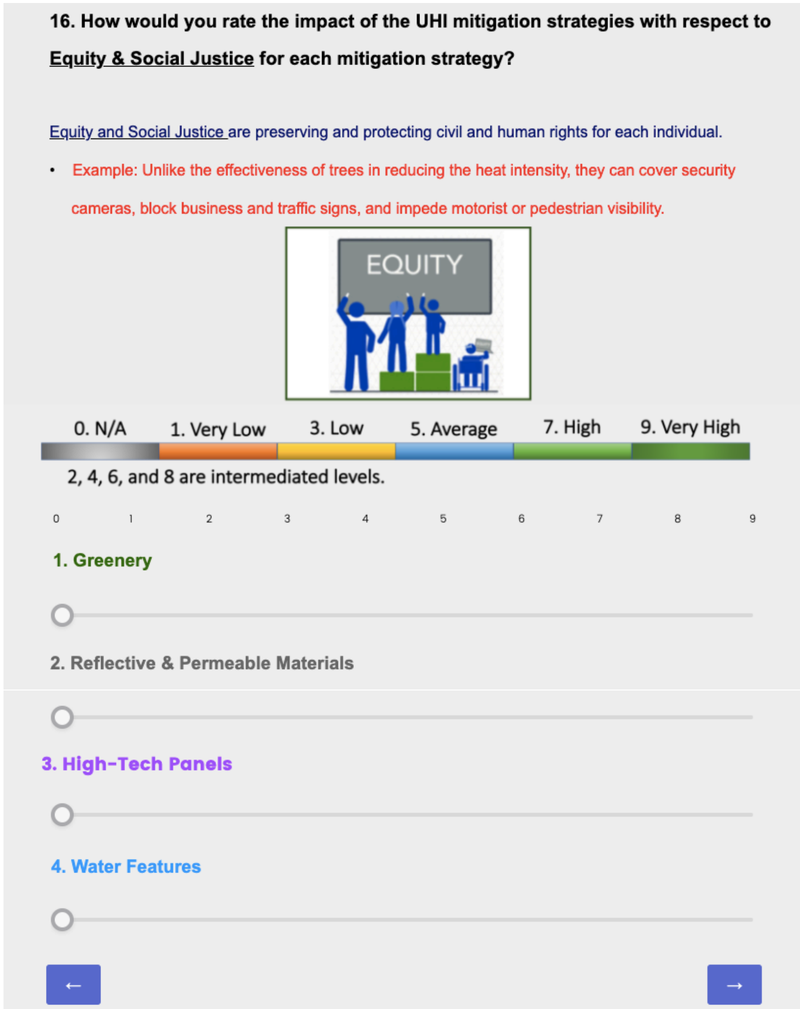
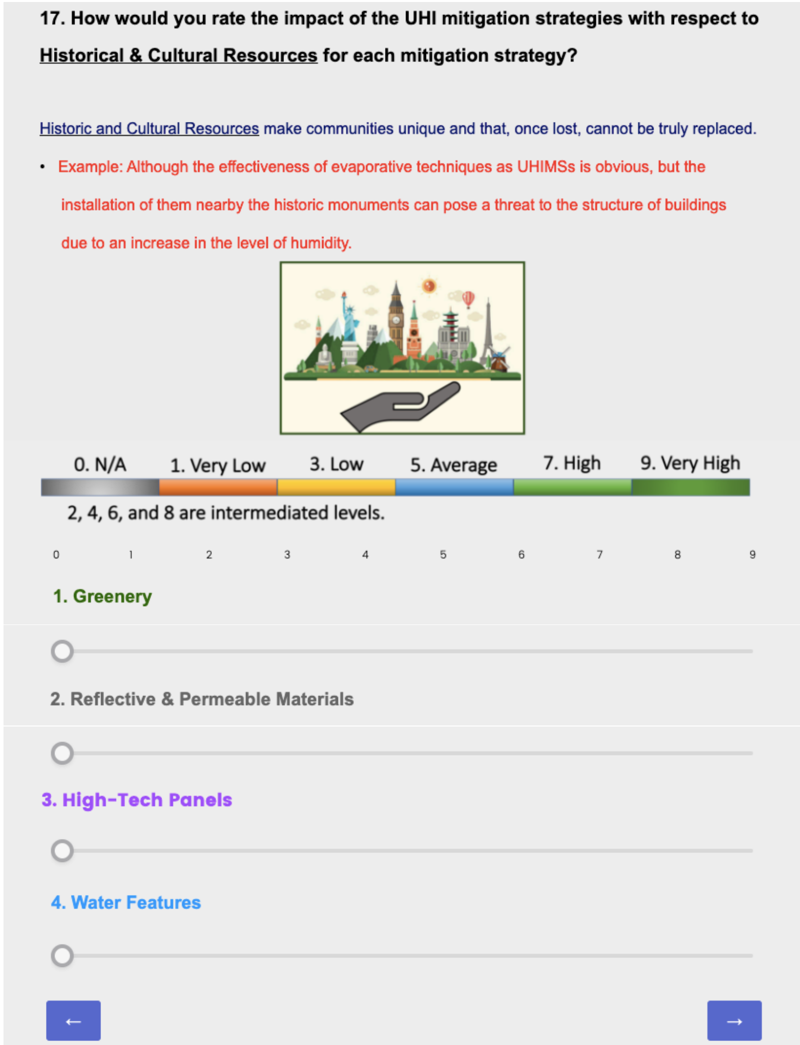


Figure 38: Question 16 of the 2nd part of expert elicitation on Qualtrics XM



17. How would you rate the impact of the UHI mitigation strategies with respect to Historical & Cultural Resources for each mitigation strategy?

Historic and Cultural Resources make communities unique and that, once lost, cannot be truly replaced.

- Example: Although the effectiveness of evaporative techniques as UHIMSs is obvious, but the installation of them nearby the historic monuments can pose a threat to the structure of buildings due to an increase in the level of humidity.

0. N/A 1. Very Low 3. Low 5. Average 7. High 9. Very High

2, 4, 6, and 8 are intermediated levels.

0 1 2 3 4 5 6 7 8 9

1. Greenery

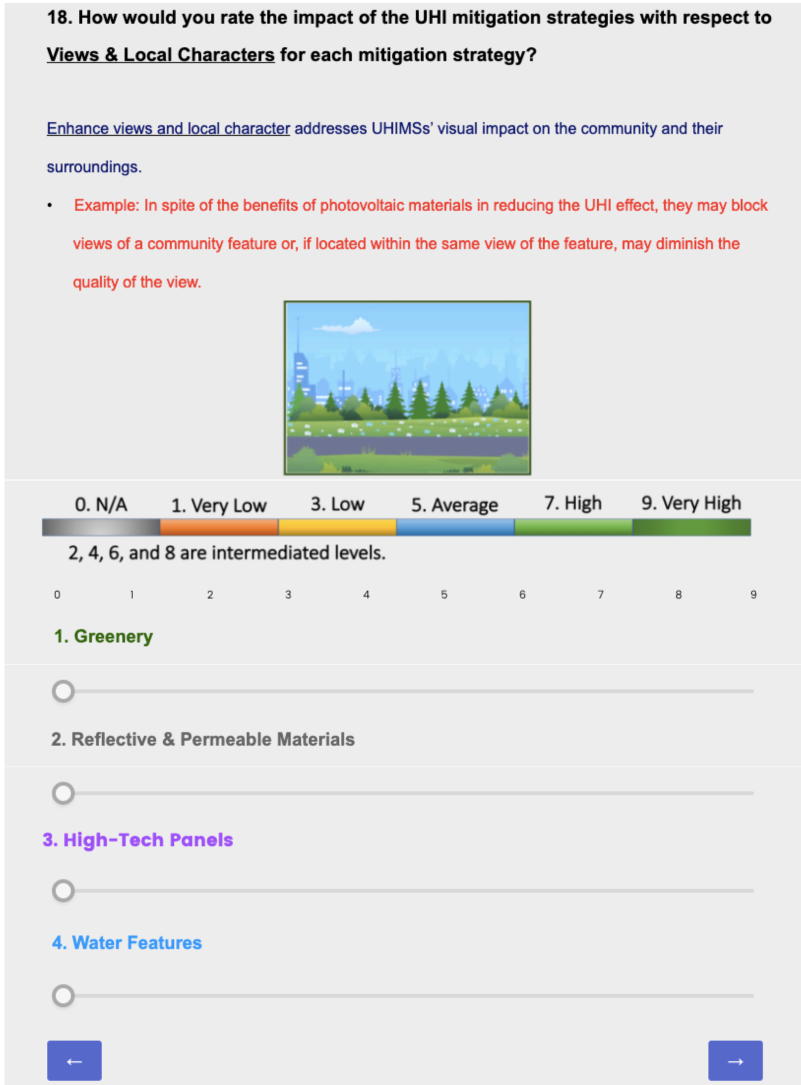
2. Reflective & Permeable Materials

3. High-Tech Panels

4. Water Features

← →

Figure 39: Question 17 of the 2nd part of expert elicitation on Qualtrics XM


18. How would you rate the impact of the UHI mitigation strategies with respect to Views & Local Characters for each mitigation strategy?

Enhance views and local character addresses UHIMSs' visual impact on the community and their surroundings.

- Example: In spite of the benefits of photovoltaic materials in reducing the UHI effect, they may block views of a community feature or, if located within the same view of the feature, may diminish the quality of the view.

0. N/A 1. Very Low 3. Low 5. Average 7. High 9. Very High

2, 4, 6, and 8 are intermediated levels.

0 1 2 3 4 5 6 7 8 9

1. Greenery

2. Reflective & Permeable Materials

3. High-Tech Panels

4. Water Features

← →

Figure 40: Question 18 of the 2nd part of expert elicitation on Qualtrics XM

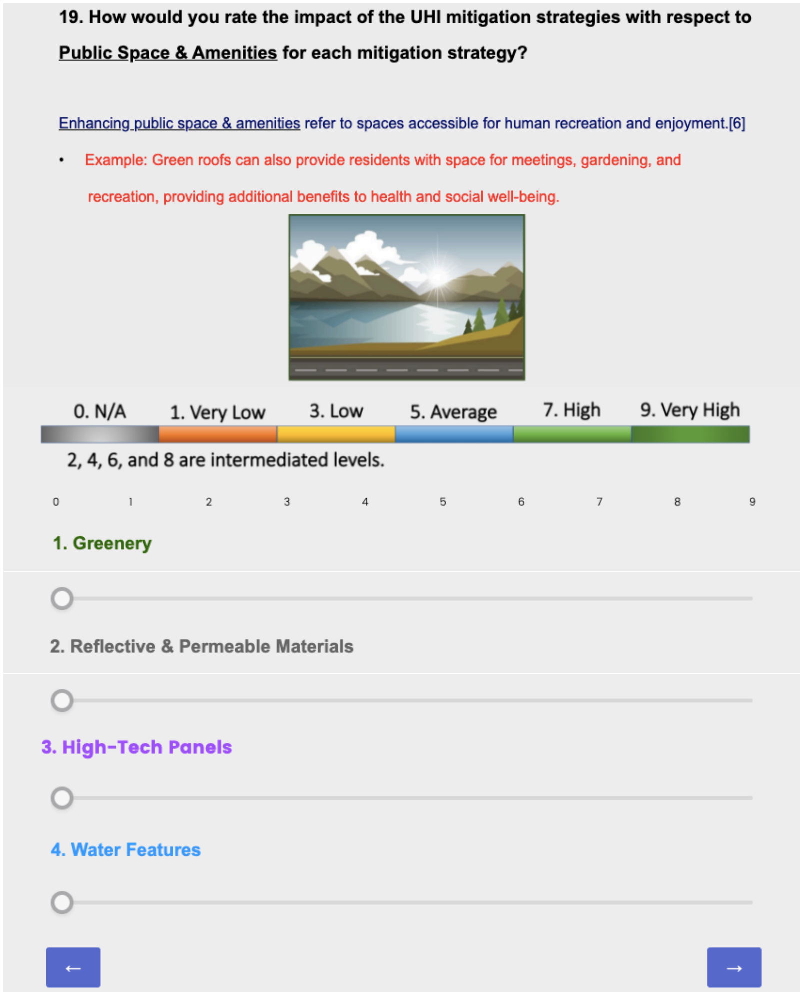


Figure 41: Question 19 of the 2nd part of expert elicitation on Qualtrics XM

APPENDIX C

APPENDIX C

EXPERT ELICITATION EXERCISE PART 3

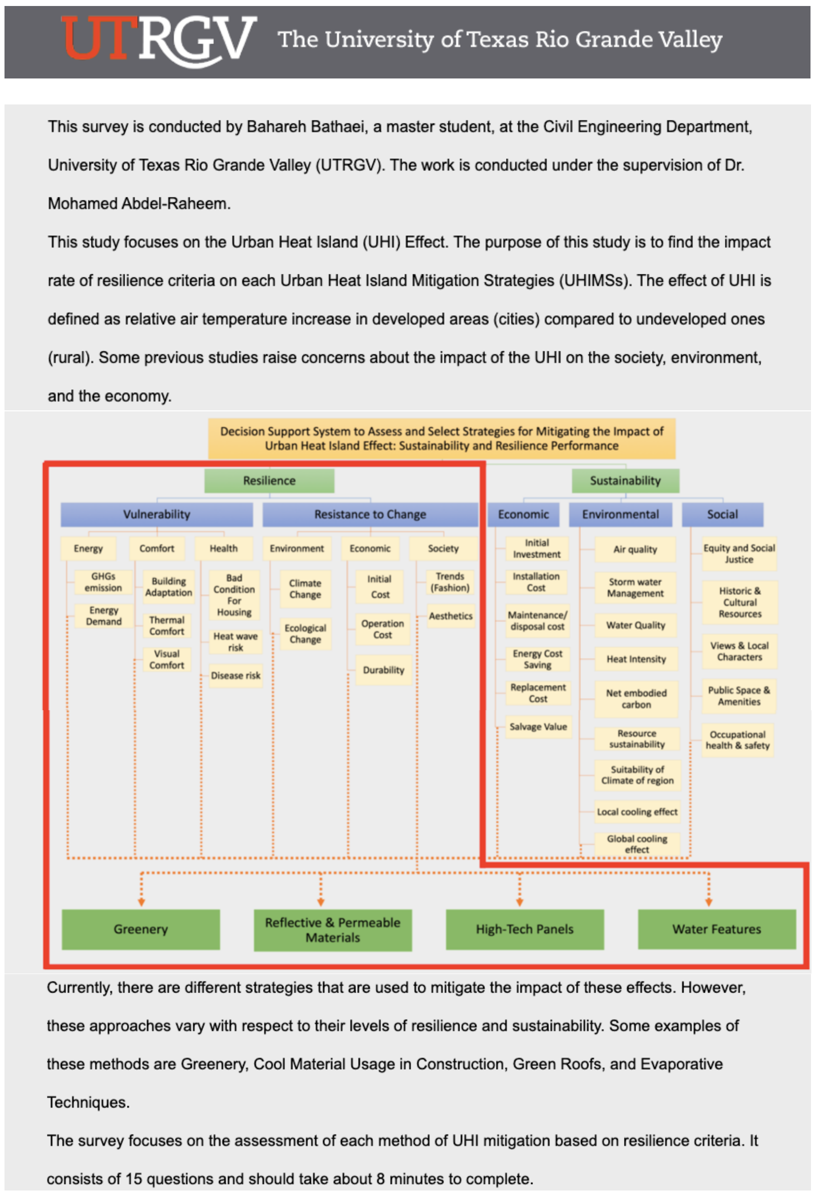
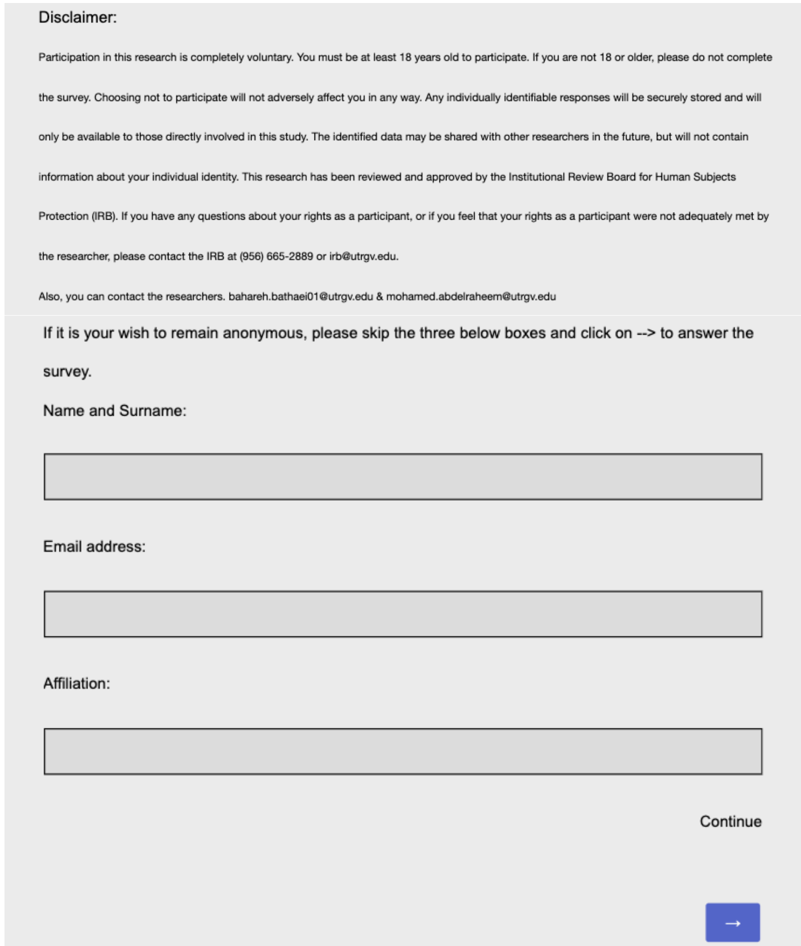


Figure 42: Introduction slide of the 3rd part of expert elicitation on Qualtrics XM



Disclaimer:

Participation in this research is completely voluntary. You must be at least 18 years old to participate. If you are not 18 or older, please do not complete the survey. Choosing not to participate will not adversely affect you in any way. Any individually identifiable responses will be securely stored and will only be available to those directly involved in this study. The identified data may be shared with other researchers in the future, but will not contain information about your individual identity. This research has been reviewed and approved by the Institutional Review Board for Human Subjects Protection (IRB). If you have any questions about your rights as a participant, or if you feel that your rights as a participant were not adequately met by the researcher, please contact the IRB at (956) 665-2889 or irb@utrgv.edu.

