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An Evaluation Study of Urban Development Strategy Based on of Extreme Climate Conditions

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Abstract: The extreme change of climate has recently influenced numerous cities around the world. This change has resulted in a higher frequency and increased intensity of natural disasters. Habitat and development types even cause complex disaster types. In 2005, the report of Natural Disaster Hotspots-A Global Risk Analysis declared that 73% of world population and land area are exposed to more than three types of natural disasters. Ninety-nine percent of the land area and population are exposed to natural disasters worldwide. These above records are much higher than those of other countries worldwide. Taiwanese people face high risks of natural disasters. The present study attempts to look into sustainable development policies that seek to prevent disasters through an expert questionnaire. The results of the questionnaire are further analysed with methodologies of the fuzzy Delphi method (FDM) and analytic network process (ANP). The analyses suggest that disaster prevention strategies should be prioritised in urban planning, accounting for the effects of climate change. In addition to disaster prevention and mitigation, pre-disaster preparation in daily life is critical because it ensures the execution of appropriate emergency responses in the event of a disaster. Although the current mainstream environmental policy emphasises non-structural mitigation, conventional structural mitigation remains imperative. By and large, the priority of disaster prevention strategy in Taiwan must be land use management and planning, as well as the public advocacy and training.

Keywords: climatic change; urban disasters prevention and rescue system; climate responsive; fuzzy Delphi method; analytic network process

1. Introduction

This study reviews the influences of climate change on the conditions and problems in Taiwan. It also explores the strategies for disaster prevention and mitigation in urban areas to elucidate the ways strategies operate and the ways public departments implement related policies.

In recent years, disasters related to climate change have damaged cities worldwide with an increase in frequency and severity. In addition, urbanisation and various development patterns have contributed to increasingly complex typologies of disasters. Since the early 1960s, public awareness on environmental pollution has increased. The topic of sustainable development has drawn considerable attention, and various international declarations and protocols have emerged. Under the influences of extreme climate, all countries worldwide are gradually focusing on the topic of disaster reduction. At the 1994 World Conference on Natural Disaster Reduction (WCNDR), the Yokohama Strategy and Plan of Action for a Safer World was announced with an aim to establish international and social actions and directions for disaster reduction. In 2005, the Hyogo Declaration and Hyogo Framework for Action 2005–2015 were issued, both of which clearly stated the close relationship between the overall planning of sustainable development and strategies for disaster prevention and mitigation (UNISDR (2007) [1]). In 2015, the Sendai Framework for Disaster Risk Reduction 2015–2030 was announced, with seven major targets for disaster risk reduction promulgated for implementation in the following 15 years (UNISDR (2015) [2]). Table 1 presents a detailed compilation of the WCNDRs. According to the declarations above, disaster prevention is one of the main policies in all of the governments worldwide. Many strategies could be executed for future sustainable development and natural resilience; however, when the strategic effects on social or natural systems exceed a critical threshold, the capacity for disaster prevention would be limited so that the goal to develop long-term adaptability for climate change in the built environment would be severely challenged. Disaster risk management and adjustment methods can enhance social, economic, and environmental sustainability. Implementing the most effective adjustment and disaster reduction methods could benefit the environment in the short term and reduce environmental vulnerability in the long term. Under the constant changes of extreme climate conditions, relevant hypotheses, cases, and simulation methods must be continuously examined to stimulate new responsive approaches to disaster prevention and mitigation and to increase the effects of resilience, thus, achieving the goal of sustainable development.

Table 1. Compilation of the WCNDRs.

Conference	Country/Location	Year	Outline of the Main Content
First WCNDR	Japan/Yokohama	1994	• Yokohama Strategy and Plan of Action for a Safer World issued to establish international and social actions and directions for disaster reduction.
Second WCNDR	Japan/Kobe	2005	• Hyogo Declaration announced • Hyogo Framework for Action 2005–2015 announced for formulating national and social strategies for disaster reduction in 10 years.
Third WCNDR	Japan/Sendai	2015	• Sendai Framework for Disaster Risk Reduction 2015–2030 announced. • Agreement on the following seven global targets for 2015–2030: 1. Substantially reduce global disaster mortality by 2030; 2. Substantially reduce the number of affected people globally by 2030; 3. Reduce direct disaster economic loss in relation to global gross domestic product by 2030; 4. Substantially reduce disaster damage to critical infrastructure and disruption of basic services; 5. Substantially increase the number of countries with national and local disaster risk reduction strategies by 2020; 6. Substantially enhance international cooperation to developing countries through adequate and sustainable support to complement their national actions for implementation of the framework by 2030; 7. Substantially increase the availability of and access to multi-hazard early warning systems and disaster risk information and assessments to the people by 2030.

2. Literature Review

The influences and impacts of climate change are amplified in urban areas with particularly high population densities and highly developed industries, particularly those influences that are substantial to natural environments and socioeconomic systems. Bouwer et al. (2010) [3] predicted and analysed the river flood damage caused by climate change in the Netherlands and indicated that a combination of climate and socioeconomic change might increase expect losses by 96%–719% by 2040 if no additional measures were executed to reduce flood probabilities or consequences. Specifically, the risks of disasters in urban areas are high. The influences of climate change can be divided into the following three main dimensions: (1) natural environment; (2) economy and society; and (3) changes in sea level, temperature, rainfall, and the occurrence of extreme climate events resulting from climate change and global warming. These three main dimensions have directly or indirectly influenced the original management mechanism of government departments related to water resources, ecosystems, food supplies, infrastructure condition, transportation, and energy. The influence will result in the impact of various aspects in urban areas such as deteriorated air and water quality and increased water flooding and energy load. On the basis of the key elements associated to climate change, the indices selected for this study are described as follows.

On 30 September 2013, the Intergovernmental Panel on Climate Change [4] released the Fifth Assessment Report, which indicates that the warming of the climate system is unequivocal and that continual greenhouse gas emissions will cause further warming of and changes in the climate system; moreover, the higher the degree of climate warming, the more substantial the impacts of climate change will become. Therefore, mitigating change requires a continual and considerable reduction in greenhouse gas emissions. Satterthwaite (2008) [5] reported that the influences of climate change on urban areas include floods, storms, rising sea levels, heat waves, and disease. Despite the severity of urban disasters caused by extreme climate in urban areas, urban planning and land use management can effectively reduce the risk of such disasters.

According to Climate Change Scientific Report in Taiwan in 2011, rainfall pattern has changed significantly. While the days of heavy rains increase during the last 30 years compared with those of the last 50 years, the unevenness of rain fall pattern has in fact caused drought in some areas. The change in frequency and intensity of rainfall also paralleled the global increase in heavy rain days and reduction in mid- to low-level rains (Karl and Knight (1998) [6], Goswami et al. (2006) [7], Lau and Wu (2007) [8]).

With regard to potential impacts of climate change on Taiwanese cities, Feng et al. (2007) [9] reported changes in energy usage, epidemic, flood and drought patterns, water resources management, impacts on agricultural and fishery resources, coastal areas, soil erosion and loss, and mudslides. Related studies on the various patterns of how climate change affects urban cities have indicated that the impacts of climate change on megacities or metropolises are severe and complex because of the population density and industrial development intensity in such areas. Ho et al. (2008) [10] maintain that urban cities in coastal areas are directly impacted by rising sea levels; thus, early response measures must be implemented.

