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STATE OF THE ART IN RISK SENSITIVE URBAN DEVELOPMENT: A SYSTEMATIC LITERATURE REVIEW

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ABSTRACT

Risk-sensitive urban development is an innovative planning approach that can transform the way cities are built in order to face the uncertainties that arise from climate-induced disaster risks. There are many actions taken by individuals, households, communities, urban development companies and relevant regulatory bodies to manage the risk through the risk sensitive urban development methods. However, there is a disconnection between the existing urban development projects and urban risk management process. Therefore, urban developers and disaster risk managers should understand each other and collaborate in order to provide a solution for this disconnection. In this regard, identifying the state of the art of a risk sensitive urban development is beneficial for both urban development and disaster management authorities to achieve their objectives. This study therefore explores the state of art revealing indices, models, concepts, tools and approaches which guide both urban developers and disaster managers to achieve risk sensitive urban development. A systematic literature review using PRISMA method covering the publications from 2017 to 2022 was carried out to identify the state of the art in risk sensitive urban development. Having followed a systematic filtering process, a total of 45 out of 281 research contributions have been considered for an in-depth analysis. The study found storm surge disaster loss (SSDL), GRaBS assessment tool and early warning systems as the key approaches of risk sensitive urban development which can lead both urban developers and disaster managers to synchronise their ideas to achieve risk sensitive urban development.

Keywords: *Climate Change; PRISMA; Risk Sensitive Urban Development; Urbanisation.*

1. INTRODUCTION

Populations in rural areas move to cities in search of employment and better living conditions since there are existing infrastructure encourages investment in industry and commerce; increased standards of health and nutrition; increased life expectancy and lower infant mortality; the perception that the city offers better education, training, employment and leisure opportunities; and the occurrence of natural and human induced hazards in rural areas (Malalgoda and Amaratunga, 2015). Matsuoka and Shaw (2014)

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have explored that urban population, urban setting, urban structures, compact urban forms, and urban dependence on rural areas, urban primacy, urban informal settlement, urban economic imbalances, urban services, urban natural environment, urban built environment, and urban governance and management lead to urban risks and major challenges for Asian countries in future. According to Deely, et al., (2010), people are concentrating in large cities with poor housing with lack of basic protective infrastructure, hence will cause to generate higher urban risks. Further, the authors fear that this urban risk may be a major challenge for humankind in the 21st century.

"Risk-sensitive urban development is an innovative planning approach that can transform the way cities are built in order to face the uncertainties that arise from climate-induced disaster risks" (Roslan, et al., 2021). According to United Nations Economic and Social Council (2015), risk-sensitive development involves integrating disaster risk reduction into development planning across all sectors of development that help to protect gains made towards achieving development goals. Furthermore, it is promoted in order to reduce existing risk in the city and to properly address risk while planning new developments, which is typically done in the context of uncertainties and threats (Jones and Preston, 2011). The risk sensitive urban development, focused on more appropriate building design, construction and land-use planning, enhanced infrastructure access and maintenance, risk awareness raising, and planning for emergency response and reconstruction including social safety nets and insurance (Leck, et al., 2018a). There are several frameworks such as Sendai Framework, Hyogo framework, Community Resilience Framework (CRF) and Sri Lanka Comprehensive Disaster Management Programme (SLCDMP) which provide guidance to risk sensitive urban development projects (Saja, et al., 2020). Those frameworks have identified and designed several strategies such as hazard vulnerability and risk assessment, risk knowledge and risk governance, policy environment and legal/institutional framework, multi-hazard early warning and effective dissemination, disaster mitigation and DRR mainstreaming into development, reconstruction and rehabilitation, training and awareness, preparedness and response, and monitoring and evaluation which can be used for a risk sensitive urban development (Malalgoda and Amaratunga, 2015; Republic of Palau, 2016; Saja, et al., 2020; Yang, et al., 2021)

There are many actions taken by individuals, households, communities, urban development companies and relevant regulatory bodies to manage the risks through the risk sensitive urban development methods. However, there are gaps between what they have expected and what they have accomplished under risk sensitive urban development. The ability of urban cities to effectively manage their urban risks and well-being of the population, sustain balanced growth, and tackle climate change impacts is not only determined by sector legislation but also by the framework of outdated urban regulations that is still in force (Asian Development Bank, 2015). Moreover, it has been explored that, there is a disconnection between the existing urban development projects and urban risk management process. Pelling, et al., (2017) has also pinpointed that urban planning in many parts of the world, but particularly in developing regions, has become increasingly disconnected from contemporary urban challenges linked to rapid urbanisation, poverty, informality, spatial fragmentation and climate change. In order to provide a solution for this disconnection and the climate change risk, urban developers and disaster risk managers should communicate and collaborate with each other to move to risk sensitive urban development. This study explores the state of the art in risk

sensitive urban development by analysing the currently used models, concepts, indices and approaches. The state of the art refers to the study on a phenomenon based on the level of development that has reached at a particular time, where the development can be in the form of a device, procedure, process, technique or science. Accordingly, the systematic literature review is followed to explore the state of art in the risk sensitive urban development. The next section discusses the research methodology adopted. Then the analysis of systematic literature review is presented followed by the conclusions.