Also, you can contact the researchers. bahareh.bathaei01@utrgv.edu & mohamed.abdelraheem@utrgv.edu

If it is your wish to remain anonymous, please skip the three below boxes and click on --> to answer the survey.

Name and Surname:

Email address:

Affiliation:

Continue

→

Figure 43: Descriptive question of the 3rd part of expert elicitation on Qualtrics XM

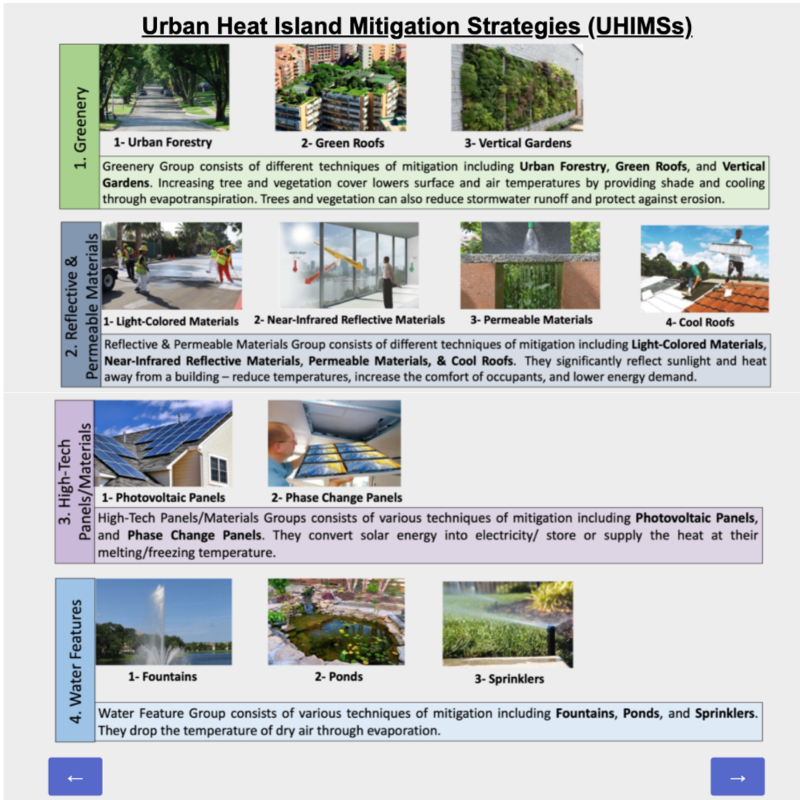


Figure 44: UHIMSs introduction slide of the 3rd part of expert elicitation on Qualtrics XM

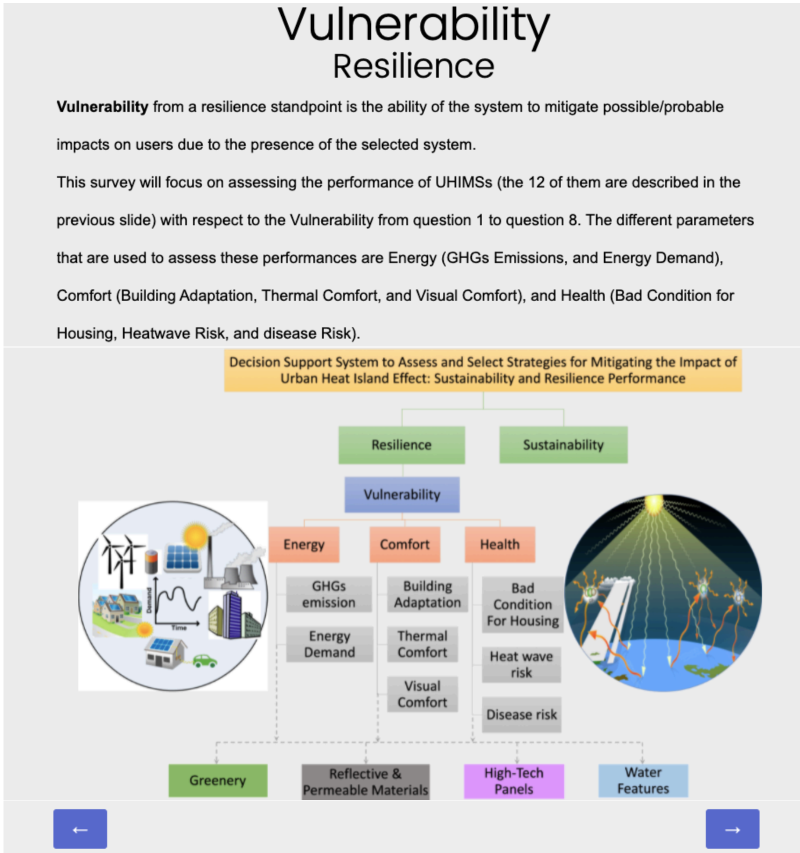


Figure 45: Vulnerability introduction slide of the 3rd part of expert elicitation on Qualtrics XM

1. How would you rate the impact of the UHI mitigation strategies with respect to the Greenhouse Gas Emission associated with their installation and operation?

The objective is to reduce the users' vulnerability and enhance the overall resilience by minimizing GHGs emissions.

Greenhouse Gases (GHGs) are "chemical compounds in the earth's atmosphere that absorb and emit radiation, which causes the greenhouse effect that affects the regulation of the earth's temperature. Water vapor (H2O), carbon dioxide (CO2), nitrous oxide (N2O), methane (CH2), and fluorinated gases" are examples of these compounds.[6]

- Example: While mitigation methods like light color materials do not generate GHGs, others like water sprinklers or fountains indirectly generate GHGs due to their dependency on electricity for running and their electricity is supplied from generating plants that might use fossil fuels.

0. N/A | 1. Very Low | 3. Low | 5. Average | 7. High | 9. Very High

2, 4, 6, and 8 are intermediated levels.

0 1 2 3 4 5 6 7 8 9

1. Greenery

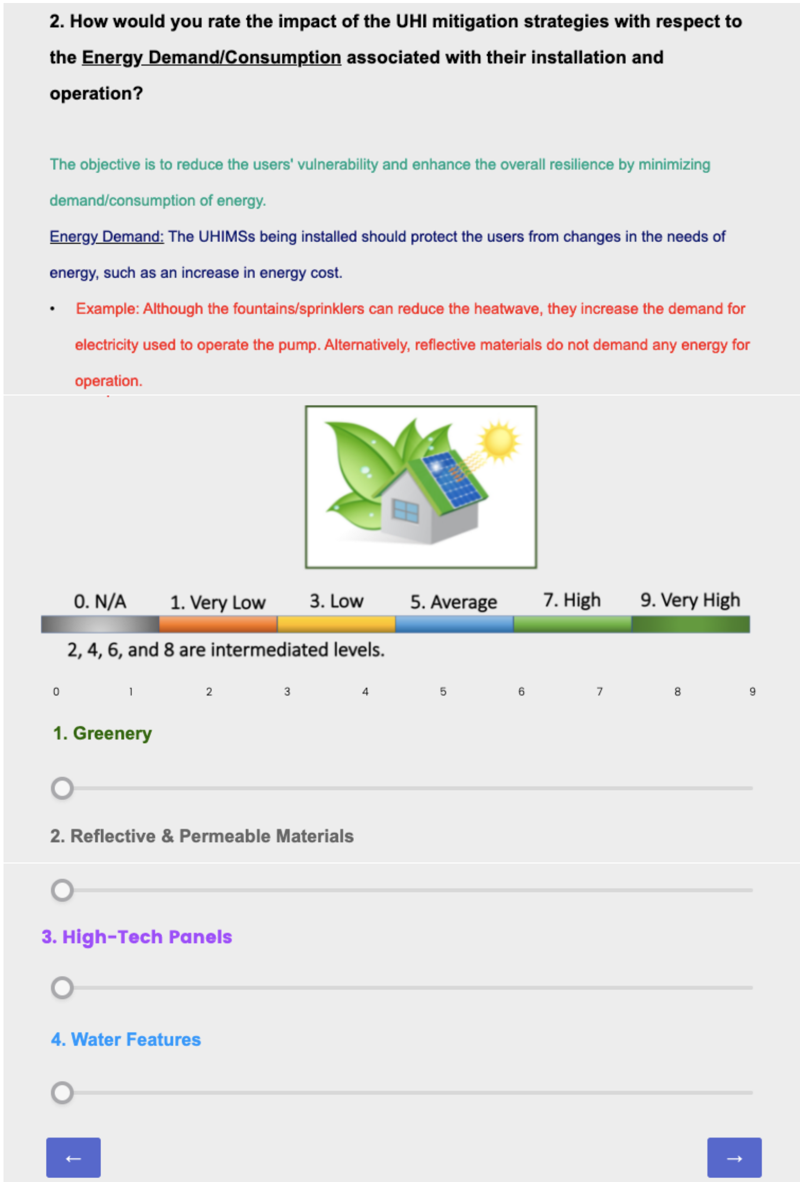
2. Reflective & Permeable Materials

3. High-Tech Panels

4. Water Features

← →

Figure 46: Question 1 of the 3rd part of expert elicitation on Qualtrics XM



2. How would you rate the impact of the UHI mitigation strategies with respect to the Energy Demand/Consumption associated with their installation and operation?

The objective is to reduce the users' vulnerability and enhance the overall resilience by minimizing demand/consumption of energy.

Energy Demand: The UHIMSs being installed should protect the users from changes in the needs of energy, such as an increase in energy cost.

- Example: Although the fountains/sprinklers can reduce the heatwave, they increase the demand for electricity used to operate the pump. Alternatively, reflective materials do not demand any energy for operation.

0. N/A | 1. Very Low | 3. Low | 5. Average | 7. High | 9. Very High

2, 4, 6, and 8 are intermediated levels.

0 1 2 3 4 5 6 7 8 9

1. Greenery

2. Reflective & Permeable Materials

3. High-Tech Panels

4. Water Features

← →

Figure 47: Question 2 of the 3rd part of expert elicitation on Qualtrics XM

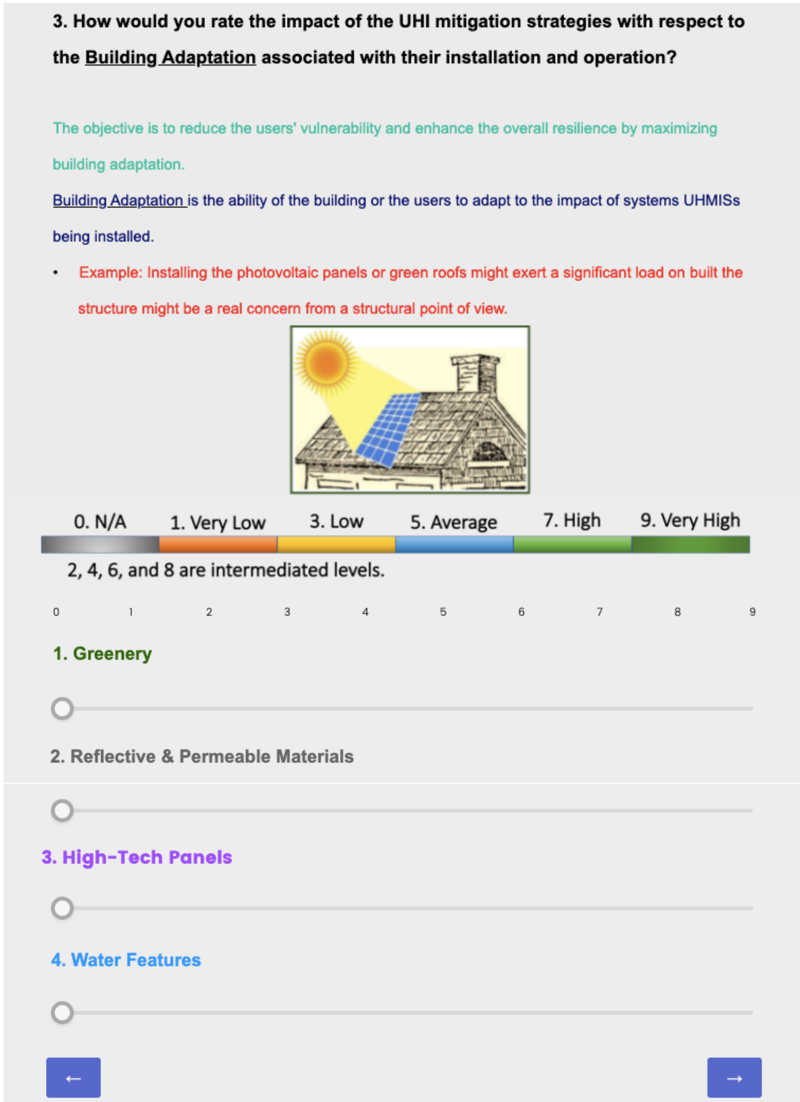


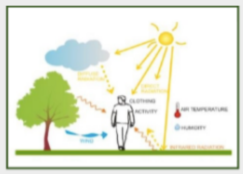
Figure 48: Question 3 of the 3rd part of expert elicitation on Qualtrics XM

4. How would you rate the impact of the UHI mitigation strategies with respect to the Thermal Comfort associated with their installation and operation?

The objective is to reduce the users' vulnerability and enhance the overall resilience by maximizing thermal comfort.

Thermal Comfort refers to the ability of UHIMSs to provide users satisfaction with the thermal conditions of the environment.

- Example: Although air conditioning systems achieve thermal comfort inside the building, they might compromise the exterior comfort of the users. While green roofs or vertical gardens can maintain thermal comfort externally and internally.
- Example: Evaporative techniques in dry climates can significantly enhance comfort by balancing the moisture level hence lowering the real feel temperature.
- Example: Although, evaporative methods are effective in enhancing the comfort level especially in a dry climate, some of the humidity-related health issues generated by evaporative techniques.



0. N/A | 1. Very Low | 3. Low | 5. Average | 7. High | 9. Very High

2, 4, 6, and 8 are intermediated levels.

0 1 2 3 4 5 6 7 8 9

1. Greenery

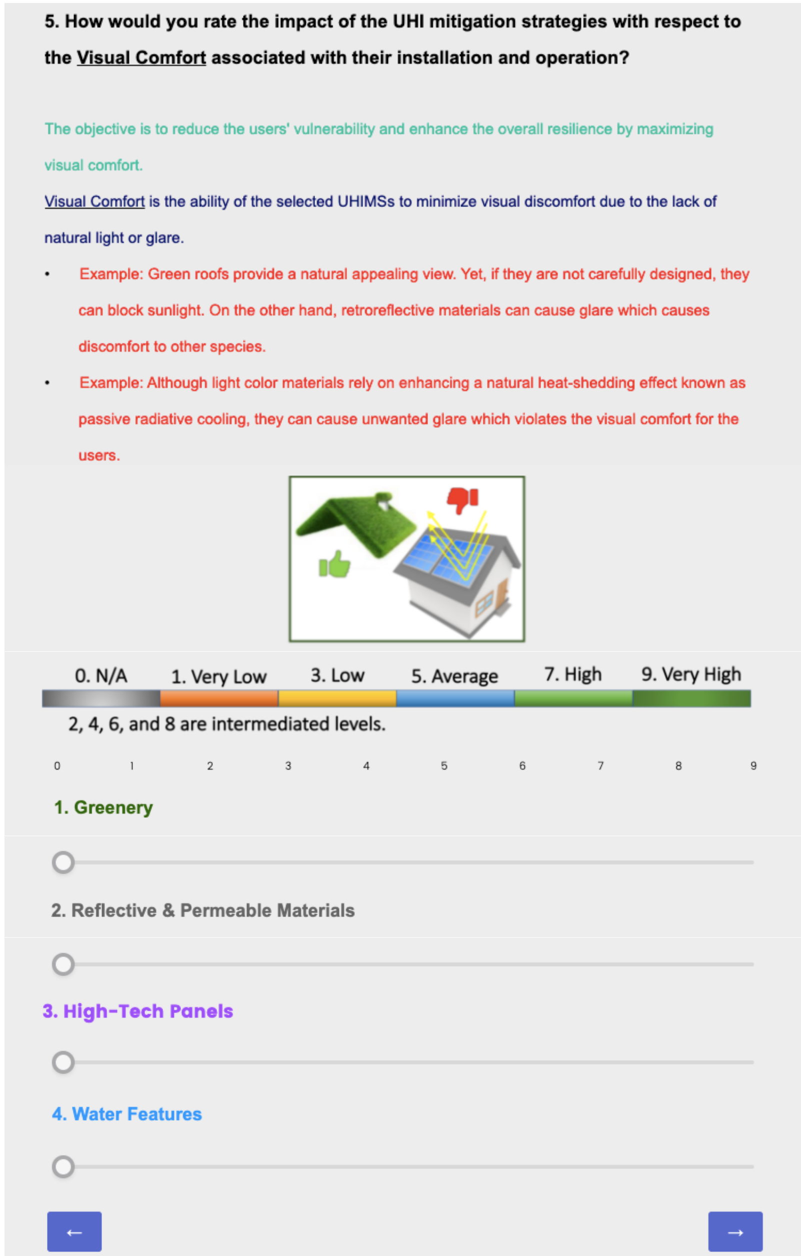
2. Reflective & Permeable Materials

3. High-Tech Panels

4. Water Features

← →

Figure 49: Question 4 of the 3rd part of expert elicitation on Qualtrics XM



5. How would you rate the impact of the UHI mitigation strategies with respect to the Visual Comfort associated with their installation and operation?