Climate change-induced phenomena involve heavy rain, strong winds, floods, landslides, and rising sea levels, thus leading to disasters in urban areas and impacting various urban facilities and government departments. With the development of urban cities, the degree and scale of impacts caused by climate change have increased, such as the impacts on the supply of food and water resources and increase of the frequency and scale of floods, infectious diseases, and health problems, and infrastructure damage. Satterthwaite (2008) [5] stated the possible impacts of climate change on urban facilities and governmental sectors. Accordingly, this research listed in Table 2 possible impacts of climate change on urban areas in Taiwan in order to assess the adoptive strategy in the face of potential disaster.

Disaster is globally and commonly defined as the influences caused by hazards that may severely disrupt social functioning and result in human, material, and environmental losses at a large scale, the severity of which exceeds society's ability to respond by merely using social resources (Mileti (1999) [11]). Disasters and society are closely connected because social changes typically affect the frequency and scale of disasters. With urban development, densely populated areas are prone to a higher number and intensity of disasters because of inadequate urban and architectural planning.

Table 2. Compilation of the impacts of climate change on urban areas in Taiwan.

Climate Change Phenomenon	Current Influence/Vulnerability	Social Factors and Related Facilities	Areas/Group under Influence
Tropical cyclone/storm	Casualties and damages caused by floods and storms; Increased vulnerability of coastal areas; economic loss; transportation; tourism industry; infrastructures (e.g., energy and transport facilities); and disaster insurance	Land use and population density in flood risk areas; flood prevention; and government response	Residents living in coastal areas; areas with limited capability and resources; infrastructure; and disaster insurance
Extreme rainfall/ torrential floods	Soil erosion and landslides; floods; inhabited areas; transportation system; and infrastructure	Basic drainage systems; land development regulation (flood plain, potential flooding area, development regulation of geologically sensitive slope area)	Residential areas in geologically sensitive slopes and potential flood area
Heat wave/cold front	Influences on health, social stability, energy, water resource, people's other basic needs (e.g., water, food, and infrastructure) (e.g., energy facility)	Architectural design and internal temperature control; social environment; and government responsiveness	Mid-latitude areas; older adults; children, and people living in poverty
Drought	Water supply; people's livelihoods; electricity infrastructure; population migration; and water transportation	Water supply system; distribution of limited water resources; energy demand; and limited water supply	The first, second and third level industries in Taiwan
Temperature	Energy demand and cost; air quality in urban cities; permafrost thawing; tourism and entertainment; retail consumption; people's livelihoods; and ice melting and loss	Population and economic changes; land use changes; technological innovation; air pollution; and government responsiveness	The influences are widespread, with high-population-density areas in particular being required to adapt to the changes in resources and the environment
Saltwater intrusion	Impacts on water infrastructure	Flow of groundwater	Coastal and lowland areas, particularly areas with limited resources and capability
Rising sea levels	Coastal land use; flood risk; flooding; and water infrastructure	Coastal areas, and development of and land use in inhabited areas	Coastal and lowland areas, specially areas with limited resources and capability
Abrupt climate change	Disaster potential analysis	Population, economic, and technological changes; and system development	Numerous areas and groups

Disaster management refers to the employment of management methods and measures to alleviate the impacts of disasters on physical environments and is also a measure for preventing disasters. Maa (2002) [12], in an analysis of topics on disaster, followed the official definition indicated by the Federal Emergency Management Agency of the United States and divided the items of disaster management initiatives into the following: disaster mitigation, risk reduction, prevention, preparedness, response, and recovery. Accordingly, the definitions and examples of disaster management initiatives relevant to this study are determined (Table 3).

According to the definitions of disaster management initiatives in Table 3, disaster recovery emphasises recovery and reconstruction initiatives after disasters have occurred. Since disasters can cause substantial changes in environmental factors, developing specific strategies and plans in advance is challenging. The present study focused on urban planning methods and investigated the following five items of disaster management initiatives: mitigation, risk reduction, prevention, preparedness, and response.

Table 3. Compilation of the items of disaster management initiatives.

Initiative		Definition and Description	Example
Mitigation	Structural mitigation	Prevent disasters by reducing the risks of human and architectural disasters and by strengthening the architecture	Dyke and flood control channel
	Basic structural mitigation	Strengthen urban infrastructures	Hydropower system and sewer system
	Non-structural mitigation	Disperse crowds and minimize loss in built environments	Land planning and management and disaster insurance
Risk reduction		Risk reduction is a goal in disaster mitigation	Disaster insurance
Prevention		Prevent disasters such as fires from occurring	Relevant regulations on architecture, fire control, and labour safety and health.
Preparedness		Develop emergency response and management capacity in advance to offer timely and effective emergency responses in the event of a disaster	Analysis of potential hazards, risk analysis and detection, early warning and evacuation systems, maintenance of emergency supplies and communication systems, and community education and training
Response		Immediately rescue people, mitigate loss, and strengthen effective actions before, during, and after disasters	Disaster forecasting, casualty evacuations, settlement and emergency treatment of victims, search and rescue initiatives, and property safety and protection
Recovery		Restore or reconstruct urban facilities and systems in stages	Architectural reconstruction, restoration of life support system (short term), and restoration of industrial and living functions (long term)

In response to the increasing frequency of natural disasters, government ministries in Taiwan regard disaster and risk management as critical issues and focus in particular on flood and mudslide preventions. Floods in urban cities are associated with the characteristic of dynamic risk; that is, mutual changes are observed between urbanisation and flood occurrences in urban cities, such as changes in population, industry development, architectural form, and asset intensity. Urban planning is part of spatial planning and, thus, relevant strategies and management tools should be implemented to mitigate the intensity of disasters and to strengthen the capacity for urban disaster management. Regulations on disaster prevention measures and public construction are restricted in scope and scale; thus, only by implementing disaster reduction initiatives during spatial planning can the potential hazards caused by disasters be mitigated (Chen and Chen (2007) [13], Chan et al. (2003) [14]) constructed a framework of flood risk evaluation and employed a geographical information system to analyse the flood risk in the Taipei area and to map flood risk zones on the basis of the analysis results. Hsu et al. (2014) [15] performed a terrain analysis to identify and mark out geologic sensitive areas prone to mudslide occurrence. In recent years, losses caused by natural disasters have intensified despite structural mitigation measures. Consequently, numerous scholars have proposed implementing non-structural mitigation measures to minimise the possible losses resulting from future natural disasters. Kundzewicz (2002) [16] indicated that non-structural measures should be prioritised for matters related to climate change and sustainability. Bouwer et al. (2010) [3] estimated the future potential damage from river flooding in the Netherlands and reported that adapting to the environment and reducing disaster risk are the most effective measures for reducing flooding. Wu and Lee (2010) [17] also proposed that non-structural mitigation measures should be integrated into spatial planning and management and classified the measures into the following seven categories: development restriction policies, private land expropriation, capital investment and improvement projects, special assessments, disaster insurance and taxation, public education and community disaster prevention, and relevant database construction. Lai and Pai (2012) [18] investigated flood adaptation strategic planning and classified the following seven adaptation strategies formulated by a panel of experts: land use planning and management, infrastructure, disaster prevention facilities, staging and partitioning, risk communication, taxation system, and cooperation mechanisms. Accordingly, the adaptation strategies for spatial planning and management relevant to this study are determined (Table 4).