2. RESEARCH METHODOLOGY

A systematic literature review was used to explore the state of art in risk sensitive urban development. A systematic literature synthesis was conducted by adopting Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) mainly to explore the research question of "What is the state of the art in risk sensitive urban development?" which was developed using the PICO (Population, Intervention, Comparison, and Outcomes) approach (Aslam and Emmanuel, 2010). The PICO approach provides a sound basis for formulating the research question and defining the keywords for the literature survey from the terms included in the research question. Following the PICO approach, the first step was to construct a logic grid (Table 1) and conduct an initial search using the key terms in the grid. Alternative terms or synonyms for the identified concepts were then added by scanning the titles and abstracts of retrieved articles in this initial search to populate a comprehensive logic grid (Table 2). According to Taylor (2017) a comparison is not always required or appropriate depending on the type of research question. As such the Comparator (C) component was neglected in this study since there is no comparator to compare with the intervention in the research question. Table 2 provides a comprehensive search strategy consisting of both keywords/free-text words and index terms. Accordingly, the index terms of the study were searched from the list of keywords offered by the initial literature search. As the final step in developing key terms for the search, search-field descriptors and wildcard characters were applied to the identified keywords and index terms in the logic grid (wildcards are indicated by the '*' sign in Table 2).

Table 1: Initial logic grid aligned with the PICO elements of the review question

Population	Intervention	Comparator	Outcome
Urban development	Risk sensitive urban development	-	State of the art

Table 2: Logic grid with identified keywords added

Population	Intervention	Comparator	Outcome
Urban development	Risk sensitive urban development	-	State of the art
Urban*	Hazard sensitive		Modern*
Sustainab* development	Disaster sensitive		New*
Land development	Flood sensitive		
Urban water management	Landslide sensitive		
	Ecological sensitive		
	Environment* sensitive		

Population	Intervention	Comparator	Outcome
	Vulnerab* sensitive Urban* sensitive		

Once all the search terms were collected and finalised, the final search strategy was developed. Initially, the key terms and synonyms in the logic grid were combined using Boolean operators: 'OR' to combine words/phrases within a column; 'AND' to combine words/phrases in different columns. Subsequently, the second search was undertaken across all the selected citation databases with the use of the developed search strategy shown in Figure 1.

"**State of the art**" OR "modern*" OR "new*" AND "**risk sensitive**" OR "hazard sensitive" OR "disaster sensitive" OR "flood sensitive" OR "landslide sensitive" OR "ecological* sensitive" OR "environment* sensitive" OR "vulnerab* sensitive" OR "urban* sensitive" AND "**urban development**" OR urban* OR "sustainab* development" OR "land development" OR "urban water management

Figure 1: Literature search strategy developed for the study

Once the final search was conducted, the search strategy was further refined by selecting relevant filters under search fields, publication year, subject/research area, document type, and language (Refer Table 3).

Table 3: Filters assigned for the literature search

Categories	Filters
Search Fields	Title, Abstract, Keywords
Publication Year	From 2017 to 2022
Document Type	Article, Proceedings paper
Language	English

After defining the scope of the research and search strategy, the next step of the systematic literature review is database selection process. The search was conducted within two highly recommended databases such as Scopus and Web of Science. These databases allowed a literature search within a broad range of international scientific journals, as well as in high-ranking conference proceedings. Furthermore, a Google search was also conducted to identify non-journal sources such as periodic reports issued by subject-related organisations. Finally, all the records generated from the above-mentioned databases were imported to the Mendeley software for screening and systematic analysis.

Having conducted the search strategy on the above-mentioned databases, 271 articles were identified and 2 duplicates were removed. From the 269 articles 136 articles were removed by referring the title of the paper, 37 articles were removed by referring the abstract and 56 articles were removed after reading the full research paper. After removing the non-suitable articles, 40 articles were selected from the main databases and 5 articles were added from the Google search. Finally, in depth literature synthesis was carried out on the 45 articles that were selected for analysis. The following section elaborates the state of art in risk sensitive urban development based on the systematic review of literature.