The objective is to reduce the users' vulnerability and enhance the overall resilience by maximizing visual comfort.

Visual Comfort is the ability of the selected UHIMSs to minimize visual discomfort due to the lack of natural light or glare.

- Example: Green roofs provide a natural appealing view. Yet, if they are not carefully designed, they can block sunlight. On the other hand, retroreflective materials can cause glare which causes discomfort to other species.
- Example: Although light color materials rely on enhancing a natural heat-shedding effect known as passive radiative cooling, they can cause unwanted glare which violates the visual comfort for the users.

0. N/A | 1. Very Low | 3. Low | 5. Average | 7. High | 9. Very High

2, 4, 6, and 8 are intermediated levels.

0 1 2 3 4 5 6 7 8 9

1. Greenery

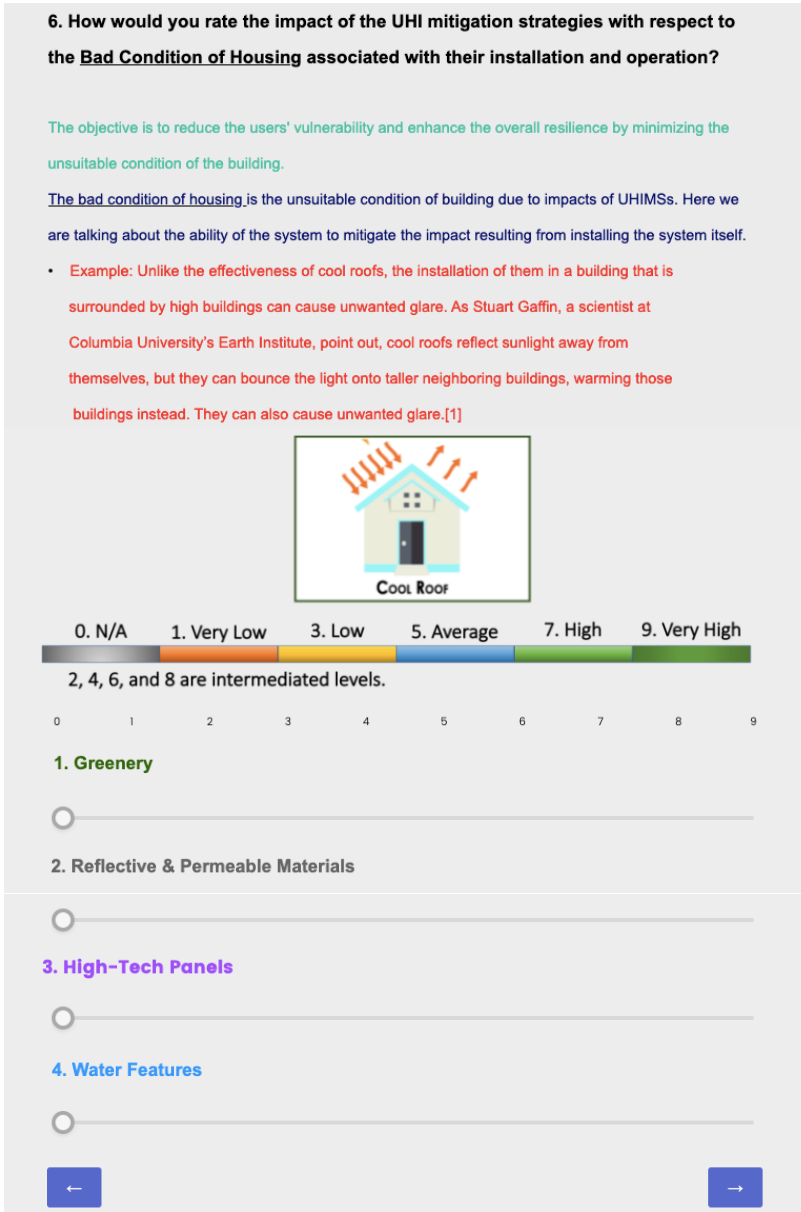
2. Reflective & Permeable Materials

3. High-Tech Panels

4. Water Features

← →

Figure 50: Question 5 of the 3rd part of expert elicitation on Qualtrics XM



6. How would you rate the impact of the UHI mitigation strategies with respect to the Bad Condition of Housing associated with their installation and operation?

The objective is to reduce the users' vulnerability and enhance the overall resilience by minimizing the unsuitable condition of the building.

The bad condition of housing is the unsuitable condition of building due to impacts of UHIMSs. Here we are talking about the ability of the system to mitigate the impact resulting from installing the system itself.

- Example: Unlike the effectiveness of cool roofs, the installation of them in a building that is surrounded by high buildings can cause unwanted glare. As Stuart Gaffin, a scientist at Columbia University's Earth Institute, point out, cool roofs reflect sunlight away from themselves, but they can bounce the light onto taller neighboring buildings, warming those buildings instead. They can also cause unwanted glare.[1]

0. N/A | 1. Very Low | 3. Low | 5. Average | 7. High | 9. Very High

2, 4, 6, and 8 are intermediated levels.

0 1 2 3 4 5 6 7 8 9

1. Greenery

2. Reflective & Permeable Materials

3. High-Tech Panels

4. Water Features

← →

Figure 51: Question 6 of the 3rd part of expert elicitation on Qualtrics XM


7. How would you rate the impact of the UHI mitigation strategies with respect to the Heatwave Risk associated with their installation and operation?

The objective is to reduce the users' vulnerability and enhance the overall resilience by minimizing heatwave risk.

A heat wave is considered extreme weather that can be a natural disaster, and a danger because heat and sunlight may overheat the human body.

- Example: Although retroreflective materials could reduce the UHI effect, the development of them in the urban area with the risk of heatwave risk could pose a threat to users' bodies and health.

0. N/A 1. Very Low 3. Low 5. Average 7. High 9. Very High

2, 4, 6, and 8 are intermediated levels.

0 1 2 3 4 5 6 7 8 9

1. Greenery

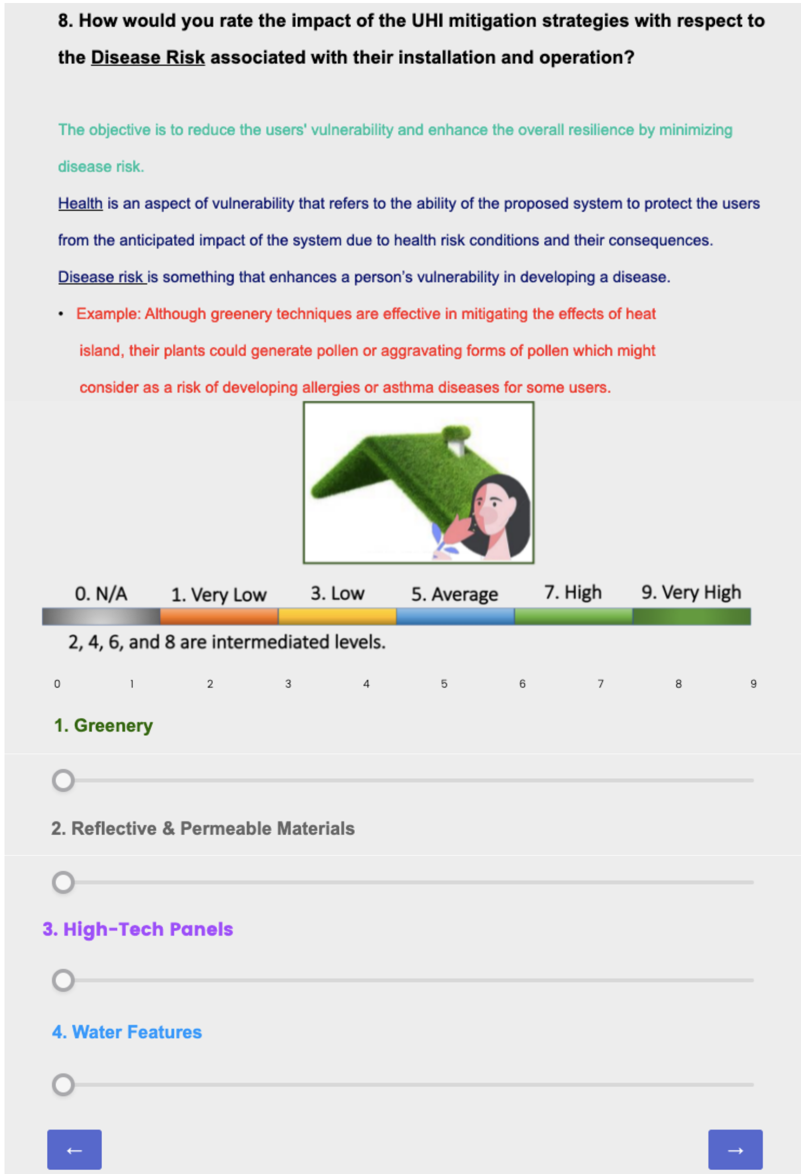
2. Reflective & Permeable Materials

3. High-Tech Panels

4. Water Features

← →

Figure 52: Question 7 of the 3rd part of expert elicitation on Qualtrics XM



8. How would you rate the impact of the UHI mitigation strategies with respect to the Disease Risk associated with their installation and operation?

The objective is to reduce the users' vulnerability and enhance the overall resilience by minimizing disease risk.

Health is an aspect of vulnerability that refers to the ability of the proposed system to protect the users from the anticipated impact of the system due to health risk conditions and their consequences.

Disease risk is something that enhances a person's vulnerability in developing a disease.

- Example: Although greenery techniques are effective in mitigating the effects of heat island, their plants could generate pollen or aggravating forms of pollen which might consider as a risk of developing allergies or asthma diseases for some users.

0. N/A 1. Very Low 3. Low 5. Average 7. High 9. Very High

2, 4, 6, and 8 are intermediated levels.

0 1 2 3 4 5 6 7 8 9

1. Greenery

2. Reflective & Permeable Materials

3. High-Tech Panels

4. Water Features

← →

Figure 53: Question 8 of the 3rd part of expert elicitation on Qualtrics XM

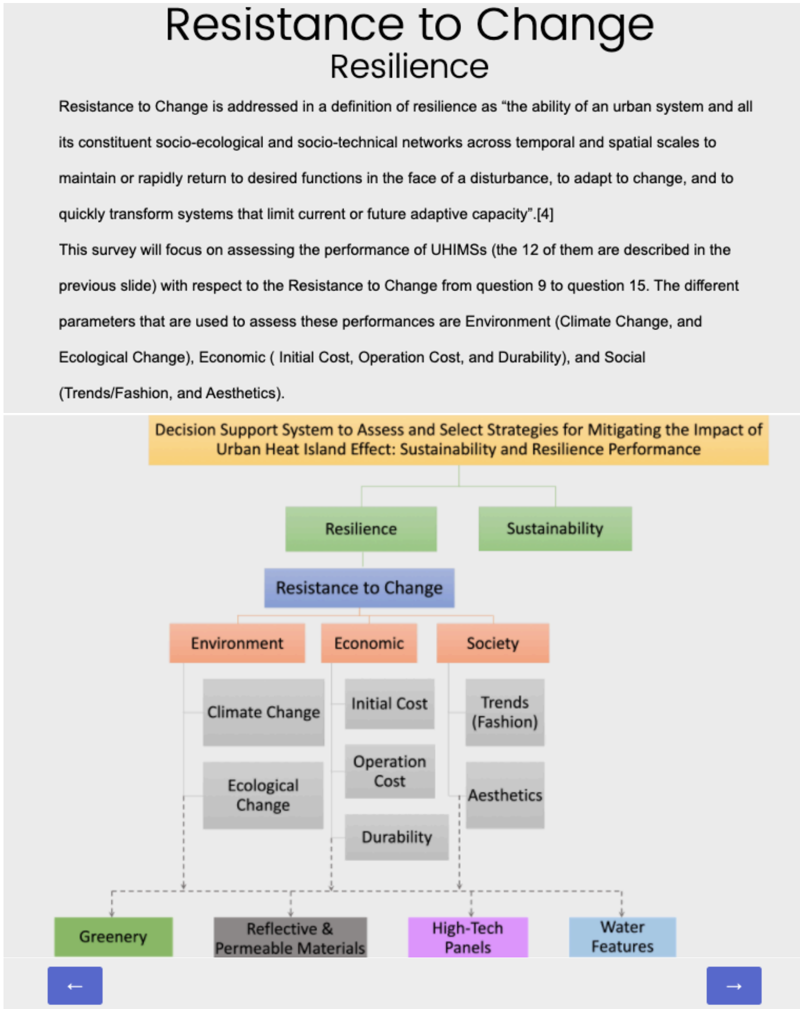
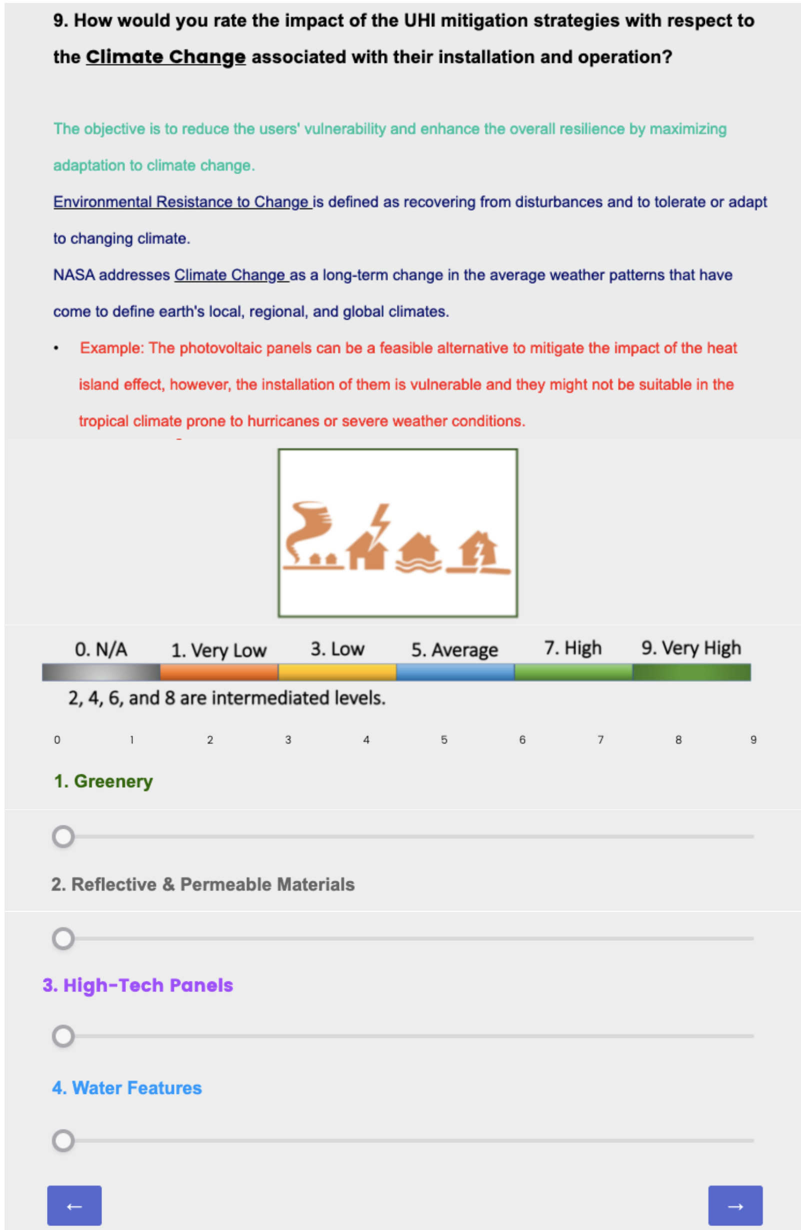


Figure 54: Resistance to change introduction slide of the 3rd part of expert elicitation on Qualtrics XM



9. How would you rate the impact of the UHI mitigation strategies with respect to the Climate Change associated with their installation and operation?