Table 4. The adaptation strategies for spatial planning and management.

Strategy for Spatial Planning and Management	Adaptation Strategy
Land use planning and management	1. Enhance ecological land-use planning. 2. Encourage land use designation change for potential disaster areas to minimise/minimize the effects of disasters. 3. Establish strict standards for environmental impact assessments. 4. Assess the vulnerability of major development programs. 5. Implement relevant development permits for potential disaster areas. 6. Enhance land-use monitoring. 7. Control the total amount of land development. 8. Review overall urban planning. 9. Stipulate land-use planning and regulations. 10. Enhance watershed conservation. 11. Actively offer afforestation advice. 12. Prohibit over use of land. 13. Establish alarm systems in environmentally sensitive areas. 14. Examine the distribution of road width and evacuation spaces during urban renewal. 15. Establish buffer areas in potential disaster areas. 16. Stipulate legal regulations for setback lines in potential disaster areas.
Infrastructure	1. Enhance drainage and flood protection facilities and increase the coverage of rainwater sewer systems. 2. Review the location and design capacity of public facilities.
Disaster prevention facilities	1. Enhance the planning and execution of disaster prevention projects in urban planning and relevant development projects. 2. Improve the design of disaster-resistant architectures. 3. Establish water detention facilities in parks and public green spaces. 4. Reinforce systems for monitoring weather, landslide disaster, as well as the conditions of river and water bodies' conditions.
Staging and partitioning	1. Develop management strategies to stimulate urban and rural development. 2. Regulate the total area of land development. 3. Designate national conservation areas in urban and rural environments. 4. Develop plans for urban and rural areas. 5. Promote compact development in urban cities.
Risk communication	1. Reinforce risk communication and understanding among urban and rural residents regarding disaster warnings. 2. Publicise/publicize city and county maps of disaster areas.
Taxation system	1. Enhance disaster insurance mechanisms and promotion. 2. Levy development impact fees when developing areas of high disaster risk.
Public education and community disaster prevention	1. Produce and publicise/publicize potential disaster area maps. 2. Government promotion (enhance people's disaster risk awareness). 3. Promote community disaster prevention.
Cooperation mechanisms of government	1. Establish a watershed management authority and enhance comprehensive watershed governance. 2. Establish a government department of environmental resources and enhance horizontal and vertical integration. 3. Establish an integrated database platform. 4. Establish a basic disaster-related database.

Relevant studies have indicated that high-density development in urban cities increases the impervious surface ratio and, thus, heightens surface runoff and peak discharge from rainfall and caused flood peak to occur ahead of expected time (Lin, Ho, and Yang (2005) [19]; Arnold and Gibbons (1996) [20]). In an experiment involving indoor rainfall simulations, Wang et al (2006) [21] indicated that the total amount of soil erosion from impervious-base soil boxes was considerably more than the sum of soil erosion from slurry and impervious-base soil boxes; moreover, in their experiments, soil erosion from the impervious base was extremely intensive during the second simulated rainfall, in which the amount of soil loss was fivefold more than the sum. An increased artificial cover ratio in urban cities causes an urban heat island effect or ecological destruction in urban environments (Lu et al. (2011) [22]). Parks and public green spaces in urban cities can effectively reduce the surrounding temperature and alleviate the urban heat island effect. Bowler et al. (2010) [23] indicated that urban parks and green areas could reduce the surrounding temperature by up to 1 °C on average. Cheng and Chiu (2015) [24] reported that high evapotranspiration could stabilise the comfort level of the surrounding environment and that different planting configurations could improve that comfort level. In summary, when urban planning initiatives are implemented, certain proportions of environmentally sensitive areas or urban areas should be planned or left for developing green spaces to increase the area and proportion of permeable layers in urban cities.

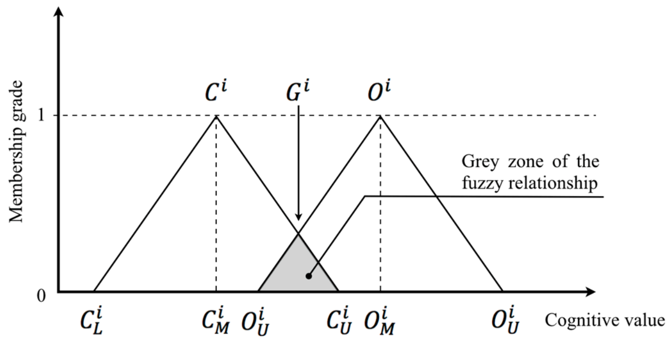
Taiwan lags behind in the studies of urban disaster prevention. It was not until recent years that concepts of urban disaster prevention been incorporated into urban planning. Therefore, more thorough studies on the relationships between urban planning and urban disaster prevention have been wanting. Lee (2000) [25] reported that disaster prevention is intended to ensure the safety of human life and property and that urban planning incorporates all types of development and planning related to living in urban cities; thus, in disaster prevention planning, space-related planning should be incorporated into urban planning for an overall consideration. Lee and Ho (2000) [26] reviewed the current situation of urban cities in Taiwan and indicated that Taiwan's urban cities must progressively promote constructions on urban disaster prevention to achieve the goal of transforming urban cities into disaster-prevention cities. To implement relevant procedures, extant urban spatial resources should be first examined and the possible disaster prevention functions of urban cities should subsequently be considered with the aim of constructing spatial systems for urban disaster prevention and emergency response. With the accumulation of disaster experiences, the damages from disasters can be minimised by establishing a holistic disaster prevention system; specifically, with the planning of urban disaster prevention systems, human life and property in urban areas can be protected in the event of a disaster (Ho et al. (2009) [27]). The complete construction of a spatial system for urban disaster prevention can ensure that successful and highly-effective rescue and emergency response initiatives are executed effectively should a disaster occur. Since spatial systems for disaster prevention are critical in urban disaster prevention planning, the following factors must be considered to completely plan, construct, and equip locations for disaster prevention: characteristics of an urban city, actual urban spaces, and urban population distribution. Accordingly, spatial systems for disaster prevention should be incorporated into urban planning to improve the capacity for urban cities in disaster prevention and rescue.

Taiwan's land planning system is categorized as regional and urban land managements. While it requires urban planning proposals to include disaster prevention plans, the spatial strategy of the overall system is still insufficient. So far, the plan has remained dependent on the current needs in the residential, commercial, and public facility areas of the urban planning, while ignoring the overall carrying capacity, leading to developments in potential disaster areas. Regulatory requirements on submitting disaster prevention and relief plan can be seen in the fifth, sixth, and ninth articles of Measures for the Implementation of Urban Planning Review, announced on 6 January 2011, as well as the twentieth article of Disaster Prevention and Relief Act, announced on 28 November 2012. The requirement, however, does not specify the content of the disaster prevention and relief plan, leading to a lack of integrated overall strategy when it comes to the land use and spatial development of urban planning areas. The traditional methodology of quantifying needs through demography neglected the potential problems of disasters and vulnerability analysis, therefore, excluding the scenario of disaster outside the sustainable development of future environment.