3. STATE OF THE ART IN RISK SENSITIVE URBAN DEVELOPMENT

Table 4 presents the outcome of the systematic literature review undertaken on 47 scientific articles. The key approaches used in risk-sensitive urban development are presented in Table 4.

Table 4: Approaches used in risk sensitive urban development

Approach	Description	References
3D Ecological Footprint Model	3D Ecological footprint model has been developed to measure natural capital utilisation pattern which directly affects the urban environment. The model has three dimensions such as Ecological Carrying Capacity Intensity ($EC_{intensity}$), Ecological footprint depth (EF_{depth}) and Partial Least Squares (PLS) model. EC intensity was calculated to optimize the accounting of ecological carrying capacity (EC) and EF depth and EC intensity were quantitatively investigated and influencing factors were further explored based on a partial least squares (PLS) model. The findings of the above-mentioned 3D model could provide guidance for risk sensitive urban development.	(Wang, et al., 2020; Ress and Wackernagel, 1996; Wackernagel and Ress, 1997; Galli et al., 2012; Wood and Garnett, 2009)
Malmquist - Luenberger (M-L) index	M-L index has been developed to analyse the changes in efficiency and the impact of technological innovation on risk sensitive urban development, and give policy recommendations to promote risk sensitive urban development.	(Wang, et al., 2020; Hong, et al., 2017)
Mobile Mapping System (MMS) with 3D GIS Model	3D Geographical Information System (GIS) support urban planners and consumers to improve their spatial perception and awareness of urban areas. In the long term, it is hoped that this work will help the public or increase community-engaged participation for additional urban planning. Currently, Mobile Mapping Systems (MMS) with 3D GIS are used to create precise and detailed 3D city modelling, which gives essential information for planning the urban development projects. 3D city modelling allows urban planners and the public to understand the areas of interest in the urban design-context in a spatial, timely, and virtual manner. Various approaches for building textures for a 3D model exist, e.g., 3D city modelling can use airborne images, airborne light detection and ranging (LiDAR), ground-based or vehicle-borne sensing techniques, and combinations of these.	(Yang, 2019; Kilicoglu, 2022; Wei, et al., 2020; Afzali, et al., 2021)

Approach	Description	References
Environmentally Sensitive Areas Index (ESAI)	Environmentally Sensitive Areas Index (ESAI) was developed to identify areas vulnerable to the threat of desertification. Variables and thematic indicators such as climate, soil quality, land use, amount of plant cover and management are included in the ESAI.	(Uzuner and Dengiz, 2020 ; Ding, et al., 2021)
Storm surge disaster loss (SSDL)	Storm surge is one of the most severe marine disasters in the world and it is affecting the whole coastal area. Therefore, to prevent from storm surge disasters, estimating the storm surge disaster loss (SSDL) is very useful and it will support the risk sensitive urban development process. When estimating the storm surge loss, hazards of the project, disaster causing factors, the vulnerability and resilience of disaster bearing bodies are considered. Accordingly, when planning an urban development project, the estimation of SSDL is beneficial as it provides a basis to make the decisions about project.	(Zhang, et al., 2022; Jin, et al., 2020; Guo, et al., 2022)
Marine Ecological Red Line (MERL)	Coastal marine ecosystems are sensitive to anthropogenic stressors and environmental change. The Chinese Government proposed an ecosystem-based marine spatial planning scheme called the "Marine Ecological Red Line" (MERL), which aimed at protecting ecologically sensitive areas. The assessment and mapping of ecosystem sensitivity provide important tools for regional MERL and setting conservation priorities. This model provides details to decide which area is suitable to develop an urban development project. It gives an operational approach to provide relevant scientific knowledge on the process of ecosystem-based marine spatial planning, and facilitates policy-making decisions in marine management with risk sensitive urban development.	(Hu, et al., 2019 ; Lu, et al., 2015)
Standardised Precipitation - Evapotranspiration Index (SPEI)	This index is explained about the impact of climate change on Land degradation and desertification (LDD) by detecting the temporal oscillations in drought in the context of climate change, and it is therefore a reliable climate parameter for this method. At present, LDD is one of the greatest environmental challenges caused by climate change resulting mainly from anthropogenic activities. SPEI is pointing to a link between not only environmental sensitive areas and climate change, but also the impact of other factors, such as vegetation, topography and soil. Therefore, the details received from SPEI is valuable for the risk sensitive urban development.	(Perović, et al., 2021; Stajkowski, et al., 2021)