The objective is to reduce the users' vulnerability and enhance the overall resilience by maximizing adaptation to climate change.

Environmental Resistance to Change is defined as recovering from disturbances and to tolerate or adapt to changing climate.

NASA addresses Climate Change as a long-term change in the average weather patterns that have come to define earth's local, regional, and global climates.

- Example: The photovoltaic panels can be a feasible alternative to mitigate the impact of the heat island effect, however, the installation of them is vulnerable and they might not be suitable in the tropical climate prone to hurricanes or severe weather conditions.

0. N/A 1. Very Low 3. Low 5. Average 7. High 9. Very High

2, 4, 6, and 8 are intermediated levels.

0 1 2 3 4 5 6 7 8 9

1. Greenery

2. Reflective & Permeable Materials

3. High-Tech Panels

4. Water Features

← →

Figure 55: Question 9 of the 3rd part of expert elicitation on Qualtrics XM

10. How would you rate the impact of the UHI mitigation strategies with respect to the <u>Ecological Changes</u> associated with their installation and operation?

The objective is to reduce the users' vulnerability and enhance the overall resilience by minimizing any changes to the ecosystem.

According to MA (Millennium Ecosystem Assessment), <u>Ecological Change</u> is any variation in the state, outputs, or structure of an ecosystem.

- Example: Although evaporative techniques have a high level of effectiveness especially in dry climates, they increase the demands of water supply (increase its ecological footprint). So, if there is a curtsy of water (drought), they might not be the best solution.

0. N/A   1. Very Low   3. Low   5. Average   7. High   9. Very High

2, 4, 6, and 8 are intermediated levels.

0 1 2 3 4 5 6 7 8 9

1. Greenery

2. Reflective & Permeable Materials

3. High-Tech Panels

4. Water Features

← →

Figure 56: Question 10 of the 3rd part of expert elicitation on Qualtrics XM

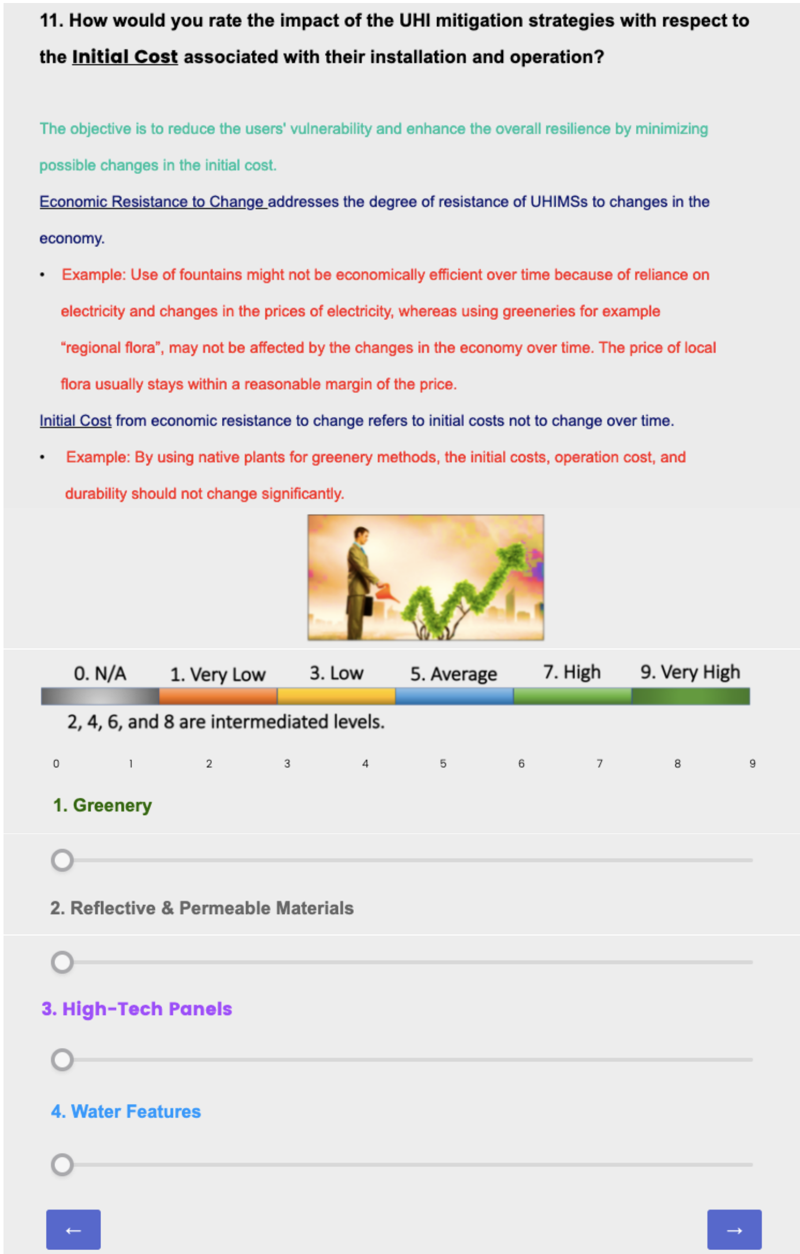
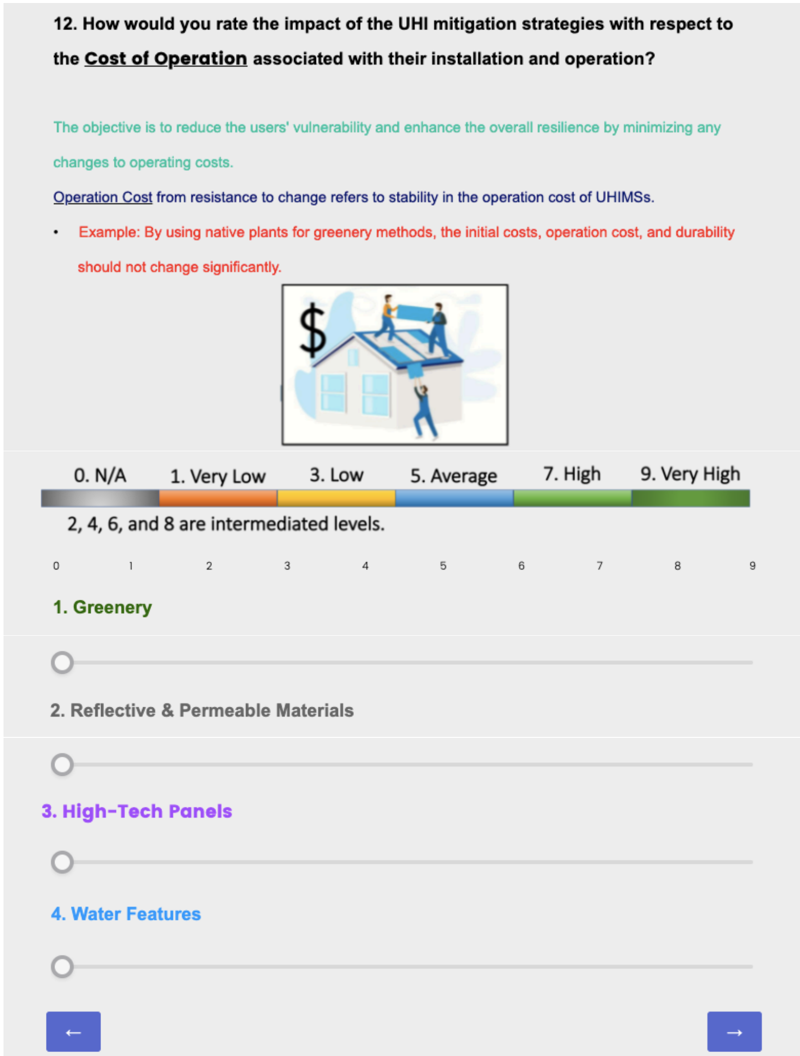


Figure 57: Question 11 of the 3rd part of expert elicitation on Qualtrics XM



12. How would you rate the impact of the UHI mitigation strategies with respect to the Cost of Operation associated with their installation and operation?

The objective is to reduce the users' vulnerability and enhance the overall resilience by minimizing any changes to operating costs.

Operation Cost from resistance to change refers to stability in the operation cost of UHIMSs.

- Example: By using native plants for greenery methods, the initial costs, operation cost, and durability should not change significantly.

0. N/A | 1. Very Low | 3. Low | 5. Average | 7. High | 9. Very High

2, 4, 6, and 8 are intermediated levels.

0 1 2 3 4 5 6 7 8 9

1. Greenery

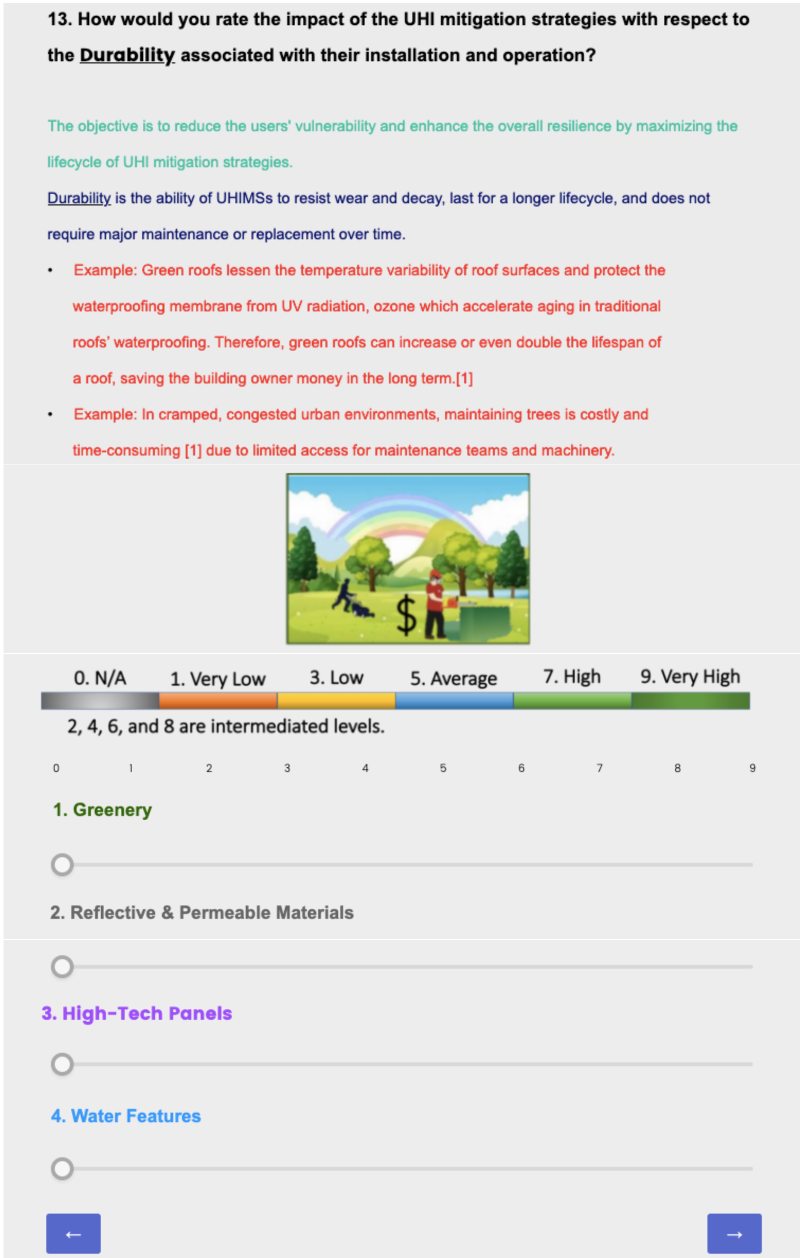
2. Reflective & Permeable Materials

3. High-Tech Panels

4. Water Features

← →

Figure 58: Question 12 of the 3rd part of expert elicitation on Qualtrics XM



13. How would you rate the impact of the UHI mitigation strategies with respect to the Durability associated with their installation and operation?

The objective is to reduce the users' vulnerability and enhance the overall resilience by maximizing the lifecycle of UHI mitigation strategies.

Durability is the ability of UHIMSs to resist wear and decay, last for a longer lifecycle, and does not require major maintenance or replacement over time.

- Example: Green roofs lessen the temperature variability of roof surfaces and protect the waterproofing membrane from UV radiation, ozone which accelerate aging in traditional roofs' waterproofing. Therefore, green roofs can increase or even double the lifespan of a roof, saving the building owner money in the long term.[1]
- Example: In cramped, congested urban environments, maintaining trees is costly and time-consuming [1] due to limited access for maintenance teams and machinery.

0. N/A 1. Very Low 3. Low 5. Average 7. High 9. Very High

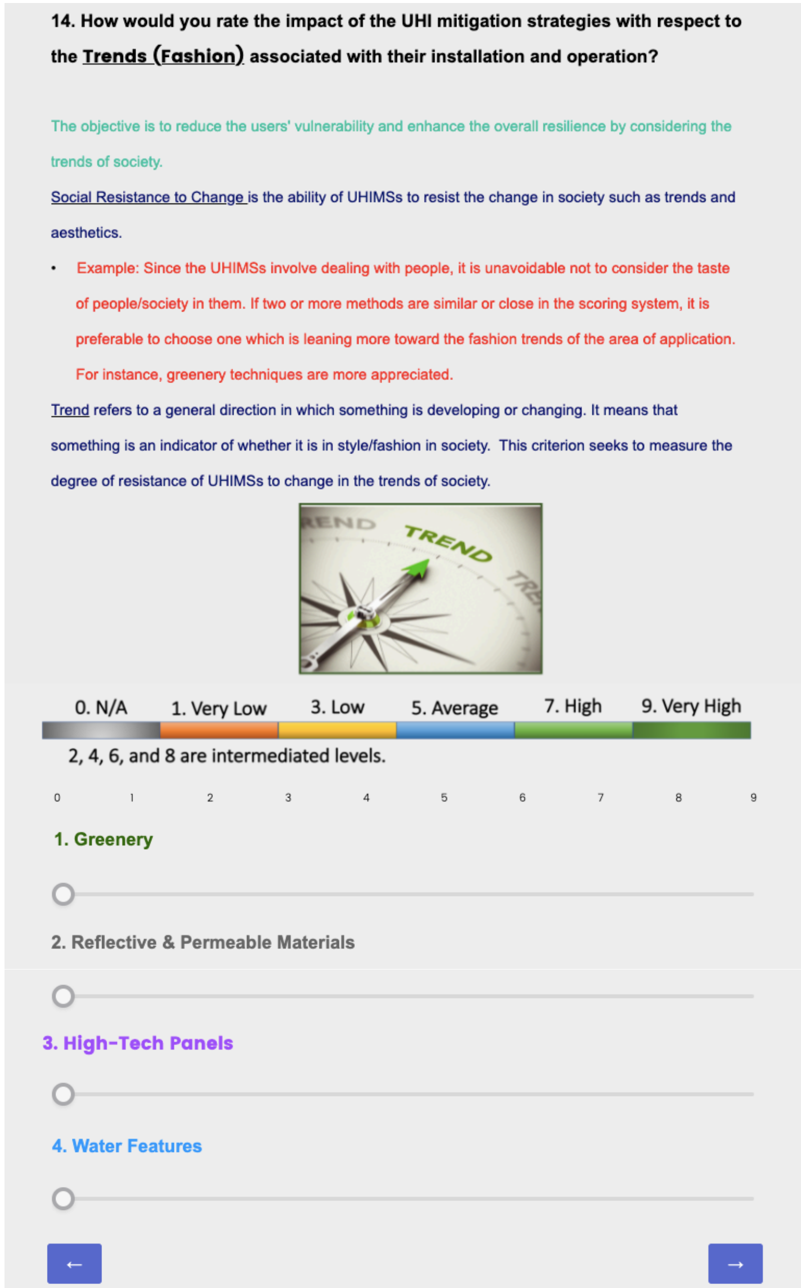
2, 4, 6, and 8 are intermediated levels.

0 1 2 3 4 5 6 7 8 9

1. Greenery
2. Reflective & Permeable Materials
3. High-Tech Panels
4. Water Features

← →

Figure 59: Question 13 of the 3rd part of expert elicitation on Qualtrics XM



14. How would you rate the impact of the UHI mitigation strategies with respect to the Trends (Fashion) associated with their installation and operation?

The objective is to reduce the users' vulnerability and enhance the overall resilience by considering the trends of society.

Social Resistance to Change is the ability of UHIMSs to resist the change in society such as trends and aesthetics.

- Example: Since the UHIMSs involve dealing with people, it is unavoidable not to consider the taste of people/society in them. If two or more methods are similar or close in the scoring system, it is preferable to choose one which is leaning more toward the fashion trends of the area of application. For instance, greenery techniques are more appreciated.