3. Research Method

This study focused on developing urban disaster prevention and mitigation indices and selecting strategies for urban disaster prevention as well as safe and sustainable urban planning. Accordingly, we employed the fuzzy Delphi method (FDM) and an expert questionnaire to confirm the urban disaster prevention and mitigation indices. Subsequently, the analytic network process (ANP) was adopted to select the optimal strategy. The details of each research method are as follows.

The fuzzy Delphi method (FDM) evolved from combining the conventional Delphi method and fuzzy set theory. The Delphi method was developed by Olaf Helmer, Norman Dalkey, and Nicholas Rescher at the RAND Corporation in the 1960s. The Delphi method is tedious and time-consuming to implement, and the questions in the questionnaire might be semantically confusing, thus, causing erroneous responses; as such, subsequent scholars improved the drawbacks of the conventional Delphi method. Ishikawa et al. (1993) [28] incorporated fuzzy set theory into the Delphi method to overcome these problems and employed the concepts of cumulative frequency distribution and fuzzy integral to transform the expert opinions into fuzzy numbers, through which the FDM was developed. Jeng (2001) [29] employed the double triangular fuzzy technique and grey zone test method to examine and integrate expert opinions and to reduce the frequency of repeated questionnaire surveys. Since these approaches (Figure 1) are more objective and reasonable than the single triangular fuzzy technique for obtaining the geometric mean, the present study developed the relevant criteria and indices for assessing urban disaster prevention and mitigation.



C^i: Conservative cognitive value
C_L^i: Minimum conservative cognitive value
C_M^i: Meridian conservative cognitive value
C_U^i: Maximum conservative cognitive value
O^i: Minimum optimistic cognitive value
O_L^i: Optimistic cognitive value
O_M^i: Meridian optimistic cognitive value
O_U^i: Maximum optimistic cognitive value
G^i: Experts consensus value

Figure 1. Double triangular fuzzy technique.

Proposed by Saaty in 1996 [30], the analytic network process (ANP) is derived from the previously-developed analytic hierarchy process and presented in the form of a network. The ANP offers a systematic method for confirming organisational goals and weighting values according to priority in order to systematically achieve decisions. In addition, the network relationship of the ANP method can present the relationship among the criteria and facilitate determining the limiting influences among all control criteria by forming a supermatrix. After a comprehensive assessment is executed on the supermatrix according to the priority order of the hierarchy of control, each supermatrix was assigned an appropriate weight. A supermatrix, which can effectively be used to solve the various criteria dependencies in the system, is formed by combining several submatrices. Each submatrix incorporates the interaction of each group element, and is derived from a paired comparison when the elements interact with other group elements. The numerical value of each submatrix is the weight of a submatrix derived from the calculated characteristic vector, which is obtained through the paired comparison; finally, a supermatrix is formed (Figure 2). If the matrix elements are co-dependent, then a fixed convergence value will be obtained after several times of matrix multiplications, and the extreme value is fixed.

$$
\mathbf{W}=
\begin{array}{cc}
 & \begin{array}{cccc} \mathbf{C_1} & \mathbf{C_2} & \cdots & \mathbf{C_n} \\ e_{11}e_{12}\cdots e_{1}m_{1} & e_{21}e_{22}\cdots e_{2}m_{2} & & e_{n1}e_{n2}\cdots e_{n}m_{n} \end{array} \\
\begin{array}{cc} \mathbf{C_1} & \begin{array}{c} e_{11} \\ e_{12} \\ \vdots \\ e_{1}m_{1} \end{array} \\ \mathbf{C_2} & \begin{array}{c} e_{21} \\ e_{22} \\ \vdots \\ e_{2}m_{2} \end{array} \\ \vdots & \vdots \\ \mathbf{C_n} & \begin{array}{c} e_{n1} \\ e_{n2} \\ \vdots \\ e_{n}m_{n} \end{array} \end{array} &
\begin{bmatrix} W_{11} & W_{12} & \cdots & W_{1n} \\ W_{21} & W_{22} & \cdots & W_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ W_{n1} & W_{n2} & \cdots & W_{nn} \end{bmatrix}
\end{array}
$$

W: Weight

Figure 2. Supermatrix.

Due to the current trends in climate change, urban planning methods must correspond with the current and local environmental conditions to effectively mitigate the influences of disasters on urban cities. Among the diverse methods of urban planning, each differs in its goals and methods; thus, it is difficult to objectively and quantitatively assess the most useful methods to accomplish this task. Accordingly, we employed the FDM to categorise and select the urban disaster prevention and mitigation indices that account for the effects of climate change to provide a reference for follow-up development of the strategies for urban safety and sustainable planning. Due to the interdependence between the selection of urban planning strategies and the various indices, the ANP was employed to quantify the interdependency to calculate the weights, rank the strategies, and establish a model for assessing the methods of integrated urban planning that account for the effects of climate change. Therefore, objective and credible reference information could be offered to urban planning decision-makers. The research results and their explanations are summarised as follows:

3.1. Assessment Indices of Urban Disaster Prevention and Mitigation

The study analysed, summarised, and compiled information from relevant studies on the influences of climate change on urban disasters, and proposed assessment indices for urban disaster prevention and mitigation. After the expert questionnaire data was analysed using the FDM, the following nine indices were selected: floods and storms, landslides, flooding, land use in coastal areas, flood risk, urban population density, the number of people residing in areas prone to mudslides, construction areas, and potential flood areas. All nine indices achieved expert consensus, indicating that all of them were appropriate assessment items for urban disaster prevention and mitigation.

3.2. Proposal and Selection of Strategies for Urban Safety and Sustainable Planning

At the first stage of this study, the FDM was employed to select the nine indices, which served as the main items for follow-up strategy proposal and assessment. We analysed, summarised, and compiled information from relevant urban planning studies on disaster prevention and mitigation to propose the strategies for urban safety and sustainable planning. After the various strategies were assessed through an expert questionnaire and statistically analysed using the ANP matrix, the weighted values of the strategies with interdependency among the urban disaster prevention and mitigation indices were obtained. On the basis of the weighted values, the high-priority strategies for urban safety and sustainable planning were selected. According to their weighted values, these strategies are ranked from high to low as follows: land use management and planning, public advocacy and training, facility construction and enhancement, management of and cooperation among government departments, and taxation system.

3.3. Establishment and Application of the Procedure for the Climate Responsive Strategy for Urban Planning

The FDM was employed to select the assessment indices and the ANP was subsequently adopted to rank the weighted values (from high to low) of the various strategies. Subsequently, an assessment model for the methods of integrated urban planning that accounts for the effects of climate change was established, from which objective and credible reference information and assessment methods could be offered to urban planning decision-makers. The assessment model corresponded with the spatial needs of today, in which urban problems resulting from high urban development must be urgently mitigated. In addition, the model can serve as a reference for policy promotion and relevant studies on follow-up urban planning.