Approach	Description	References
Early warning system	In order to face the uncertainties that arise from climate-induced disaster risks there is an urgent need of early warnings system. Through this system, people can be aware about the risk and prevent the risk before it leads to a disaster. As such, early warning system is a beneficial approach, for the risk sensitive urban development.	(Wang, et al., 2018; Ding, et al., 2021; Leck, et al., 2018b)
Driving-Pressure-State-Influence-Response (DPSIR) Model	Driving-Pressure-State-Influence-Response (DPSIR) model is based on environmental early warning system which combines three aspects such as ecology, resources, and environment. DPSIR model also includes human activities, stress, and environmental state, impacts on ecosystems, human health, and political responses. First, the DPSIR model covers important elements of economy, society, resources, and environment, which can clearly and simply reflect the relationship between the environment and other factors, thus it can provide a scientific theoretical basis for policymakers. Secondly, it not only indicates the influence of society, economic development, and human behaviour on the consumption of resources and ecological environment, but also shows the feedback of human behaviour and its final lead to the state of resources and environment, which makes the whole system a cycle. Thirdly, it provides a basic framework for the construction of the environmental index system which is suitable for early warnings and the assessment of the environment. Lastly, its evaluation process is relatively easy to operate and use, which brings convenience to scientific researchers. Therefore, when countries go for a risk sensitive urban development this model will be very useful in minimising the risk of urban areas.	(Wang, et al., 2018 ; He, et al., 2019; Stajkowski, et al., 2021)
Sustainable design	Urban designs that consider regional climatic conditions are one of the most important approaches in risk sensitive urban development. The design of the urban development should be developed by considering the climatic conditions of the area.	(Watanabe, et al., 2017; Petrea, et al., 2021; Ding, et al., 2021; Petrea, et al., 2021)
Climate change risk assessment tools	Assessment of climate change risks and vulnerability is essential in order to inform and implement appropriate adaptation strategies. Assessment of climate change risk helps to improve the resilience of urban areas since, it is provided information to develop strategies to reduce future risks associated with climate change impacts. There are several climate change risk assessment tools such as decision-making frameworks, portals or platforms and screening models. These tools are used to manipulate and visualise the general risk or impact of the climate change.	(Lindley, 2009; Malalgoda and Amaratunga, 2015, Shaw., 2009; Archer, 2016)

Approach	Description	References
GRaBS assessment tool	GRaBS has been developed as a collaborative, innovative, cost effective and a user friendly assessment tool to highlight the climate change risks and vulnerabilities in urban areas in order to aid the strategic planning and delivery of climate change adaptation responses.	(Lindley, 2009; Malalgoda and Amaratunga, 2012; Kazmierczak and Handley, 2018)
Community engagement	Community views have been identified as one of the major approaches that can be used when planning an urban development project. Community is the party who is facing the risk of urban development projects and their views and suggestions will be very useful to reduce such risks to create a risk sensitive urban development project.	(Archer, 2016; Abeje, et al., 2019; Archibald, et al., 2017; Malalgoda and Amaratunga, 2012; Ding, et al., 2021)
Smart urban plans	Smart urban planning is an innovative method of risk sensitive urban development since it is planned to develop all the urban facilities by considering the environmental aspects.	(Kaur and Garg, 2018; Yang, 2019; Abid, et al., 2021)

According to Pei, et al. (2022), when analysing the impacts of urbanisation on cities' adaptation to climate events, the fitting effects of these approaches were far better than those of traditional development approaches which is not considered the risks related to the urban development. The approaches discussed in Table 4 have emphasised the ways of urban development with minimal impact to the environment. Among the identified risk sensitive urban development approaches, storm surge disaster loss (SSDL), GRaBS assessment tool and early warning systems directly address disaster risk reduction while providing guidance to both urban developers and disaster risk managers. Whereas other approaches are focusing on mitigating the disaster risks during the urban development projects. Moreover, it has been highlighted that community engagement to the risk management process in the urban development projects will be one of the major approaches that will lead to a risk sensitive urban development.

Figure 3 shows the conceptual framework on the state of the art in risk sensitive urban development that was explored through this study. The framework presents the identified risk sensitive urban development approaches that can minimise the disconnection between urban development and disaster risk management activities. The main beneficiaries of this study are the key stakeholders related to disaster management and urban development authorities who should work together in creating risk sensitive urban development projects.