Trend refers to a general direction in which something is developing or changing. It means that something is an indicator of whether it is in style/fashion in society. This criterion seeks to measure the degree of resistance of UHIMSs to change in the trends of society.

0. N/A | 1. Very Low | 3. Low | 5. Average | 7. High | 9. Very High

2, 4, 6, and 8 are intermediated levels.

0 1 2 3 4 5 6 7 8 9

1. Greenery

2. Reflective & Permeable Materials

3. High-Tech Panels

4. Water Features

← →

Figure 60: Question 14 of the 3rd part of expert elicitation on Qualtrics XM

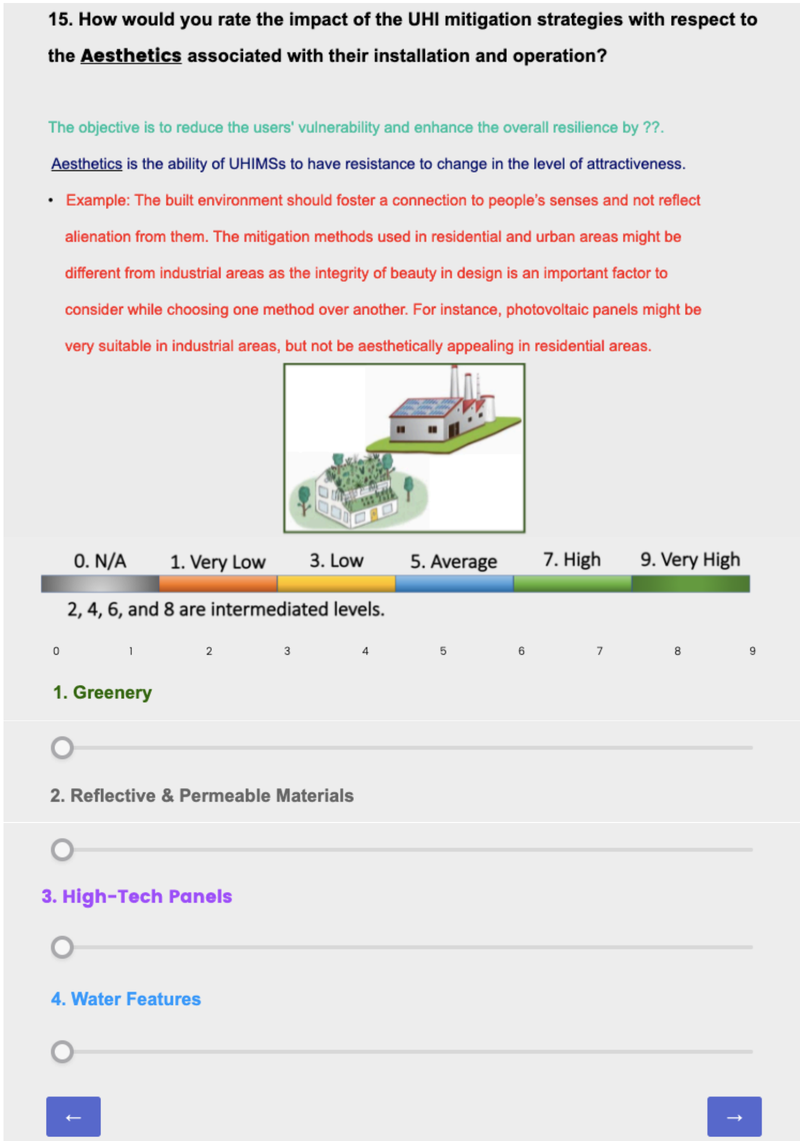


Figure 61: Question 15 of the 3rd part of expert elicitation on Qualtrics XM

APPENDIX D

APPENDIX D

COLLECTED DATA

	Question 1		Question 2		Question 3			Question 4		Question 5		
1	60.92	39.08	60.08	39.92	28.99	29.83	41.18	40.97	59.03	28.78	38.24	32.98
2	24.76	75.24	65.99	34.01	9.74	10.08	80.18	29.93	70.07	60.20	19.21	20.59
3	60.00	40.00	30.00	70.00	50.00	25.00	25.00	50.00	50.00	40.00	30.00	30.00
4	43.45	56.55	75.21	24.79	37.55	3.56	58.89	29.47	70.53	57.23	41.88	0.89
5	40.00	60.00	30.00	70.00	40.00	30.00	30.00	70.00	30.00	40.00	40.00	20.00
6	30.00	70.00	30.00	70.00	30.00	30.00	40.00	50.00	50.00	40.00	50.00	10.00
7	53.99	46.01	68.28	31.72	24.79	40.55	34.66	36.97	63.03	37.61	32.98	29.41
8	40.00	60.00	30.00	70.00	20.00	40.00	40.00	50.00	50.00	40.00	40.00	20.00
9	30.00	70.00	70.00	30.00	50.00	20.00	30.00	20.00	80.00	40.00	40.00	20.00
10	50.00	50.00	50.00	50.00	0.00	0.00	100.00	50.00	50.00	34.00	33.00	33.00
11	41.09	58.91	41.09	58.91	26.42	32.70	40.88	45.70	54.30	56.60	23.48	19.92
12	50.00	50.00	40.00	60.00	25.00	25.00	50.00	40.00	60.00	40.00	50.00	10.00
13	30.00	70.00	50.00	50.00	60.00	40.00	0.00	70.00	30.00	30.00	70.00	0.00
14	50.00	50.00	20.00	80.00	25.00	25.00	50.00	80.00	20.00	10.00	50.00	40.00
15	20.00	80.00	70.00	30.00	30.00	30.00	40.00	40.00	60.00	40.00	40.00	20.00
16	50.00	50.00	50.00	50.00	20.00	40.00	40.00	50.00	50.00	15.00	80.00	5.00
17	60.00	40.00	35.00	65.00	20.00	20.00	60.00	60.00	40.00	35.00	50.00	15.00
18	60.00	40.00	30.00	70.00	25.00	25.00	50.00	20.00	80.00	25.00	50.00	25.00
19	20.00	80.00	70.00	30.00	30.00	35.00	35.00	90.00	10.00	30.00	50.00	20.00
20	40.00	60.00	40.00	60.00	60.00	20.00	20.00	40.00	60.00	50.00	25.00	25.00
21	60.17	39.83	60.38	39.62	29.56	9.85	60.59	71.91	28.09	20.55	69.81	9.64
22	40.00	60.00	20.00	80.00	70.00	20.00	10.00	40.00	60.00	70.00	30.00	0.00
23	50.00	50.00	40.00	60.00	60.00	20.00	20.00	60.00	40.00	40.00	40.00	20.00
24	30.04	69.96	50.00	50.00	50.00	25.00	25.00	75.00	25.00	40.00	40.00	20.00
25	42.31	57.69	83.95	16.05	19.15	21.81	59.04	57.53	42.47	33.52	51.45	15.03
26	70.80	29.20	28.78	71.22	12.82	48.73	38.45	31.09	68.91	21.64	48.74	29.62
27	50.00	50.00	50.00	50.00	20.00	40.00	40.00	50.00	50.00	20.00	20.00	60.00
28	50.00	50.00	40.34	59.66	60.08	28.57	11.35	39.71	60.29	49.79	19.54	30.67

29	40.00	60.00	40.00	60.00	25.00	35.00	40.00	60.00	40.00	40.00	35.00	25.00
30	40.00	60.00	70.00	30.00	25.00	35.00	40.00	40.00	60.00	20.00	60.00	20.00
31	60.00	40.00	65.00	35.00	18.45	48.85	32.70	50.10	49.90	31.66	50.31	18.03
32	70.00	30.00	20.00	80.00	15.00	35.00	50.00	40.00	60.00	40.00	30.00	30.00
33	51.89	48.11	0.00	100.00	0.00	0.00	100.00	0.00	100.00	0.00	0.00	100.00
34	20.00	80.00	80.00	20.00	30.00	30.00	40.00	50.00	50.00	30.00	60.00	10.00
35	20.00	80.00	70.00	30.00	70.00	20.00	10.00	30.00	70.00	30.00	50.00	20.00
36	60.17	39.83	49.27	50.73	29.77	30.40	39.83	39.20	60.80	30.19	50.10	19.71
37	39.10	60.90	50.62	49.38	31.91	36.70	31.39	30.65	69.35	27.75	60.12	12.13
38	50.00	50.00	50.00	50.00	30.00	30.00	40.00	40.00	60.00	40.00	30.00	30.00
39	40.13	59.87	51.05	48.95	39.50	11.55	48.95	70.38	29.62	59.66	20.38	19.96
40	39.00	61.00	50.00	50.00	32.00	38.00	30.00	30.00	70.00	27.00	60.00	13.00
41	70.00	30.00	28.00	72.00	12.00	48.00	40.00	31.00	69.00	28.00	41.00	31.00
42	35.00	65.00	75.00	25.00	35.00	20.00	45.00	80.00	20.00	21.00	60.00	19.00
43	50.00	50.00	50.00	50.00	33.00	33.00	34.00	60.00	40.00	20.00	50.00	30.00
44	29.56	70.44	49.48	50.52	8.81	28.09	63.10	69.60	30.40	24.11	61.64	14.25
45	51.89	48.11	50.00	50.00	32.00	38.00	30.00	30.00	70.00	27.00	60.00	13.00

Table 1: Data set of the 1st part of expert elicitation on Qualtrics XM (Questions 1-5)

	Question 6			Question 7			Question 8		Question 9			Question 10	
1	35.92	40.13	23.95	24.00	36.00	40.00	53.00	47.00	22.00	36.00	42.00	58.00	42.00
2	25.56	37.22	37.22	52.00	37.00	11.00	50.00	50.00	51.00	25.00	24.00	31.00	69.00
3	50.00	30.00	20.00	60.00	20.00	20.00	50.00	50.00	40.00	30.00	30.00	20.00	80.00
4	39.76	26.46	33.78	51.00	34.00	15.00	46.00	54.00	36.00	50.00	14.00	44.00	56.00
5	20.00	40.00	40.00	50.00	20.00	30.00	70.00	30.00	30.00	40.00	30.00	70.00	30.00
6	40.00	40.00	20.00	30.00	40.00	30.00	70.00	30.00	30.00	40.00	30.00	50.00	50.00
7	36.56	34.45	28.99	53.00	29.00	18.00	52.00	48.00	24.00	32.00	44.00	53.00	47.00
8	20.00	40.00	40.00	40.00	30.00	30.00	70.00	30.00	30.00	30.00	40.00	60.00	40.00
9	80.00	10.00	10.00	20.00	40.00	40.00	20.00	80.00	40.00	30.00	30.00	20.00	80.00
10	34.00	33.00	33.00	34.00	33.00	33.00	50.00	50.00	25.00	25.00	50.00	80.00	20.00
11	41.51	32.49	26.00	34.00	23.00	43.00	51.00	49.00	25.00	32.00	43.00	40.00	60.00
12	30.00	50.00	20.00	35.00	35.00	30.00	65.00	35.00	50.00	20.00	30.00	40.00	60.00
13	20.00	80.00	0.00	0.00	80.00	20.00	50.00	50.00	90.00	10.00	0.00	50.00	50.00
14	30.00	50.00	20.00	60.00	15.00	25.00	70.00	30.00	70.00	20.00	10.00	60.00	40.00
15	35.00	30.00	35.00	30.00	40.00	30.00	40.00	60.00	30.00	30.00	40.00	60.00	40.00
16	5.00	80.00	15.00	5.00	70.00	25.00	80.00	20.00	85.00	10.00	5.00	20.00	80.00
17	30.00	10.00	60.00	30.00	30.00	40.00	50.00	50.00	40.00	40.00	20.00	40.00	60.00
18	30.00	20.00	50.00	60.00	20.00	20.00	30.00	70.00	20.00	40.00	40.00	40.00	60.00
19	30.00	50.00	20.00	40.00	20.00	40.00	70.00	30.00	25.00	25.00	50.00	80.00	20.00
20	60.00	30.00	10.00	20.00	60.00	20.00	60.00	40.00	60.00	20.00	20.00	70.00	30.00
21	29.98	9.64	60.38	50.00	29.00	21.00	60.00	40.00	18.00	29.00	53.00	61.00	39.00
22	20.00	20.00	60.00	40.00	40.00	20.00	80.00	20.00	70.00	20.00	10.00	50.00	50.00
23	20.00	40.00	40.00	20.00	60.00	20.00	70.00	30.00	34.00	33.00	33.00	50.00	50.00
24	25.00	50.00	25.00	40.00	40.00	20.00	50.00	50.00	40.00	30.00	30.00	40.00	60.00
25	34.71	25.29	40.00	7.00	76.00	17.00	51.00	49.00	63.00	27.00	10.00	55.00	45.00
26	52.10	31.09	16.81	34.00	42.00	24.00	40.00	60.00	50.00	20.00	30.00	30.00	70.00
27	30.00	30.00	40.00	50.00	30.00	20.00	50.00	50.00	25.00	25.00	50.00	25.00	75.00
28	28.36	31.30	40.34	50.00	15.00	35.00	50.00	50.00	30.00	51.00	19.00	50.00	50.00
29	40.00	35.00	25.00	30.00	30.00	40.00	30.00	70.00	35.00	35.00	30.00	50.00	50.00
30	25.00	35.00	40.00	30.00	25.00	45.00	60.00	40.00	40.00	30.00	30.00	60.00	40.00
31	49.69	17.19	33.12	34.00	33.00	33.00	38.00	62.00	23.00	32.00	45.00	30.00	70.00
32	50.00	40.00	10.00	30.00	30.00	40.00	50.00	50.00	30.00	30.00	40.00	20.00	80.00
33	0.00	0.00	100.00	0.00	0.00	100.00	0.00	100.00	0.00	0.00	100.00	0.00	100.00
34	20.00	20.00	60.00	20.00	60.00	20.00	40.00	60.00	50.00	25.00	25.00	30.00	70.00
35	10.00	70.00	20.00	10.00	30.00	60.00	50.00	50.00	60.00	30.00	10.00	60.00	40.00
36	27.04	18.66	54.30	60.00	29.00	11.00	61.00	39.00	8.00	37.00	55.00	29.00	71.00
37	17.65	41.76	40.59	41.00	38.00	21.00	53.00	47.00	52.00	18.00	30.00	77.00	23.00
38	40.00	40.00	20.00	10.00	30.00	60.00	70.00	30.00	20.00	20.00	60.00	50.00	50.00

39	34.45	33.40	32.15	39.00	24.00	37.00	70.00	30.00	18.00	55.00	27.00	39.00	61.00
40	17.00	40.00	43.00	41.00	39.00	20.00	53.00	47.00	53.00	17.00	30.00	76.00	24.00
41	52.00	31.00	17.00	35.00	45.00	20.00	40.00	60.00	50.00	20.00	30.00	30.00	70.00
42	40.00	45.00	15.00	35.00	40.00	25.00	65.00	35.00	70.00	20.00	10.00	35.00	65.00
43	25.00	50.00	25.00	34.00	33.00	33.00	50.00	50.00	33.00	33.00	34.00	50.00	50.00
44	19.29	31.45	49.26	51.00	15.00	34.00	60.00	40.00	10.00	40.00	50.00	39.00	61.00
45	34.00	33.00	33.00	34.00	33.00	33.00	50.00	50.00	25.00	25.00	50.00	80.00	20.00

Table 2: Data set of the 1st part of expert elicitation on Qualtrics XM (Questions 6-10)

	Question 11			Question 12								
1	16.00	51.00	33.00	11.00	13.00	17.00	4.00	8.00	15.00	21.00	5.00	6.00
2	32.00	35.00	33.00	12.00	14.00	13.00	10.00	9.00	10.00	12.00	12.00	8.00
3	70.00	10.00	20.00	10.00	10.00	20.00	20.00	5.00	5.00	10.00	10.00	10.00
4	42.00	8.00	50.00	3.00	4.00	0.00	14.00	12.00	37.00	2.00	13.00	15.00
5	60.00	20.00	20.00	20.00	0.00	0.00	20.00	10.00	0.00	20.00	10.00	20.00
6	40.00	30.00	30.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	20.00	10.00
7	40.00	24.00	36.00	6.00	4.00	11.00	17.00	11.00	7.00	16.00	20.00	8.00
8	40.00	30.00	30.00	5.00	10.00	0.00	30.00	5.00	20.00	20.00	10.00	0.00
9	30.00	40.00	30.00	10.00	20.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00
10	30.00	40.00	30.00	12.00	12.00	12.00	12.00	12.00	11.00	11.00	11.00	7.00
11	29.00	25.00	46.00	13.00	12.00	19.00	11.00	14.00	7.00	10.00	8.00	6.00
12	50.00	30.00	20.00	15.00	8.00	14.00	8.00	8.00	9.00	13.00	14.00	11.00
13	40.00	50.00	10.00	0.00	10.00	0.00	30.00	0.00	0.00	10.00	50.00	0.00
14	70.00	15.00	15.00	20.00	10.00	20.00	15.00	5.00	10.00	10.00	5.00	5.00
15	40.00	40.00	20.00	0.00	10.00	20.00	10.00	10.00	20.00	10.00	10.00	10.00
16	20.00	70.00	10.00	20.00	20.00	20.00	10.00	10.00	5.00	5.00	5.00	5.00
17	40.00	30.00	30.00	20.00	5.00	20.00	5.00	10.00	20.00	10.00	5.00	5.00
18	50.00	20.00	30.00	10.00	10.00	10.00	10.00	5.00	10.00	20.00	20.00	5.00
19	40.00	30.00	30.00	20.00	10.00	10.00	20.00	10.00	15.00	10.00	5.00	0.00
20	15.00	60.00	25.00	10.00	5.00	10.00	5.00	20.00	15.00	10.00	15.00	10.00
21	24.00	14.00	62.00	29.00	20.00	20.00	7.00	21.00	3.00	0.00	0.00	0.00
22	30.00	40.00	30.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	20.00
23	40.00	35.00	25.00	15.00	14.00	14.00	14.00	14.00	14.00	15.00	0.00	0.00
24	40.00	40.00	20.00	10.00	0.00	15.00	5.00	20.00	10.00	15.00	10.00	15.00
25	29.00	36.00	35.00	14.00	17.00	11.00	16.00	11.00	16.00	13.00	2.00	0.00
26	40.00	30.00	30.00	20.00	15.00	20.00	5.00	2.00	3.00	20.00	5.00	10.00
27	30.00	40.00	30.00	30.00	1.00	37.00	1.00	1.00	10.00	10.00	5.00	5.00
28	49.00	18.00	33.00	18.00	8.00	12.00	9.00	9.00	12.00	13.00	13.00	6.00
29	30.00	40.00	30.00	25.00	5.00	25.00	3.00	15.00	4.00	15.00	5.00	3.00
30	30.00	25.00	45.00	10.00	5.00	20.00	5.00	5.00	10.00	30.00	5.00	10.00