4. Establishing the Assessment Index System for the Strategies of Urban Disaster Prevention and Mitigation

On the basis of the literature review in Section 2, we determined the urban disaster prevention and mitigation indices that account for the effects of climate change and subsequently design an expert questionnaire. After the assessment factors of the initially proposed expert questionnaire was surveyed, the FDM was adopted to statistically analyse the results of the expert questionnaire in order to explore the co-dependence among the various indices, thereby enabling selection of the assessment indices that meet the criteria.

The indices are classified into two types of subjects: A denotes the index group of natural environmental conditions, and B denotes the index group of socioeconomic environmental conditions. As shown in Table 5, four assessment items were included in Index Group A and three assessment items were included in Index Group B; furthermore, these assessment items were subdivided into 19 assessment indices.

Satty (2005) [31] has indicated the optimal number of five and a maximum of fifteen experts for the expert questionnaire method. Considering the extensive complexity of disaster impacts, nine experts in urban planning (three experts from industry, the government, and academia) were recruited for questionnaire in order to determine assessment indices. All of the distributed questionnaires were retrieved and were valid for the analysis. The questionnaire results were assessed using the FDM. In addition, the double triangular fuzzy technique and grey zone test method proposed by Jeng (2001) [29] were adopted to examine and integrate the experts' opinions. Table 6 presents the results of the selection calculated by the FDM.

The methods employed in previous relevant studies for selecting the FDM were consulted. Wu and Huang (2011) [32] indicated that, for scales with values ranging from 0 to 10, the threshold value is generally set at 5–7. In the present study, the obtained expert consensus values were all higher than 5; accordingly, when the threshold value are low, the effects of index selection cannot be adequately determined. Therefore, the threshold value was set at 6.51, which was the geometric mean of the expert consensus values, and 10 assessment indices associated with relatively low consensus values were excluded; thus, nine critical assessment indices were selected. The ten critical assessment indices that did not pass the threshold value are listed on the right side of the Table 7, and the remaining nine items are listed on the left. These nine major and critical assessment indices of urban disaster prevention and mitigation that account for the effects of climate change were analysed using the ANP at the second stage of this study. Before the ANP was performed, we confirmed the internal and mutual dependencies among the indices (Figure 3) through meeting with the experts to determine whether interdependency existed among the nine selected indices. The direction of the arrows indicates the direction of influence. When C1 Floods and storms points to C2 Landslides, for example, it means the former influences the latter and not vice versa. Here C3 Flooding and C5 Flood risk point to each other, therefore, the influences are mutual according to the identification of experts. In addition, we consulted relevant studies and interviewed experts and scholars to propose a project plan for urban disaster prevention and mitigation. Subsequently, we employed the ANP to compare the weighted values of the proposed projects to serve as a basis for projects on urban safety and sustainable development.

Table 5. Contents of the urban disaster prevention and mitigation indices that account for the effects of climate change.

Assessed Subject	Assessment Item	Assessment Index	Index Explanation
Index Group A (natural environmental conditions)	A1 Typhoon/storm	A1-1 Flood and storm	A flood refers to an overflow of water from water bodies, such as rivers, lakes, or the ocean, in which the water body exceeds the regular water level. A storm refers to winds measuring 10 or 11 on the Beaufort scale, which is an equivalent wind speed of 88–117 km/h (48–63 NM/h or 24–33 m/s).
		A1-2 Disease infection	Infectious diseases such as dysentery and cholera frequently breakout following disasters.
		A1-3 Vulnerability of coastal areas	Vulnerability can be viewed as a function of impact, sensitivity, and adaptability.
	A2 Extreme rainfall (flood)	A2-1 Landslide	Landslides are geological phenomena involving downward slope movements of the ground, often resulting from extremely heavy rainfall.
		A2-2 Flooding	Flooding, which can also be known as inundation, is a natural disaster caused by a flood.
		A2-3 Soil erosion loss	The problems caused by soil erosion loss involved land losses and reduced productivity of agricultural lands and forest lands, in which the influences are long-term and irreversible. Soil erosion may simultaneously cause sedimentation in reservoirs, rivers, irrigation canals, and other water channels.
	A3 Drought	A3-1 Water supply	Water supply refers to the supply of necessary domestic and industrial water.
		A3-2 Energy supply	Energy supply refers to the supply of necessary domestic and industrial energy.
		A3-3 Transfer of water resources	In conditions of imbalance between water supply and demand, water resources are transferred to balance the water supply with demand.
	A4 Rising sea levels	A4-1 Land use in coastal areas	Land use methods in coastal areas are influenced by rising sea levels.
		A4-2 Flood risk	Flood risk refers to the increased flooding risk in low-lying areas resulting from rising sea levels.
		A4-3 Coastal retreat	Coastal retreat causes farmlands, villages, and land to be eroded and flooded by seawater.
Index Group B (socioeconomic environmental conditions)	B1 Characteristics of the population easily affected by disasters	B1-1 Urban population density	Urban population density is the average population of a specific unit area of land at a specific time.
		B1-2 Death toll from disasters over the years	Number of people killed by natural disasters over the years.
		B1-3 Number of people residing in areas prone to mudslides	Number of people who are residing in areas prone to mudslides.
	B2 Industrial economy	B2-1 Household income	Total income per household
		B2-2 National workforce	The employed population refers to the population aged 15 or above and meeting the following conditions within the standard survey period (i.e., 1 year): engaged in paid employment for 6 months or longer with an annual income of ≥NT$115,000.
	B3 Built environment	B3-1 Construction area	Construction area refers to the maximum horizontal projection area calculated from the centreline of the building's outer wall or substituted construction post.
		B3-2 Potential flood areas	Demographic surveys are conducted to design the rainfall condition, collect topographic and geomorphologic data, and construct a hydrodynamic model for simulating potential flooding conditions while flood control facilities are operating normally.

Table 6. Chart of the assessment factors from the expert consensus values G^i.

Critical Assessment Indices that Passed the Threshold Value of 6.51				Critical Assessment Indices that Did Not Pass the Threshold Value of 6.51			
Rank		**Assessment Factors**	**Expert Consensus Value G^i**	**Rank**		**Assessment Factors**	**Expert Consensus Value G^i**
1	B3-2	Potential flood areas	8.50	10	A2-3	Soil erosion loss	6.43
2	A2-2	Flooding	7.52	11	A3-1	Water supply	6.42
3	A4-1	Land use in coastal areas	7.46	12	B2-2	Employed population	6.11
4	A1-1	Floods and storms	7.43	13	A3-3	Transfer of water resources	5.94
5	B3-1	Construction area	7.37	14	A1-3	Vulnerability of coastal areas	5.88
6	B1-1	Urban population density	7.34	15	A3-2	Energy supply	5.62
7	B1-3	Vulnerability of coastal areas	6.96	16	A1-2	Disease infection	5.61
8	A2-1	Landslides	6.91	17	B2-1	Household income	5.60
9	A4-2	Flood risk	6.64	18	A4-3	Coastal retreat	5.58
-		-	-	19	B1-2	Death toll in disasters over the years	5.47

Table 7. Strategies for urban safety and sustainable planning.