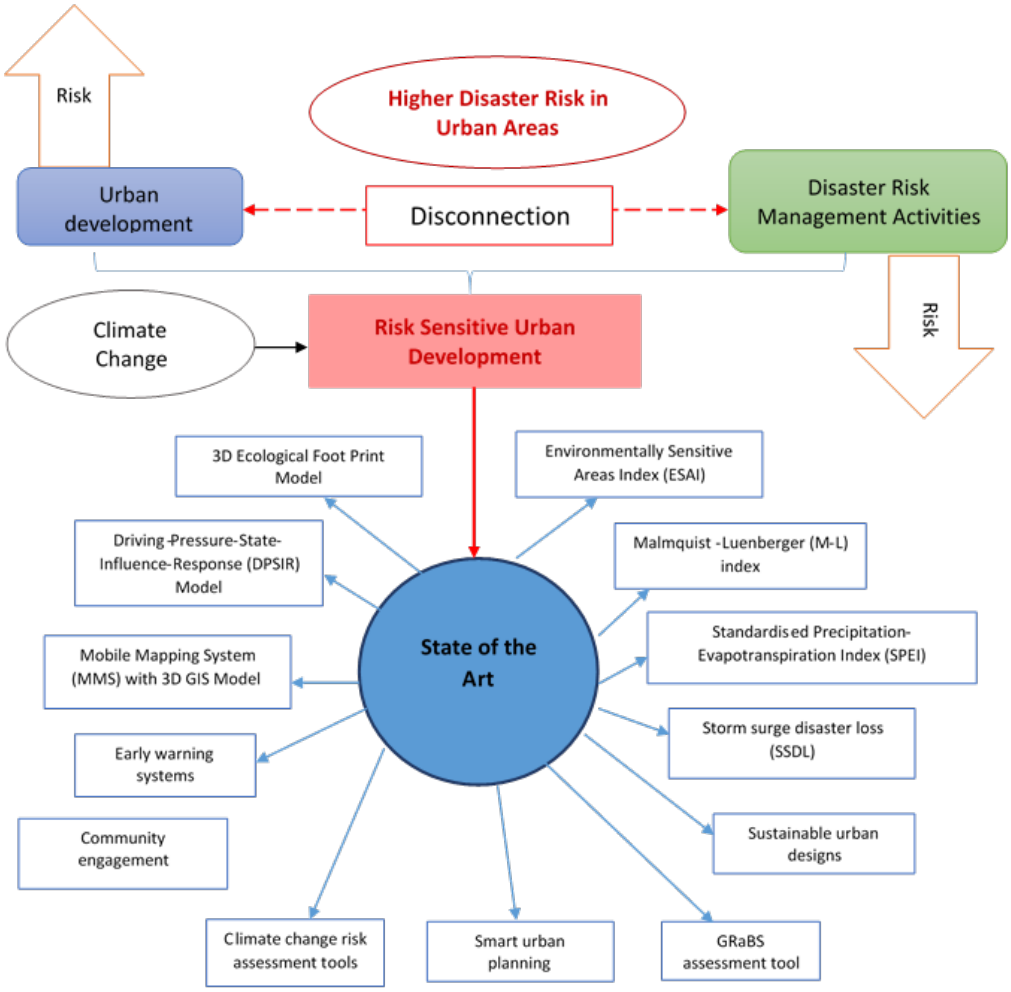

Figure 2: Conceptual framework

4. CONCLUSIONS

The increasing vulnerability of urban areas to disasters has been recognised in recent years, due to the rapid urbanisation and unplanned urban development without considering the urban risks. In providing a solution for this issue, urban development and disaster management activities needed to be linked to establish a risk sensitive urban development. This research conducted a systematic literature review to establish a sound understanding on the state of the art in risk sensitive urban development. This research explored several approaches for risk sensitive urban development; they are 3D ecological foot print model, Malmquist -Luenberger (M-L) index, Mobile Mapping System (MMS) with 3D GIS Model, Environmentally Sensitive Areas Index (ESAI), Storm surge disaster loss (SSDL), Marine Ecological Red Line (MERL), Standardised Precipitation-Evapotranspiration Index (SPEI), Early warning system, Driving-Pressure-State-Influence-Response (DPSIR) Model, Sustainable design, Climate change risk assessment tools, GRaBS assessment tool, Community engagement and smart urban plans. Accordingly, the approaches presented in this paper illustrate the considerable potential for urban planners and disaster managers to support a transition towards a more integrated vision, process and practice of risk management. Thus, the findings of this study are beneficial to the stakeholders who are involving in both urban development and disaster management to make informed decisions in creating risk sensitive urban development.

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