31	43.00	39.00	18.00	14.00	5.00	14.00	7.00	21.00	12.00	3.00	21.00	3.00
32	30.00	30.00	40.00	20.00	0.00	20.00	0.00	10.00	20.00	10.00	10.00	10.00
33	0.00	0.00	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00
34	60.00	20.00	20.00	0.00	5.00	5.00	10.00	5.00	10.00	25.00	40.00	0.00
35	20.00	50.00	30.00	10.00	5.00	5.00	30.00	5.00	5.00	10.00	25.00	5.00
36	70.00	19.00	11.00	29.00	0.00	19.00	0.00	0.00	20.00	20.00	0.00	12.00
37	40.00	38.00	22.00	15.00	10.00	10.00	15.00	10.00	15.00	10.00	5.00	10.00
38	30.00	30.00	40.00	15.00	5.00	10.00	15.00	10.00	10.00	10.00	15.00	10.00
39	49.00	29.00	22.00	18.00	8.00	18.00	11.00	7.00	6.00	17.00	6.00	9.00
40	40.00	38.00	22.00	15.00	10.00	10.00	15.00	10.00	15.00	10.00	5.00	10.00
41	40.00	30.00	30.00	20.00	15.00	20.00	5.00	2.00	3.00	20.00	5.00	10.00
42	80.00	15.00	5.00	11.00	10.00	14.00	10.00	9.00	13.00	12.00	9.00	12.00
43	34.00	33.00	33.00	10.00	10.00	10.00	10.00	10.00	15.00	15.00	10.00	10.00
44	32.00	15.00	53.00	24.00	9.00	21.00	7.00	10.00	7.00	12.00	5.00	5.00
45	60.00	20.00	20.00	0.00	5.00	5.00	10.00	5.00	10.00	25.00	40.00	0.00

Table 3: Data set of the 1st part of expert elicitation on Qualtrics XM (Questions 11 &12)

	Question 13						Question 14			
1	44.00	9.00	8.00	14.00	18.00	7.00	12.00	23.00	33.00	32.00
2	20.00	20.00	15.00	13.00	16.00	16.00	35.00	28.00	19.00	18.00
3	20.00	20.00	15.00	20.00	15.00	10.00	50.00	10.00	20.00	20.00
4	8.00	4.00	14.00	37.00	37.00	0.00	42.00	18.00	17.00	23.00
5	25.00	10.00	25.00	20.00	10.00	10.00	40.00	30.00	10.00	20.00
6	10.00	20.00	20.00	30.00	10.00	10.00	20.00	20.00	30.00	30.00
7	20.00	15.00	23.00	21.00	16.00	5.00	24.00	24.00	25.00	27.00
8	30.00	10.00	5.00	40.00	5.00	10.00	20.00	20.00	20.00	40.00
9	20.00	20.00	10.00	30.00	10.00	10.00	10.00	30.00	50.00	10.00
10	18.00	18.00	17.00	12.00	17.00	18.00	30.00	17.00	24.00	29.00
11	10.00	8.00	40.00	11.00	18.00	13.00	24.00	16.00	28.00	32.00
12	25.00	20.00	15.00	20.00	10.00	10.00	20.00	30.00	30.00	20.00
13	40.00	10.00	0.00	50.00	0.00	0.00	15.00	40.00	15.00	30.00
14	40.00	20.00	20.00	10.00	5.00	5.00	35.00	35.00	15.00	15.00
15	20.00	15.00	15.00	20.00	10.00	20.00	20.00	30.00	20.00	30.00
16	35.00	35.00	10.00	10.00	10.00	0.00	40.00	20.00	10.00	30.00
17	25.00	10.00	20.00	15.00	15.00	15.00	35.00	20.00	25.00	20.00
18	20.00	10.00	30.00	20.00	10.00	10.00	20.00	30.00	20.00	30.00
19	40.00	20.00	10.00	10.00	15.00	5.00	30.00	15.00	15.00	40.00
20	20.00	30.00	15.00	10.00	15.00	10.00	40.00	20.00	20.00	20.00
21	15.00	10.00	14.00	40.00	10.00	11.00	53.00	7.00	13.00	27.00
22	20.00	20.00	0.00	20.00	20.00	20.00	10.00	20.00	30.00	40.00

23	25.00	25.00	25.00	10.00	10.00	5.00	25.00	25.00	25.00	25.00
24	30.00	15.00	15.00	20.00	10.00	10.00	35.00	35.00	10.00	20.00
25	48.00	22.00	11.00	4.00	6.00	9.00	41.00	22.00	11.00	26.00
26	32.00	35.00	5.00	15.00	10.00	3.00	15.00	40.00	20.00	25.00
27	25.00	5.00	5.00	50.00	10.00	5.00	10.00	20.00	20.00	50.00
28	12.00	23.00	12.00	20.00	20.00	13.00	28.00	22.00	23.00	27.00
29	25.00	25.00	15.00	15.00	12.00	8.00	30.00	20.00	25.00	25.00
30	15.00	25.00	15.00	20.00	15.00	10.00	25.00	25.00	25.00	25.00
31	30.00	16.00	4.00	28.00	18.00	4.00	16.00	19.00	34.00	31.00
32	40.00	30.00	0.00	30.00	0.00	0.00	40.00	10.00	20.00	30.00
33	0.00	0.00	0.00	0.00	0.00	100.00	0.00	0.00	0.00	100.00
34	15.00	20.00	0.00	60.00	5.00	0.00	15.00	15.00	20.00	50.00
35	20.00	20.00	10.00	30.00	5.00	15.00	20.00	30.00	20.00	30.00
36	19.00	18.00	40.00	15.00	6.00	2.00	49.00	29.00	8.00	14.00
37	20.00	20.00	15.00	30.00	10.00	5.00	35.00	25.00	20.00	20.00
38	20.00	20.00	20.00	20.00	10.00	10.00	20.00	10.00	40.00	30.00
39	13.00	14.00	23.00	22.00	21.00	7.00	39.00	20.00	20.00	21.00
40	20.00	20.00	15.00	30.00	10.00	5.00	35.00	25.00	20.00	20.00
41	33.00	35.00	5.00	15.00	10.00	2.00	15.00	40.00	20.00	25.00
42	40.00	15.00	11.00	12.00	11.00	11.00	35.00	25.00	15.00	25.00
43	15.00	15.00	20.00	20.00	15.00	15.00	25.00	20.00	20.00	35.00
44	12.00	12.00	27.00	37.00	11.00	1.00	51.00	17.00	18.00	14.00
45	30.00	16.00	4.00	28.00	18.00	4.00	16.00	19.00	34.00	31.00

Table 4: Data set of the 1st part of expert elicitation on Qualtrics XM (Questions 13 & 14)

	Question 1				Question 2				Question 3				Question 4			
1	5.00	3.00	8.00	7.00	5.00	5.00	6.00	4.00	7.00	8.00	4.00	5.00	8.00	8.00	3.00	5.00
2	6.00	4.00	7.00	3.00	6.00	4.00	4.00	4.00	5.00	4.00	6.00	5.00	6.00	5.00	6.00	5.00
3	8.00	5.00	5.00	9.00	5.00	8.00	8.00	6.00	7.00	8.00	8.00	6.00	9.00	7.00	7.00	8.00
4	5.00	6.00	4.00	4.00	6.00	6.00	5.00	3.00	8.00	8.00	3.00	5.00	6.00	8.00	6.00	4.00
5	7.00	3.00	9.00	7.00	7.00	3.00	9.00	9.00	9.00	5.00	5.00	5.00	5.00	5.00	5.00	3.00
6	5.00	5.00	6.00	7.00	6.00	7.00	7.00	7.00	5.00	5.00	7.00	6.00	5.00	6.00	8.00	5.00
7	7.00	7.00	9.00	7.00	8.00	8.00	8.00	8.00	7.00	8.00	8.00	7.00	9.00	9.00	9.00	9.00
8	6.00	6.00	1.00	2.00	2.00	8.00	9.00	2.00	4.00	3.00	4.00	3.00	3.00	2.00	7.00	1.00
9	6.00	5.00	9.00	6.00	5.00	4.00	9.00	6.00	3.00	6.00	3.00	4.00	8.00	5.00	7.00	5.00
10	7.00	5.00	9.00	4.00	7.00	8.00	9.00	5.00	7.00	5.00	7.00	4.00	6.00	8.00	8.00	3.00
11	7.00	5.00	9.00	8.00	4.00	7.00	9.00	8.00	1.00	5.00	9.00	1.00	9.00	5.00	7.00	2.00
12	7.00	3.00	3.00	1.00	7.00	4.00	3.00	3.00	2.00	6.00	6.00	4.00	0.00	7.00	7.00	8.00
13	5.00	3.00	0.00	0.00	5.00	3.00	0.00	0.00	3.00	1.00	5.00	8.00	2.00	1.00	5.00	0.00
14	4.00	3.00	9.00	6.00	6.00	5.00	4.00	7.00	4.00	3.00	5.00	7.00	2.00	4.00	2.00	2.00

15	6.00	5.00	5.00	6.00	5.00	6.00	7.00	6.00	6.00	8.00	8.00	7.00	8.00	5.00	4.00	4.00
16	9.00	7.00	3.00	7.00	6.00	3.00	9.00	7.00	3.00	1.00	9.00	7.00	8.00	2.00	5.00	0.00
17	3.00	5.00	8.00	4.00	8.00	5.00	4.00	8.00	7.00	8.00	9.00	6.00	7.00	5.00	5.00	6.00
18	5.00	2.00	8.00	6.00	7.00	6.00	5.00	8.00	7.00	2.00	4.00	6.00	6.00	1.00	7.00	5.00
19	5.00	6.00	4.00	4.00	5.00	5.00	4.00	2.00	5.00	4.00	9.00	4.00	9.00	7.00	7.00	8.00
20	7.00	8.00	5.00	5.00	7.00	6.00	9.00	3.00	5.00	5.00	8.00	4.00	6.00	8.00	6.00	4.00
21	8.00	8.00	4.00	5.00	6.00	7.00	6.00	3.00	4.00	3.00	6.00	3.00	8.00	6.00	7.00	7.00
22	5.00	6.00	4.00	5.00	4.00	4.00	5.00	2.00	5.00	8.00	3.00	4.00	8.00	7.00	7.00	9.00
23	7.00	8.00	5.00	4.00	7.00	6.00	3.00	4.00	5.00	6.00	7.00	4.00	6.00	8.00	6.00	5.00
24	8.00	7.00	4.00	5.00	6.00	7.00	3.00	4.00	4.00	5.00	9.00	4.00	7.00	6.00	6.00	8.00
25	5.00	6.00	4.00	3.00	5.00	6.00	5.00	3.00	5.00	5.00	7.00	4.00	9.00	7.00	7.00	8.00
26	7.00	8.00	5.00	6.00	5.00	5.00	5.00	2.00	4.00	3.00	7.00	4.00	6.00	7.00	5.00	4.00
27	8.00	7.00	3.00	4.00	6.00	7.00	3.00	4.00	5.00	4.00	9.00	3.00	8.00	6.00	6.00	7.00
28	7.00	6.00	5.00	3.00	7.00	6.00	4.00	2.00	4.00	4.00	8.00	4.00	8.00	5.00	5.00	6.00
29	6.00	5.00	3.00	2.00	8.00	6.00	3.00	4.00	4.00	3.00	8.00	3.00	7.00	5.00	5.00	6.00
30	4.00	5.00	3.00	3.00	6.00	6.00	4.00	2.00	5.00	5.00	9.00	8.00	8.00	6.00	6.00	7.00

Table 5: Data set of the 2nd part of expert elicitation on Qualtrics XM (Questions 1-4)

	Question 5				Question 6				Question 7				Question 8			
1	6.00	8.00	3.00	5.00	7.00	6.00	4.00	5.00	8.00	5.00	4.00	7.00	8.00	6.00	2.00	3.00
2	7.00	5.00	7.00	6.00	6.00	5.00	5.00	5.00	9.00	2.00	2.00	4.00	8.00	6.00	1.00	4.00
3	3.00	8.00	7.00	6.00	6.00	4.00	3.00	4.00	9.00	7.00	6.00	9.00	8.00	6.00	6.00	9.00
4	6.00	6.00	6.00	5.00	8.00	9.00	7.00	6.00	6.00	8.00	8.00	6.00	7.00	4.00	4.00	7.00
5	9.00	3.00	5.00	7.00	5.00	5.00	5.00	5.00	5.00	7.00	7.00	7.00	7.00	1.00	1.00	5.00
6	5.00	6.00	7.00	7.00	6.00	6.00	7.00	5.00	7.00	5.00	7.00	5.00	5.00	6.00	6.00	5.00
7	9.00	8.00	8.00	7.00	6.00	6.00	6.00	6.00	8.00	7.00	8.00	6.00	9.00	9.00	7.00	8.00
8	2.00	6.00	8.00	1.00	2.00	1.00	1.00	3.00	9.00	0.00	0.00	0.00	9.00	0.00	0.00	0.00
9	5.00	6.00	2.00	5.00	8.00	6.00	5.00	6.00	9.00	4.00	5.00	6.00	9.00	2.00	4.00	3.00
10	7.00	5.00	7.00	4.00	3.00	4.00	4.00	2.00	9.00	1.00	1.00	1.00	9.00	8.00	1.00	2.00
11	1.00	6.00	9.00	5.00	9.00	2.00	2.00	5.00	9.00	4.00	1.00	4.00	9.00	7.00	1.00	5.00
12	5.00	7.00	8.00	8.00	1.00	1.00	1.00	1.00	9.00	1.00	1.00	3.00	9.00	1.00	1.00	6.00
13	2.00	0.00	5.00	8.00	0.00	9.00	0.00	0.00	5.00	0.00	5.00	1.00	9.00	0.00	0.00	3.00
14	6.00	4.00	8.00	5.00	6.00	1.00	4.00	2.00	8.00	1.00	5.00	1.00	8.00	4.00	1.00	5.00
15	6.00	7.00	5.00	3.00	6.00	4.00	5.00	4.00	7.00	4.00	2.00	2.00	7.00	1.00	1.00	7.00
16	5.00	1.00	4.00	5.00	9.00	4.00	3.00	6.00	9.00	3.00	2.00	4.00	8.00	1.00	1.00	4.00
17	5.00	7.00	7.00	5.00	2.00	2.00	0.00	1.00	5.00	2.00	1.00	5.00	9.00	3.00	0.00	7.00
18	7.00	3.00	5.00	8.00	8.00	3.00	4.00	8.00	9.00	1.00	6.00	4.00	8.00	1.00	1.00	9.00
19	4.00	3.00	8.00	5.00	7.00	8.00	6.00	5.00	9.00	7.00	6.00	9.00	7.00	4.00	4.00	7.00
20	4.00	4.00	7.00	3.00	6.00	4.00	3.00	4.00	6.00	8.00	8.00	6.00	8.00	4.00	5.00	8.00
21	5.00	5.00	8.00	6.00	8.00	9.00	6.00	7.00	5.00	7.00	7.00	4.00	8.00	6.00	7.00	9.00