Strategy Selection	Item Implementation	Item Explanation	Author/Source, Year
Facility construction and enhancement	Infrastructure	• Enhance the construction of drainage and flood control facilities • Further develop rainwater sewage systems • Increase the green coverage rate and environmental permeability in urban cities	Bowler et al. (2010) [23]; Maa (2001) [12]; Wu and Huang (2011) [32]; Lin et al. (2005) [19]
	Facilities with disaster prevention and rescue functions	• Plan the evacuation range and shelters • Implement policies that ensure corresponding police and fire stations are assigned to operate in local evacuation ranges to prevent disasters • Plan road network systems to prevent disasters • Increase the flood retention volume in parks and green spaces and the number of people that evacuation shelters can accommodate • Establish systems for monitoring potential disaster areas	Maa (2001) [12]; Ho et al. (2007) [33]; Wu and Huang (2011) [32]
Land use management and planning	Development restrictions	• Restrict land use in potential disaster areas to uses that will not be easily affected by disasters • Restrict developments in potential disaster areas and environmentally sensitive areas • Establish buffer areas and stipulate legal regulations for setback lines in potential disaster areas and environmentally sensitive areas • Regulate the total area of land development	Schwab et al. (1998) [34]; Bouwer et al., 2010 [3]; Pauleit et al. (2005) [35]; Wu and Lee (2010) [17]; Wu and Huang (2011) [32]
	Special assessments	• Assess the environmental influences on and vulnerability of major development projects and environmentally sensitive areas • Strengthen the standard for designing disaster-resistant buildings in areas easily affected by disasters	Schwab et al. (1998) [34]; Smith et al. (2008) [36]; Wu and Lee (2010) [17]; Wang et al. (2013) [37]
	Expropriation of private land	• Transfer the development rights of areas of high disaster risk to public departments • Expropriate lands in areas of high disaster risk after disasters have occurred	Schwab et al. (1998) [34]; Wu and Lee (2010) [17]
	Improve public facility investment	• Avoid areas of high disaster risk when investing in critical public facilities • Avoid areas of high disaster risk when reconstructing public facilities after disasters have occurred	Schwab et al. (1998) [34]; Wu and Lee (2010) [17]

Table 7. *Cont.*

Strategy Selection	Item Implementation	Item Explanation	Author/Source, Year
Public advocacy and training	Disaster risk advocacy	• Strengthen disaster warning and public risk advocacy • Ensure that the government publically discloses real-time information on disasters	Schwab et al. (1998) [34]; Wu and Lee (2010) [17]; Wu and Huang (2011) [32]
	Community disaster prevention	• Advocacy and maintenance of community evacuation ranges and shelters • Implement community disaster prevention training	Schwab et al. (1998) [34]; Cutter et al. (2008) [38]; Ho et al. (2007) [33]; Wu and Lee (2010) [17]
Taxation system	Disaster insurance	• Implement and promote disaster insurance	Schwab et al. (1998) [34]; Wu and Lee (2010) [17]; Wu and Huang (2011) [32]
	Development impact tax	• Levy a development impact tax when developing environmentally sensitive areas and potential disaster areas	Wu and Lee (2010) [17]; Wu and Huang (2011) [32]
Management of and cooperation among government departments	Dedicated government departments	• Establish a watershed management department to strength river basin management • Establish an environmental resource department to enhance the horizontal and vertical integration of relevant departments and organisations	Schwab et al. (1998) [34]; Wu and Lee (2010) [17]; Wu and Huang (2011) [32]
	Construct a relevant database	• Construct a basic database related to disasters • Establish an integrated platform for the database on disasters	Schwab et al. (1998) [34]; Wu and Lee (2010) [17]

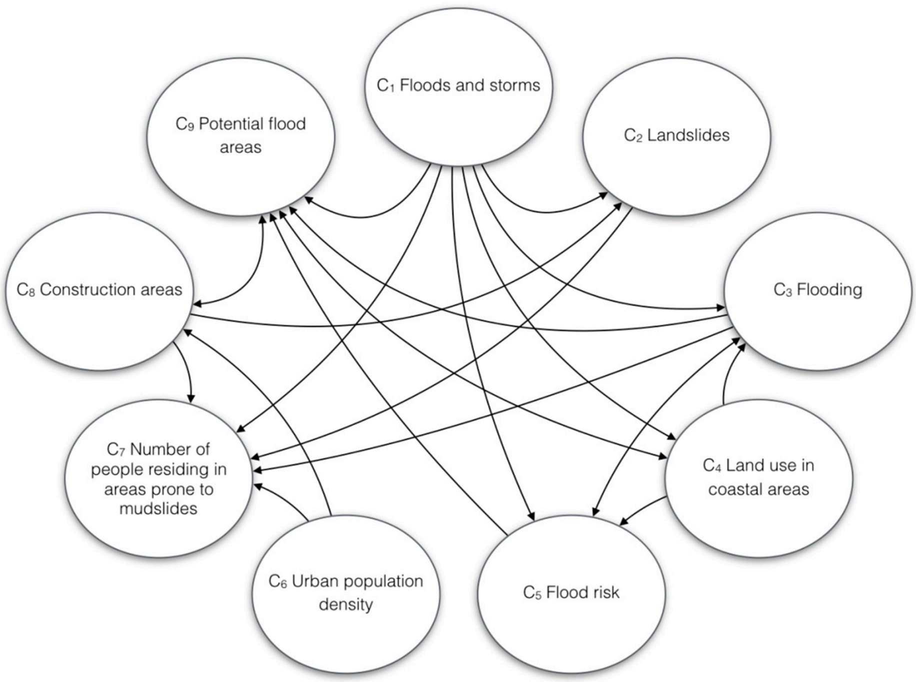


Figure 3. Relationship diagram indicating the interdependency and mutual influences among the urban disaster prevention and mitigation indices.

5. Establishment of Climate Responsive Strategy for Urban Planning

The FDM method is used to select and assess the urban disaster prevention and mitigation indices by combining relevant statements in the literature review to classify and arrange the strategies for urban safety and sustainable planning. The ANP was adopted to explore the weights of these strategies. The results may serve as a reference for urban planners when implementing climate change response strategies.

The compiled strategies for urban safety and sustainable planning were divided into the following five types of assessment strategy according to their characteristics: facility construction and enhancement, land use management and planning, public advocacy and training, taxation system, and management of, and cooperation among, government departments. In addition, these five types of assessment strategy were further categorised into 12 implementation items (Table 7 lists the strategies and their explanations; Figure 4 presents a hierarchical diagram of the assessment strategies). The selected strategies involving the items of disaster management initiative shown in Table 4 are summarised as follows.