22	5.00	3.00	8.00	6.00	7.00	8.00	5.00	6.00	8.00	7.00	6.00	9.00	7.00	5.00	5.00	7.00
23	4.00	4.00	7.00	3.00	6.00	5.00	3.00	5.00	6.00	7.00	8.00	7.00	7.00	4.00	4.00	7.00
24	4.00	4.00	7.00	3.00	8.00	7.00	5.00	6.00	6.00	7.00	7.00	5.00	8.00	4.00	5.00	8.00
25	5.00	4.00	8.00	7.00	8.00	9.00	7.00	6.00	6.00	8.00	8.00	6.00	7.00	4.00	5.00	7.00
26	4.00	3.00	8.00	5.00	7.00	7.00	6.00	6.00	5.00	7.00	7.00	5.00	8.00	4.00	5.00	8.00
27	5.00	4.00	7.00	3.00	6.00	4.00	3.00	4.00	9.00	7.00	6.00	9.00	8.00	6.00	7.00	9.00
28	4.00	4.00	6.00	3.00	7.00	8.00	6.00	5.00	5.00	7.00	6.00	5.00	8.00	4.00	5.00	7.00
29	4.00	4.00	6.00	3.00	7.00	8.00	5.00	4.00	4.00	6.00	6.00	4.00	7.00	4.00	5.00	7.00
30	5.00	5.00	7.00	6.00	6.00	4.00	3.00	4.00	9.00	7.00	6.00	8.00	7.00	5.00	5.00	9.00

Table 6: Data set of the 2nd part of expert elicitation on Qualtrics XM (Questions 5-8)

	Question 9				Question 10				Question 11				Question 12			
1	8.00	7.00	3.00	4.00	7.00	7.00	3.00	6.00	8.00	3.00	2.00	5.00	6.00	8.00	2.00	4.00
2	5.00	6.00	1.00	6.00	8.00	5.00	5.00	8.00	7.00	6.00	5.00	4.00	9.00	1.00	1.00	4.00
3	9.00	6.00	5.00	9.00	9.00	8.00	8.00	9.00	6.00	9.00	9.00	7.00	9.00	6.00	6.00	9.00
4	7.00	7.00	7.00	7.00	5.00	8.00	5.00	6.00	6.00	8.00	5.00	6.00	6.00	8.00	7.00	6.00
5	7.00	3.00	1.00	5.00	7.00	5.00	7.00	7.00	3.00	3.00	3.00	3.00	7.00	1.00	1.00	5.00
6	6.00	7.00	6.00	6.00	6.00	6.00	7.00	7.00	6.00	7.00	7.00	7.00	6.00	7.00	6.00	6.00
7	6.00	6.00	6.00	6.00	9.00	7.00	7.00	8.00	7.00	7.00	8.00	5.00	8.00	8.00	8.00	8.00
8	9.00	0.00	0.00	5.00	9.00	4.00	1.00	1.00	0.00	6.00	6.00	0.00	5.00	7.00	7.00	1.00
9	8.00	7.00	5.00	6.00	9.00	7.00	7.00	8.00	7.00	5.00	4.00	6.00	8.00	6.00	8.00	5.00
10	9.00	8.00	1.00	3.00	8.00	9.00	6.00	5.00	2.00	6.00	8.00	2.00	9.00	1.00	1.00	4.00
11	9.00	1.00	1.00	5.00	9.00	5.00	1.00	5.00	1.00	8.00	9.00	1.00	9.00	2.00	1.00	4.00
12	4.00	1.00	1.00	1.00	7.00	1.00	1.00	9.00	7.00	1.00	1.00	2.00	5.00	2.00	2.00	3.00
13	6.00	0.00	0.00	4.00	7.00	5.00	3.00	2.00	7.00	0.00	6.00	1.00	9.00	9.00	4.00	3.00
14	7.00	2.00	0.00	3.00	7.00	8.00	6.00	4.00	8.00	5.00	3.00	4.00	7.00	1.00	7.00	4.00
15	6.00	0.00	0.00	7.00	7.00	6.00	3.00	1.00	7.00	0.00	0.00	4.00	1.00	0.00	0.00	0.00
16	9.00	3.00	2.00	7.00	8.00	7.00	3.00	6.00	2.00	4.00	9.00	4.00	8.00	2.00	7.00	3.00
17	9.00	3.00	0.00	7.00	9.00	2.00	0.00	7.00	9.00	2.00	0.00	7.00	9.00	2.00	0.00	7.00
18	9.00	1.00	1.00	8.00	9.00	2.00	1.00	8.00	7.00	1.00	3.00	7.00	9.00	1.00	1.00	8.00
19	7.00	4.00	3.00	7.00	9.00	8.00	8.00	9.00	7.00	4.00	5.00	8.00	7.00	9.00	8.00	7.00
20	9.00	6.00	5.00	9.00	8.00	7.00	7.00	8.00	7.00	5.00	6.00	8.00	9.00	6.00	6.00	9.00
21	8.00	5.00	4.00	7.00	8.00	6.00	5.00	7.00	6.00	4.00	5.00	8.00	7.00	8.00	6.00	6.00
22	8.00	5.00	4.00	7.00	8.00	6.00	5.00	7.00	6.00	5.00	4.00	7.00	6.00	8.00	7.00	7.00
23	6.00	5.00	3.00	7.00	9.00	9.00	8.00	9.00	7.00	4.00	5.00	8.00	7.00	9.00	8.00	7.00
24	6.00	5.00	3.00	7.00	8.00	6.00	5.00	7.00	8.00	6.00	5.00	7.00	6.00	8.00	7.00	6.00
25	8.00	5.00	3.00	8.00	8.00	7.00	7.00	8.00	7.00	9.00	8.00	7.00	7.00	9.00	6.00	8.00
26	7.00	4.00	3.00	8.00	8.00	9.00	8.00	9.00	6.00	4.00	5.00	6.00	9.00	7.00	6.00	9.00
27	9.00	5.00	6.00	9.00	8.00	9.00	8.00	9.00	7.00	4.00	6.00	8.00	6.00	8.00	7.00	6.00
28	7.00	4.00	3.00	6.00	8.00	6.00	4.00	7.00	7.00	5.00	6.00	8.00	7.00	9.00	8.00	7.00

29	7.00	4.00	3.00	7.00	8.00	6.00	5.00	7.00	6.00	4.00	5.00	7.00	7.00	9.00	8.00	7.00
30	8.00	6.00	5.00	9.00	8.00	7.00	7.00	9.00	6.00	4.00	5.00	8.00	9.00	6.00	6.00	9.00

Table 7: Data set of the 2nd part of expert elicitation on Qualtrics XM (Questions 9-12)

	Question 13				Question 14				Question 15				Question 16			
1	3.00	7.00	6.00	4.00	6.00	4.00	2.00	8.00	6.00	8.00	8.00	6.00	6.00	6.00	6.00	6.00
2	8.00	6.00	4.00	6.00	5.00	4.00	5.00	8.00	9.00	6.00	6.00	5.00	8.00	5.00	4.00	6.00
3	9.00	7.00	5.00	9.00	9.00	8.00	6.00	9.00	9.00	6.00	4.00	9.00	9.00	5.00	6.00	9.00
4	6.00	8.00	5.00	7.00	6.00	8.00	6.00	4.00	7.00	8.00	6.00	6.00	7.00	8.00	7.00	5.00
5	7.00	1.00	1.00	7.00	7.00	7.00	5.00	7.00	5.00	5.00	5.00	3.00	5.00	5.00	5.00	5.00
6	6.00	6.00	6.00	6.00	7.00	7.00	7.00	6.00	7.00	8.00	8.00	5.00	6.00	6.00	8.00	6.00
7	9.00	8.00	8.00	8.00	9.00	9.00	7.00	8.00	5.00	5.00	5.00	5.00	5.00	7.00	5.00	5.00
8	9.00	6.00	1.00	9.00	9.00	1.00	0.00	3.00	7.00	1.00	1.00	7.00	9.00	0.00	0.00	9.00
9	8.00	6.00	7.00	7.00	9.00	7.00	8.00	8.00	9.00	8.00	8.00	8.00	8.00	5.00	7.00	8.00
10	9.00	9.00	9.00	4.00	9.00	9.00	9.00	4.00	9.00	9.00	7.00	3.00	8.00	3.00	3.00	2.00
11	9.00	4.00	1.00	4.00	9.00	8.00	2.00	8.00	9.00	2.00	1.00	2.00	9.00	4.00	1.00	4.00
12	2.00	7.00	7.00	2.00	4.00	1.00	1.00	9.00	2.00	1.00	1.00	1.00	7.00	1.00	1.00	7.00
13	6.00	8.00	9.00	1.00	9.00	9.00	1.00	5.00	9.00	5.00	9.00	1.00	9.00	0.00	9.00	3.00
14	7.00	3.00	5.00	3.00	6.00	4.00	4.00	6.00	5.00	8.00	3.00	2.00	5.00	7.00	7.00	4.00
15	6.00	1.00	1.00	1.00	8.00	0.00	1.00	1.00	7.00	3.00	0.00	1.00	5.00	3.00	3.00	3.00
16	9.00	3.00	8.00	8.00	8.00	6.00	3.00	7.00	8.00	6.00	3.00	7.00	3.00	1.00	1.00	1.00
17	9.00	2.00	0.00	7.00	9.00	3.00	4.00	8.00	4.00	5.00	6.00	4.00	6.00	2.00	0.00	6.00
18	7.00	4.00	7.00	6.00	9.00	2.00	2.00	8.00	5.00	7.00	3.00	6.00	6.00	3.00	3.00	5.00
19	9.00	7.00	5.00	9.00	8.00	6.00	5.00	7.00	5.00	7.00	6.00	4.00	9.00	5.00	6.00	9.00
20	6.00	8.00	5.00	7.00	7.00	5.00	4.00	6.00	3.00	8.00	7.00	4.00	8.00	4.00	5.00	8.00
21	6.00	8.00	5.00	6.00	8.00	5.00	6.00	7.00	5.00	7.00	6.00	4.00	9.00	6.00	5.00	9.00
22	7.00	9.00	6.00	8.00	8.00	9.00	9.00	6.00	5.00	7.00	6.00	4.00	8.00	5.00	4.00	8.00
23	9.00	5.00	7.00	9.00	8.00	7.00	6.00	7.00	5.00	7.00	6.00	4.00	8.00	4.00	5.00	7.00
24	7.00	9.00	6.00	8.00	8.00	6.00	5.00	6.00	5.00	7.00	6.00	4.00	7.00	2.00	4.00	4.00
25	7.00	8.00	7.00	8.00	7.00	5.00	4.00	6.00	3.00	6.00	7.00	4.00	9.00	5.00	6.00	9.00
26	9.00	7.00	5.00	9.00	9.00	8.00	5.00	9.00	3.00	6.00	7.00	9.00	8.00	4.00	5.00	8.00
27	6.00	7.00	5.00	7.00	8.00	6.00	5.00	7.00	6.00	9.00	7.00	6.00	7.00	3.00	4.00	8.00
28	7.00	9.00	4.00	7.00	7.00	5.00	4.00	6.00	5.00	7.00	6.00	4.00	7.00	3.00	4.00	8.00
29	6.00	8.00	5.00	6.00	7.00	5.00	4.00	6.00	5.00	7.00	6.00	4.00	7.00	3.00	4.00	8.00
30	8.00	6.00	4.00	8.00	8.00	7.00	6.00	9.00	3.00	6.00	7.00	5.00	8.00	5.00	6.00	9.00

Table 8: Data set of the 2nd part of expert elicitation on Qualtrics XM (Questions 13-16)

	Question 17				Question 18				Question 19			
1	5.00	6.00	3.00	6.00	7.00	6.00	5.00	7.00	3.00	3.00	2.00	2.00
2	7.00	3.00	2.00	7.00	7.00	5.00	3.00	7.00	9.00	4.00	1.00	9.00

3	8.00	4.00	3.00	5.00	9.00	5.00	5.00	8.00	9.00	4.00	4.00	9.00
4	7.00	7.00	7.00	6.00	7.00	8.00	8.00	6.00	8.00	9.00	6.00	6.00
5	5.00	5.00	5.00	5.00	7.00	3.00	3.00	7.00	7.00	3.00	3.00	7.00
6	7.00	8.00	6.00	6.00	6.00	5.00	7.00	6.00	7.00	6.00	7.00	5.00
7	4.00	4.00	4.00	4.00	8.00	6.00	6.00	8.00	9.00	9.00	7.00	9.00
8	5.00	0.00	0.00	5.00	9.00	3.00	3.00	9.00	9.00	1.00	0.00	6.00
9	5.00	7.00	5.00	5.00	6.00	7.00	5.00	6.00	8.00	2.00	2.00	7.00
10	6.00	1.00	1.00	6.00	9.00	1.00	1.00	7.00	9.00	1.00	1.00	7.00
11	9.00	9.00	5.00	5.00	5.00	2.00	2.00	2.00	9.00	9.00	1.00	5.00
12	2.00	1.00	1.00	5.00	7.00	5.00	7.00	9.00	7.00	1.00	1.00	7.00
13	9.00	3.00	0.00	5.00	9.00	3.00	0.00	5.00	9.00	3.00	0.00	5.00
14	4.00	4.00	2.00	6.00	7.00	5.00	3.00	3.00	7.00	3.00	2.00	7.00
15	6.00	2.00	1.00	2.00	7.00	2.00	0.00	7.00	5.00	3.00	0.00	6.00
16	5.00	2.00	4.00	5.00	3.00	3.00	6.00	3.00	7.00	2.00	2.00	7.00
17	3.00	0.00	0.00	3.00	9.00	2.00	0.00	8.00	9.00	3.00	3.00	9.00
18	6.00	4.00	4.00	5.00	8.00	2.00	3.00	8.00	8.00	2.00	4.00	7.00
19	7.00	7.00	7.00	6.00	7.00	6.00	3.00	5.00	9.00	4.00	4.00	4.00
20	5.00	6.00	5.00	4.00	9.00	5.00	5.00	8.00	9.00	8.00	5.00	7.00
21	7.00	7.00	7.00	7.00	8.00	7.00	6.00	4.00	8.00	7.00	4.00	6.00
22	7.00	7.00	7.00	7.00	9.00	5.00	5.00	7.00	7.00	8.00	6.00	4.00
23	7.00	6.00	7.00	7.00	7.00	6.00	3.00	5.00	8.00	4.00	4.00	9.00
24	5.00	6.00	5.00	4.00	7.00	6.00	3.00	6.00	8.00	7.00	4.00	6.00
25	4.00	8.00	7.00	3.00	9.00	5.00	5.00	8.00	9.00	4.00	4.00	9.00
26	7.00	7.00	7.00	7.00	8.00	7.00	5.00	6.00	9.00	8.00	5.00	7.00
27	5.00	6.00	3.00	5.00	7.00	6.00	2.00	4.00	8.00	7.00	4.00	6.00
28	5.00	6.00	5.00	4.00	7.00	6.00	3.00	3.00	8.00	6.00	4.00	5.00
29	4.00	5.00	4.00	3.00	6.00	5.00	3.00	4.00	8.00	7.00	4.00	6.00
30	4.00	8.00	7.00	3.00	9.00	5.00	6.00	8.00	9.00	4.00	4.00	8.00

Table 9: Data set of the 2nd part of expert elicitation on Qualtrics XM (Questions 17-19)

	Question 1				Question 2				Question 3				Question 4			
1	9.00	3.00	9.00	1.00	3.00	3.00	0.00	0.00	7.00	9.00	9.00	1.00	1.00	5.00	0.00	4.00
2	5.00	7.00	8.00	5.00	5.00	6.00	9.00	5.00	8.00	7.00	7.00	6.00	9.00	7.00	5.00	6.00
3	5.00	7.00	7.00	8.00	3.00	2.00	6.00	7.00	5.00	5.00	5.00	5.00	6.00	8.00	6.00	8.00
4	1.00	6.00	8.00	6.00	3.00	6.00	7.00	9.00	1.00	4.00	8.00	8.00	5.00	5.00	7.00	7.00
5	7.00	5.00	2.00	1.00	6.00	2.00	4.00	2.00	7.00	5.00	4.00	1.00	7.00	4.00	2.00	1.00
6	4.00	3.00	6.00	7.00	5.00	4.00	7.00	6.00	2.00	3.00	5.00	6.00	8.00	8.00	6.00	5.00
7	7.00	4.00	3.00	5.00	8.00	5.00	6.00	4.00	5.00	7.00	4.00	6.00	6.00	8.00	5.00	4.00
8	1.00	6.00	6.00	1.00	1.00	1.00	1.00	2.00	6.00	8.00	3.00	2.00	6.00	7.00	4.00	3.00
9	5.00	9.00	3.00	3.00	6.00	7.00	8.00	9.00	6.00	4.00	5.00	4.00	9.00	6.00	1.00	6.00

10	6.00	4.00	4.00	6.00	6.00	3.00	3.00	6.00	6.00	3.00	3.00	6.00	5.00	7.00	5.00	5.00
11	6.00	4.00	5.00	3.00	7.00	8.00	7.00	3.00	8.00	7.00	8.00	2.00	9.00	7.00	5.00	7.00
12	7.00	6.00	5.00	7.00	3.00	6.00	7.00	3.00	4.00	6.00	7.00	6.00	7.00	5.00	5.00	7.00
13	9.00	5.00	5.00	3.00	9.00	8.00	7.00	5.00	9.00	8.00	8.00	5.00	9.00	5.00	7.00	4.00
14	4.00	5.00	6.00	7.00	2.00	2.00	4.00	6.00	9.00	4.00	6.00	1.00	7.00	5.00	2.00	7.00
15	9.00	3.00	9.00	1.00	6.00	5.00	4.00	2.00	7.00	9.00	9.00	1.00	7.00	4.00	4.00	8.00
16	8.00	2.00	8.00	1.00	6.00	5.00	4.00	5.00	6.00	8.00	8.00	1.00	7.00	4.00	4.00	8.00
17	8.00	2.00	7.00	2.00	7.00	6.00	5.00	2.00	6.00	9.00	8.00	1.00	8.00	4.00	5.00	9.00
18	8.00	3.00	7.00	1.00	7.00	5.00	6.00	4.00	6.00	7.00	8.00	1.00	7.00	5.00	5.00	8.00
19	9.00	4.00	8.00	1.00	7.00	6.00	4.00	3.00	8.00	8.00	9.00	1.00	8.00	5.00	5.00	8.00
20	8.00	2.00	8.00	1.00	5.00	6.00	4.00	3.00	6.00	8.00	8.00	1.00	7.00	4.00	4.00	8.00
21	7.00	2.00	8.00	1.00	6.00	4.00	5.00	2.00	7.00	8.00	9.00	1.00	8.00	5.00	5.00	9.00
22	9.00	3.00	9.00	1.00	8.00	6.00	4.00	4.00	7.00	8.00	9.00	1.00	6.00	4.00	4.00	7.00
23	7.00	1.00	7.00	1.00	5.00	4.00	3.00	1.00	5.00	7.00	7.00	1.00	6.00	3.00	3.00	7.00
24	7.00	5.00	3.00	7.00	5.00	8.00	2.00	4.00	3.00	9.00	7.00	5.00	7.00	8.00	3.00	5.00
25	9.00	3.00	8.00	2.00	7.00	6.00	5.00	4.00	7.00	7.00	8.00	1.00	8.00	4.00	5.00	9.00
26	8.00	2.00	8.00	1.00	6.00	5.00	4.00	2.00	6.00	7.00	8.00	2.00	7.00	3.00	3.00	8.00
27	9.00	2.00	8.00	1.00	7.00	6.00	4.00	2.00	7.00	9.00	9.00	2.00	7.00	4.00	5.00	8.00
28	7.00	2.00	8.00	1.00	7.00	5.00	4.00	3.00	6.00	9.00	8.00	2.00	8.00	5.00	5.00	9.00
29	8.00	2.00	7.00	1.00	8.00	7.00	6.00	4.00	6.00	9.00	8.00	1.00	8.00	5.00	5.00	9.00
30	7.00	2.00	6.00	1.00	7.00	6.00	4.00	3.00	6.00	8.00	9.00	2.00	8.00	5.00	5.00	9.00

Table 10: Data set of the 3rd part of expert elicitation on Qualtrics XM (Questions 1-4)

	Question 5				Question 6				Question 7				Question 8			
1	9.00	3.00	3.00	9.00	0.00	0.00	0.00	0.00	9.00	5.00	0.00	7.00	9.00	0.00	0.00	1.00
2	5.00	9.00	9.00	5.00	3.00	3.00	3.00	5.00	3.00	4.00	6.00	3.00	4.00	4.00	4.00	4.00
3	7.00	3.00	2.00	7.00	9.00	5.00	5.00	9.00	7.00	5.00	5.00	8.00	4.00	4.00	4.00	6.00
4	8.00	3.00	8.00	9.00	2.00	9.00	5.00	5.00	3.00	9.00	6.00	2.00	7.00	1.00	1.00	5.00
5	7.00	2.00	1.00	4.00	6.00	4.00	2.00	1.00	8.00	7.00	6.00	2.00	7.00	5.00	4.00	5.00
6	9.00	5.00	6.00	7.00	9.00	4.00	3.00	5.00	9.00	3.00	4.00	6.00	7.00	5.00	6.00	9.00
7	8.00	5.00	2.00	8.00	7.00	4.00	6.00	7.00	8.00	2.00	3.00	7.00	6.00	3.00	4.00	5.00
8	7.00	2.00	1.00	8.00	2.00	5.00	4.00	1.00	1.00	2.00	1.00	1.00	2.00	1.00	1.00	2.00
9	9.00	4.00	1.00	9.00	1.00	1.00	1.00	1.00	4.00	9.00	2.00	9.00	4.00	4.00	4.00	4.00
10	7.00	2.00	2.00	7.00	5.00	3.00	4.00	5.00	3.00	3.00	3.00	3.00	5.00	5.00	5.00	5.00
11	9.00	8.00	7.00	7.00	8.00	9.00	8.00	4.00	8.00	7.00	4.00	8.00	7.00	4.00	4.00	6.00
12	7.00	5.00	5.00	7.00	2.00	5.00	5.00	3.00	5.00	4.00	6.00	5.00	6.00	3.00	3.00	2.00
13	9.00	7.00	7.00	5.00	9.00	5.00	5.00	5.00	9.00	8.00	7.00	5.00	2.00	6.00	6.00	2.00
14	2.00	5.00	4.00	1.00	1.00	3.00	4.00	1.00	1.00	3.00	4.00	1.00	5.00	4.00	1.00	1.00
15	9.00	3.00	3.00	9.00	7.00	4.00	4.00	8.00	9.00	5.00	1.00	7.00	4.00	7.00	6.00	5.00
16	8.00	2.00	3.00	8.00	6.00	8.00	3.00	7.00	8.00	4.00	1.00	6.00	5.00	8.00	7.00	6.00
17	6.00	2.00	3.00	7.00	6.00	7.00	2.00	6.00	8.00	4.00	2.00	6.00	5.00	7.00	8.00	6.00

18	8.00	2.00	3.00	8.00	6.00	8.00	3.00	7.00	7.00	4.00	2.00	6.00	5.00	7.00	8.00	6.00
19	9.00	2.00	3.00	9.00	6.00	8.00	3.00	7.00	9.00	5.00	1.00	6.00	6.00	8.00	7.00	5.00
20	8.00	2.00	3.00	7.00	8.00	9.00	4.00	8.00	8.00	4.00	1.00	5.00	5.00	7.00	6.00	4.00
21	7.00	3.00	2.00	8.00	7.00	9.00	4.00	7.00	9.00	6.00	1.00	6.00	5.00	8.00	6.00	7.00
22	8.00	4.00	1.00	6.00	7.00	4.00	3.00	7.00	9.00	5.00	1.00	7.00	5.00	8.00	7.00	6.00
23	7.00	1.00	2.00	7.00	6.00	3.00	3.00	7.00	7.00	3.00	1.00	5.00	3.00	6.00	5.00	4.00
24	9.00	3.00	2.00	5.00	7.00	5.00	2.00	4.00	8.00	5.00	4.00	6.00	5.00	5.00	5.00	5.00
25	9.00	2.00	3.00	8.00	5.00	8.00	4.00	7.00	9.00	6.00	2.00	7.00	5.00	9.00	7.00	6.00
26	7.00	2.00	3.00	7.00	7.00	9.00	4.00	7.00	8.00	4.00	1.00	6.00	4.00	7.00	6.00	5.00
27	9.00	3.00	4.00	9.00	6.00	8.00	4.00	7.00	9.00	5.00	2.00	7.00	5.00	8.00	7.00	6.00
28	8.00	4.00	3.00	9.00	6.00	8.00	3.00	7.00	9.00	5.00	1.00	6.00	5.00	8.00	7.00	6.00
29	8.00	2.00	3.00	8.00	6.00	8.00	4.00	7.00	9.00	5.00	1.00	6.00	5.00	8.00	7.00	6.00
30	8.00	4.00	3.00	8.00	6.00	8.00	3.00	7.00	9.00	5.00	1.00	5.00	5.00	8.00	7.00	6.00

Table 11: Data set of the 3rd part of expert elicitation on Qualtrics XM (Questions 5-8)

	Question 9				Question 10				Question 11				Question 12			
1	9.00	4.00	9.00	2.00	9.00	0.00	0.00	2.00	9.00	1.00	1.00	9.00	9.00	0.00	1.00	9.00
2	4.00	4.00	6.00	3.00	5.00	8.00	7.00	5.00	4.00	6.00	7.00	4.00	4.00	6.00	6.00	5.00
3	4.00	2.00	2.00	2.00	5.00	2.00	2.00	6.00	5.00	4.00	6.00	7.00	4.00	2.00	3.00	6.00
4	9.00	3.00	4.00	9.00	9.00	2.00	2.00	8.00	2.00	9.00	9.00	7.00	1.00	4.00	7.00	7.00
5	7.00	4.00	3.00	5.00	7.00	2.00	2.00	7.00	6.00	2.00	3.00	1.00	8.00	3.00	4.00	1.00
6	8.00	4.00	5.00	3.00	7.00	6.00	7.00	4.00	6.00	4.00	3.00	4.00	7.00	5.00	4.00	5.00
7	4.00	6.00	5.00	4.00	4.00	6.00	5.00	3.00	6.00	7.00	5.00	4.00	7.00	8.00	5.00	4.00
8	5.00	2.00	3.00	3.00	3.00	4.00	3.00	3.00	3.00	1.00	1.00	3.00	2.00	2.00	3.00	3.00
9	6.00	9.00	7.00	2.00	5.00	5.00	5.00	5.00	7.00	5.00	8.00	9.00	6.00	6.00	6.00	6.00
10	5.00	5.00	5.00	5.00	7.00	2.00	2.00	5.00	2.00	5.00	2.00	2.00	3.00	6.00	6.00	3.00
11	6.00	7.00	5.00	4.00	9.00	8.00	8.00	8.00	6.00	6.00	7.00	3.00	6.00	7.00	7.00	3.00
12	6.00	6.00	7.00	5.00	6.00	4.00	5.00	6.00	7.00	5.00	7.00	7.00	3.00	3.00	5.00	4.00
13	9.00	6.00	8.00	4.00	9.00	3.00	6.00	5.00	6.00	8.00	9.00	5.00	4.00	7.00	8.00	5.00
14	6.00	6.00	2.00	5.00	7.00	3.00	2.00	6.00	4.00	6.00	4.00	4.00	7.00	6.00	9.00	6.00
15	9.00	4.00	9.00	2.00	8.00	1.00	1.00	3.00	9.00	1.00	1.00	9.00	8.00	2.00	1.00	7.00
16	8.00	3.00	8.00	1.00	9.00	2.00	3.00	1.00	8.00	1.00	2.00	8.00	9.00	2.00	1.00	8.00
17	8.00	3.00	8.00	2.00	9.00	2.00	1.00	2.00	8.00	2.00	1.00	7.00	8.00	2.00	1.00	9.00
18	8.00	3.00	7.00	1.00	9.00	1.00	1.00	1.00	8.00	1.00	2.00	8.00	9.00	2.00	1.00	9.00
19	9.00	4.00	8.00	2.00	9.00	1.00	1.00	3.00	8.00	1.00	2.00	9.00	9.00	1.00	2.00	9.00
20	8.00	3.00	8.00	1.00	8.00	1.00	1.00	3.00	8.00	1.00	2.00	8.00	8.00	2.00	1.00	7.00
21	8.00	3.00	7.00	1.00	8.00	1.00	1.00	3.00	8.00	1.00	2.00	9.00	9.00	2.00	0.00	9.00
22	8.00	4.00	8.00	1.00	8.00	2.00	1.00	3.00	8.00	2.00	1.00	7.00	8.00	2.00	1.00	7.00
23	7.00	2.00	7.00	1.00	7.00	1.00	2.00	2.00	8.00	2.00	2.00	7.00	7.00	1.00	1.00	6.00
24	7.00	4.00	5.00	5.00	4.00	6.00	3.00	3.00	5.00	3.00	1.00	2.00	6.00	3.00	9.00	6.00
25	8.00	4.00	9.00	2.00	8.00	2.00	2.00	3.00	8.00	1.00	1.00	8.00	8.00	1.00	3.00	9.00

26	7.00	3.00	7.00	1.00	7.00	1.00	1.00	2.00	7.00	1.00	3.00	7.00	8.00	2.00	1.00	7.00
27	8.00	4.00	8.00	3.00	8.00	2.00	2.00	3.00	8.00	2.00	2.00	8.00	8.00	2.00	3.00	8.00
28	8.00	4.00	8.00	3.00	9.00	2.00	2.00	3.00	9.00	1.00	1.00	8.00	8.00	2.00	1.00	9.00
29	8.00	4.00	9.00	2.00	6.00	1.00	1.00	3.00	9.00	1.00	1.00	8.00	9.00	2.00	1.00	8.00
30	8.00	4.00	8.00	3.00	9.00	1.00	1.00	2.00	8.00	2.00	1.00	7.00	9.00	1.00	2.00	8.00

Table 12: Data set of the 3rd part of expert elicitation on Qualtrics XM (Questions 9-12)

	Question 13				Question 14				Question 15			
1	5.00	9.00	9.00	2.00	9.00	9.00	9.00	2.00	9.00	3.00	3.00	9.00
2	7.00	3.00	3.00	5.00	8.00	2.00	4.00	8.00	8.00	2.00	3.00	8.00
3	7.00	6.00	5.00	3.00	5.00	2.00	5.00	6.00	7.00	4.00	4.00	8.00
4	8.00	2.00	5.00	2.00	2.00	6.00	6.00	4.00	9.00	6.00	2.00	8.00
5	8.00	4.00	5.00	5.00	3.00	1.00	2.00	3.00	9.00	3.00	4.00	9.00
6	5.00	6.00	6.00	3.00	7.00	5.00	5.00	6.00	9.00	3.00	2.00	8.00
7	5.00	8.00	6.00	4.00	7.00	6.00	3.00	8.00	7.00	6.00	3.00	8.00
8	4.00	5.00	3.00	3.00	7.00	1.00	1.00	6.00	9.00	1.00	1.00	8.00
9	5.00	5.00	5.00	5.00	9.00	5.00	7.00	5.00	9.00	4.00	1.00	9.00
10	5.00	5.00	5.00	5.00	7.00	3.00	3.00	6.00	7.00	3.00	3.00	5.00
11	8.00	8.00	6.00	4.00	7.00	7.00	7.00	7.00	9.00	7.00	7.00	9.00
12	5.00	2.00	3.00	5.00	7.00	5.00	7.00	7.00	7.00	5.00	5.00	7.00
13	8.00	3.00	6.00	5.00	7.00	7.00	9.00	9.00	9.00	7.00	9.00	7.00
14	7.00	2.00	3.00	3.00	9.00	5.00	5.00	5.00	9.00	8.00	5.00	4.00
15	5.00	9.00	9.00	2.00	8.00	5.00	3.00	6.00	9.00	3.00	3.00	9.00
16	4.00	8.00	8.00	2.00	9.00	6.00	3.00	7.00	8.00	3.00	4.00	8.00
17	4.00	7.00	8.00	2.00	9.00	6.00	3.00	7.00	8.00	3.00	9.00	8.00
18	5.00	7.00	7.00	2.00	8.00	5.00	3.00	5.00	8.00	3.00	9.00	7.00
19	5.00	9.00	9.00	2.00	9.00	6.00	3.00	7.00	9.00	3.00	3.00	9.00
20	4.00	8.00	8.00	1.00	8.00	5.00	3.00	6.00	8.00	3.00	4.00	8.00
21	4.00	6.00	8.00	1.00	8.00	5.00	3.00	6.00	8.00	3.00	4.00	8.00
22	5.00	7.00	9.00	2.00	9.00	6.00	4.00	8.00	9.00	3.00	3.00	9.00
23	4.00	8.00	8.00	2.00	8.00	5.00	2.00	5.00	7.00	2.00	3.00	7.00
24	5.00	2.00	5.00	6.00	8.00	3.00	1.00	5.00	9.00	5.00	9.00	9.00
25	5.00	9.00	9.00	2.00	8.00	6.00	2.00	7.00	9.00	3.00	3.00	8.00
26	4.00	7.00	7.00	1.00	8.00	5.00	3.00	7.00	8.00	3.00	4.00	7.00
27	5.00	8.00	8.00	3.00	9.00	6.00	3.00	7.00	7.00	3.00	3.00	8.00
28	5.00	9.00	9.00	2.00	9.00	6.00	3.00	7.00	9.00	3.00	3.00	9.00
29	5.00	8.00	9.00	2.00	9.00	6.00	3.00	7.00	9.00	3.00	4.00	9.00
30	5.00	9.00	9.00	2.00	9.00	6.00	3.00	7.00	7.00	2.00	3.00	8.00

Table 13: Data set of the 3rd part of expert elicitation on Qualtrics XM (Questions 13-15)

BIOGRAPHICAL SKETCH

Bahareh Bathaei holds a B.A. in Architecture and an M.A. in Landscape Architecture from the University of Shahid Beheshti (USB) in Iran, as well as a Ph.D. in Urbanism from the University of Architecture and Urbanism Ion Mincu (UAUIM) in Romania. In Iran and Romania, she worked as an engineer and designer. She has worked at UTRGV as a research and teacher assistant. She is currently employed for B2Z Engineering LLC. as a Civil Engineer. In August of 2021, Bahareh received her Master of Science in Civil Engineering from the University of Texas Rio Grande Valley. She can be contacted at bahar.bathaei@gmail.com.