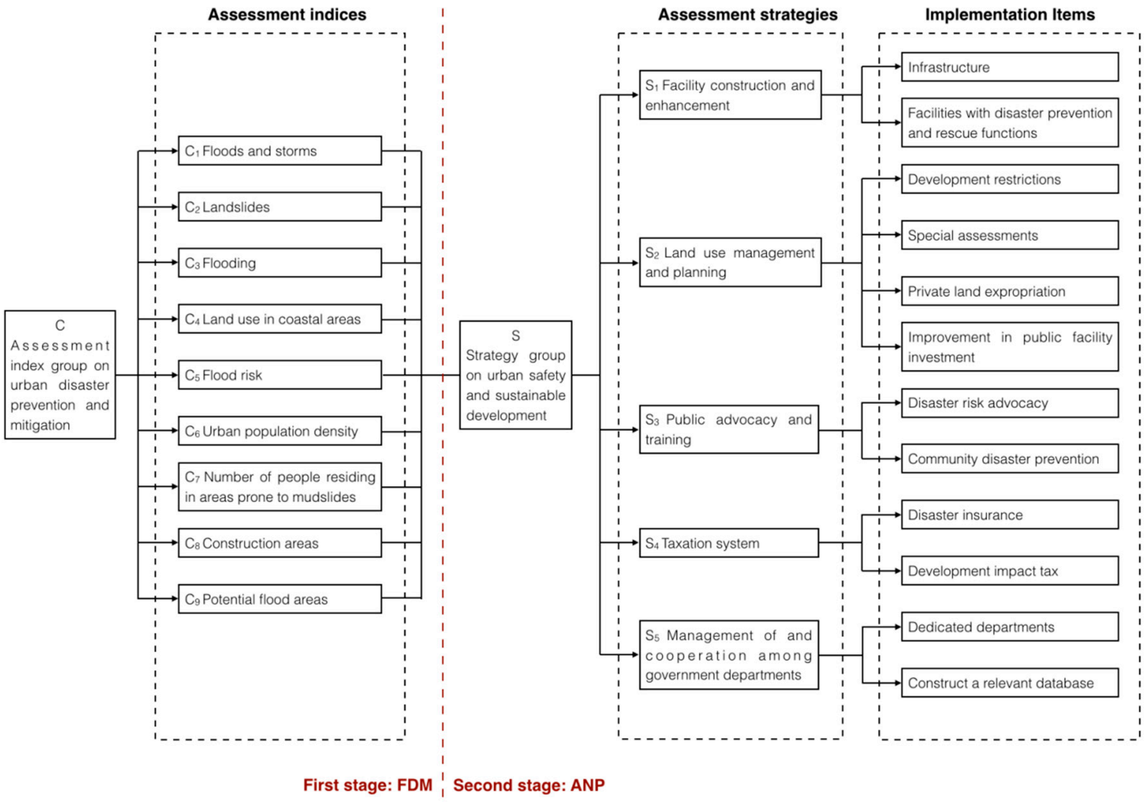


Figure 4. Framework of the assessment levels of the strategies for urban safety and sustainable planning.

(1). Facility construction/enhancement: Mitigation includes structural mitigation, basic structural mitigation, and non-structural mitigation. Since the characteristics of both structural and basic structural mitigation are associated with the enhancement of hardware facilities we, thus, categorised them as strategies for facility construction and enhancement. On the basis of the flood adaptation strategies indicated by Lai and Pai (2012) [18], the strategy for facility construction and enhancement was further divided into infrastructure, which incorporates drainage and flood protection facilities, rainwater sewer systems, and environmental permeability; and disaster prevention facilities, which incorporates designating an evacuation range and establishing evacuation shelters, police and fire stations, road network systems for disaster prevention, and parks and green spaces with disaster prevention functions.

(2). Land use management and planning: Non-structural mitigation refers to crowd dispersion and the extent of loss of built environments and mitigation achieved through land use management and planning. On the basis of the non-structural mitigation strategies compiled by Wu and Lee (2010) [17], we determined that the following were associated with land use management and planning: development restriction policies, private land expropriation, capital investment and improvement projects, and special assessments. The development restriction policies pertain to restricting the development of potential disaster areas, establishing buffer areas in potential disaster areas, and stipulating legal regulations for setback lines in potential disaster areas. The following three strategies proposed by Wu and Lee (2010) [17] were also incorporated: regulate the total area of land development, review overall urban planning, and land use planning and regulations. Specifically, special assessment refers to a specially regulated assessment mechanism involved with assessing the vulnerability of major development projects and implementing a relevant development permit system for potential disaster areas. We also incorporated the standard for improving the design of disaster-resistant buildings proposed by Wang et al. (2013) [37]. Private land expropriation is associated with transferring the development rights of areas of high disaster risk and expropriating the lands in such areas after disasters have occurred. Regarding capital investment and improvement, which pertain to avoiding major public investments and construction in areas of high disaster risk, it was categorised into public facility investment and improvement strategies. The planning of land use management can reduce the burden of the urban environment and avoid the high-risk area of built environment through management planning at the early stage.

(3). Public advocacy and training: Preparedness refers to making preparations before disasters occur, such as developing emergency response and management capacity, notifying relevant personnel, executing relevant procedures, and promoting community education and training. The non-structural mitigation strategies formulated by Wu and Lee (2010) [17] included public education and community disaster prevention. For flood adaptation strategies, Lai and Pai (2012) [18] indicated in the risk communication strategy that the urban and rural residents' risk communication and knowledge of disaster warnings should be enhanced. Many cases relating to the adaptation of city due to climate changes show the significance of participation. Wamsler et al. (2014) [39] points out that people in Swedish cities have the ability of disaster adaptation, which is generally ignored by governments. Kumar et al. (2015) [40] indicates cities in India show that the training and education of disaster prevention can improve the awareness of people and well preparation for the disaster occurrences. Accordingly, we classified these strategies into public advocacy and training, in which disaster risk advocacy and community disaster prevention were incorporated for implementation.

(4). Taxation system: Non-structural mitigation could achieve the goal of disaster mitigation and risk reduction by following the disaster insurance strategy. According to the non-structural mitigation strategies proposed by Wu and Lee (2010) [17], disaster insurance and taxation could be implemented and promoted when disaster insurance is executed and development impact fees are levied during the development of areas of high disaster risk. Wu and Huang (2011) indicated that a taxation system could be adopted to enhance insurance mechanisms and advocacy and to serve as a flood adaptation strategy.

The taxation system here includes disaster insurance and development impact. Both collect funds in advance for prevention and restoration purposes. The difference lies in the method of funds acquisition. A taxation system minimizes the risk of disaster damage through insurance, while the collected funds can be used for disaster prevention.

(5). Management of, and cooperation among, government departments: Preparedness refers to public advocacy and training, as well as potential hazard and risk analysis, risk detection, and establishing an early warning system. The results could serve as a basis for designating potential disaster areas in land use management and planning, as well as for constructing a relevant database and integrated platform to enhance the convenience of all government departments during operation, research, decision-making, and use of relevant data (Wu and Huang (2011) [32]). In addition, Wu and Huang (2011) [32] indicated that departments related to watersheds and environmental resources must be established to improve horizontal and vertical integration. According to the definitions of this research, the management strategy of and cooperation among public sectors includes the founding of a specialized department and establishment of databases. The specialized department would be in charge of the establishment and updates of disaster data—such as the potential flooding area, geological sensitive areas, real-time weather, and weather forecast data—in order to make an informed response by greater control of information. The establishment of the database, as a result, facilitates the sharing of disaster prevention data across various departments, as well as with the people, strengthening both the transversal and vertical communications and information sharing.

In the second stage of this study questionnaires were distributed to nine different urban planning experts in public and private sectors. A questionnaire method, ANP, was subsequently employed to obtain the experts' opinions on the strategies for urban sustainable planning. All of the distributed questionnaires were successfully retrieved. The ANP was adopted for evaluating the questionnaire results and examining and integrating the expert opinions, through which the weights of the urban disaster prevention and mitigation indices were determined so that they reflected the strategies for urban safety and sustainable planning derived from the indices (Saaty (1996) [30]). Table 8 lists the two weighted values for the items, which are ranked according to their importance.

Table 8 shows that the first two indices were significantly higher than the other indices, with C1 floods and storms exhibiting the highest significance and achieving 41.6% in the overall index weights. The results indicated that the experts and scholars believed that floods and storms had the strongest influence on urban disaster prevention and mitigation, followed by urban population density. The indices associated with high weights had a strong influence on the selection of the strategies for urban safety and sustainable planning. The strategies for urban safety and sustainable planning are ranked according to their importance as follows: S2, land use management and planning > S3, public advocacy and training > S1, facility construction and enhancement > S5, management of and cooperation among government departments > S4, taxation system. Table 8 also shows that the weighted values of the first two strategies were significantly higher than the other strategies, with S2 exhibiting the highest significance and achieving 29.8% in the overall strategy weights. The results indicated that the experts and scholars assigned the highest priority to S2, followed by S3.

Table 8. Ranking of the urban disaster prevention and mitigation indices and strategies for urban safety and sustainable planning according to their importance.

Ranking (Importance)	Weighted Indices of Urban Disaster Prevention and Mitigation (W_C)			Weighted Strategies for Urban Safety and Sustainable Planning (W_{ANP})		
	Item	Weight	%	Item	Weight	%
1	C_1 Floods and storms	0.41593	41.6	S_2 Land use management and planning	0.29787	29.8
2	C_6 Urban population density	0.15982	16.0	S_3 Public advocacy and training	0.21140	21.1
3	C_4 Land use in coastal areas	0.11414	11.4	S_1 Facility construction and enhancement	0.17640	17.6
4	C_3 Flooding	0.08685	8.7	S_5 Management of and cooperation among government departments	0.16991	17.0
5	C_8 Construction areas	0.06371	6.4	S_4 Taxation system	0.14442	14.4
6	C_5 Flood risk	0.05623	5.6	-	-	-
7	C_9 Potential flood areas	0.04928	4.9	-	-	-
8	C_2 Landslides	0.04162	4.2	-	-	-
9	C_7 Number of people residing in areas prone to mudslides	0.01242	1.2	-	-	-

6. Discussion

The calculated results indicate that the strategy of land use management and planning was the most prominent, accounting for 29.8% of the overall weighted value (Table 8). The results suggest that this strategy should be prioritised in urban planning that accounts for the effects of climate change. For example, the following items should be implemented: development restriction policies, special assessments, private land expropriation, and improvement in public facility investment. In addition, among the items of disaster management initiatives of mitigation (Table 4), the main contents of nonstructural mitigation and disaster prevention involved adapting to the environment to implement changes in land planning and architectural design. The research results are consistent with previous studies (Kundzewicz (2002) [16]; Bouwer et al. (2010) [3]; Wu and Lee (2010) [17]).

These results recall the recent passing of the National Land Planning Act, in particular its emphasis on sustainable environments and climate change, in light of integrated planning and management. Although no overall strategic policy has been established so far, individual physical mechanisms in large-scale urban development, stormwater planning reviews, and flood management have been implemented. When it comes to analysis, however, the lack of planning scenarios in climate change has resulted in the negligence in the rescue, reduction, and adaptation of urban disasters. The inability to consider climate change factors also contributes to inadequate responsive strategy in such hazardous events as heat wave, smog, cold front, and water shortage. In addition to analytical tools of flooding and urban wind fields, the science of planning demands diverse techniques in order to incorporate multiple disaster situations and to establish adaptive land-use planning principles. In terms of urban design and building management, simulations of urban planning subdivisions based on physical factors—such as the reduction of the urban heat island effect and smog through the urban wind field, anti-seismic elevated buildings, and micro-climate adjustment through water and green coverages—are also lacking. Although the mechanism of urban design review has begun to incorporate these aspects, multiple scenario analysis is still needed in order to actively integrate the ideas of the resilient city into current practices.

The strategy for public advocacy and training was ranked second, accounting for 21.1% of the overall weighted value, suggesting a relatively high importance (Table 8). This strategy was defined as disaster preparedness among the items of disaster management initiatives (Table 4); therefore, in addition to disaster prevention and mitigation, pre-disaster preparation in daily life is critical because it ensures that appropriate emergency responses are executed in the event of a disaster. The break-out of severe acute respiratory syndrome (SARS) in 2003 and the spread of dengue virus in Southern Taiwan has prompted the establishment of several disease-control networks and training in disaster-prevention communities. Moreover, the strategy of facility construction and enhancement was ranked third, accounting for 17.6% of the overall weighted value (Table 8), and incorporated infrastructure and facilities for disaster prevention and mitigation. Among the items of the disaster management initiatives of disaster mitigation (Table 4), this strategy was defined as structural mitigation and basic structural mitigation, indicating that although the current mainstream environment emphasises non-structural mitigation, conventional structural mitigation remains imperative.

The existing management strategy of natural coastal lines in Taiwan also implements an adaptive disaster prevention strategy while reducing its reliance on synthetic facilities. However, it still suffers from an overlapping of management institutions. The challenge in climate change is, in fact, an opportunity to consolidate these redundancies. Emphasis on integration is also one of the major goals of the National Development Council. This significant breakthrough needs more collateral supports in order to confront and adapt to future climate changes.

According to the analysis of statistical results above, the suggested prioritized strategy in Taiwan is land use management planning, which regulates the developments of potentially flooding area and geologically-sensitive slopes through growth restriction and specialize assessment, lower the risk for disaster and improve the environmental vulnerability. Meanwhile, education and training of citizens should also be strengthened. Through education of disaster risks and community training programs, people become more responsive to disasters. Of course, facility improvements for disaster prevention and reduction are still necessary and ought to continue. According to the result of the FDM index, the urban drainage system is still the major facility issue.

In conclusion, the overall suggestions for disaster prevention strategy in Taiwan should prioritize the analysis of disaster potential and vulnerability when making and reappraising urban plans, including the land use zoning plan, public facilities land use plan, key points of land use zoning control, urban design criteria and building management. To specify, respectively, the land use zoning plan includes the change of the agricultural area into a stormwater detention pond, the change of idle space into a stormwater retention pond; the public facilities land use plan includes the multi-target use of the public facilities land, changing non-flood control functional land for public facilities and the utilization of road drainage flood detention; the key points of the land use zoning control includes an increase in the proportion of the statutory land area, the need for the lands to function as a stormwater retention pond when donated or returned for public facilities; urban design guidelines include an increase of pervious area for statutory land, restrictions of the basement excavation rate, introduction of low impact development facilities, land elevation management, and an open space design for ground floors; building management is achieved through rainwater collection and storage facilities that increase the capacity of flood detention and retention in metropolitan areas.

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