Critical Analysis of Tsunami Preparedness at Local Level for Sustainable Urban Planning in Sri Lanka

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Abstract Coastal cities often suffer from extreme natural hazards such as sea level rise, coastal storms, and heavy rains. Amidst them, tsunami being a hazard with a very low frequency still claims to be the most detrimental disaster faced by coastal communities due to its unpredictable nature and the high impact caused by a single hit. The 2004 Indian Ocean tsunami affected 15 countries alarming the nations to revamp their urban planning frameworks to be more inclusive of preparedness for Tsunamis. Sri Lanka being an island greatly devastated by 2004 IOT, with the records for around 35,399 fatalities, 114,069 damaged or destroyed houses and 480,000 human displacements was undeniably compelled to build back better from the lessons learnt. Moreover, tsunami accounts for the greatest percentage, nearly 0.2% from its population of loss of lives and the greatest economic damage from a disaster in Sri Lanka in the recent history. Nevertheless, Sri Lanka's urban planning guidelines lack the preparedness measures that need implementing in tsunami prone cities. This further highlights the necessity of sustainable and resilient urban planning. This study synthesizes and critically analyzes the current level of integration of strategies for tsunami preparedness in Sri Lankan urban planning frameworks and related policies. A comprehensive review was carried out on urban planning policy frameworks and guidelines in Sri Lanka where the inclusion of tsunami preparedness measures under a set of pre-identified parameters was investigated. A critical analysis was then followed by means of comparing the existing local frameworks with globally practiced guidelines under the same categories which enabled identifying the gaps in Sri Lankan coastal city planning. In this context, this paper highlights the current state of the art of existing urban planning policy frameworks and guidelines in Sri

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Lanka which highlights that it does not adequately include the tsunami preparedness measures to better prepare the country for similar future hazards.

Keywords Sustainable urban planning · Tsunami preparedness measures · Sri Lankan policy frameworks and guidelines · Resilient cities

1 Introduction

Urban areas in Asia are among the world's fastest growing areas and are expected to house 55% of the estimated 5 billion Asians by 2030 and [1] reveal that the majority of Asian megacities and other urban municipalities are located in hazard prone areas. Also, over the past half century the statistics show that in developing countries extremely high levels of population are concentrated in cities [2]. Meanwhile, natural hazards that result in not only fatalities and property damages but eventually a huge socioeconomic and environmental disruption have been uncovered as a major contributor for death tolls in the past decade accounting for more than 0.4% of annual deaths in some years [3]. Out of them, coastal hazards account for the most severe hazards around the world bringing the most serious impacts [4] and forty-six million people per year are currently at risk from coastal flooding due to storm surges [5].

Sri Lanka being both a developing country with the aforementioned urbanization crisis and an island surrounded by the sea, Sri Lankan communities are highly vulnerable to such coastal hazards. Sri Lanka was considered as the 2nd most affected country from extreme weather events during 2018 by Germanwatch Global climate index [6]. Even though the most common natural hazards in Sri Lanka include localized and seasonal floods and associated landslides, [7] Tsunamis are considered as the event that has caused the highest impact in recent history. The unpredictable nature of its occurrence has highlighted the importance of making the coastal communities Tsunami resilient and Bryant (2014) claims it to be the most underrated natural hazard of all time [8]. Tsunamis in 1998–2017 decade accounts for casualties and damages that are of one hundred times higher than that experienced during the previous decade (1978–1997). Sri Lanka has been ranked the sixth in terms of total estimated damages from Tsunamis during the above period of time [9, 10].

The above-discussed facts and statistics spotlight that as a country unveiled to coastal hazards of which Tsunamis are the most severe in nature with the highest impact, the coastal communities should be well prepared and the cities should be well planned to act resistive to these hazards mitigating the impact. Sri Lanka is a country which undergoes many city center development projects which involve the coast and the sea, and the inclusion of risk reduction measures in building and landscape designs for Tsunamis cannot be overlooked.

Therefore, this paper presents a review of the state of the art of urban planning and development to address tsunami risk in Sri Lanka.

2 Methods

First, a literature survey was carried out in the form of a systematic review using Google Scholar and Science Direct databases. Using the keywords, Sustainable Urban Planning; Tsunami Preparedness Measures; Sri Lankan Policy Frameworks and Guidelines; Resilient Cities. The scholarly articles written in English language during the period 2004–2021 were only selected for the initial search. After removing the duplications, the inclusion and exclusion criteria 1 listed in Table 1 were applied resulting in 35 retrieved articles. Then, 13 more articles were excluded through applying the exclusion criteria 2 and during the data extraction. 22 articles retained for the study from this search. The PRISMA flow diagram followed in the process is shown in Fig. 1.

First, the feasible urban planning techniques and potential strategies to reduce tsunami risk in Sri Lankan coastal cities were identified referring the 22 articles. These articles were based on researches carried out in Sri Lanka, mostly by the local researchers to suggest the strategies for future urban planning in Sri Lanka in regard to tsunami preparedness.

Then, 6 urban planning frameworks were studied to investigate the actual level of inclusion of the suggested strategies in literature. The referred frameworks are,

1. Urban Development Authority (UDA) Frameworks and Guidelines [11]
2. National Building and Research Organization (NBRO) Guidelines [12]
3. Guidelines of Society of Structural Engineers—Sri Lanka [13]
4. Coastal Conservation Act and Coastal Zone Management Plan [14]
5. Guidelines of National Housing Development Authority, Sri Lanka [15]
6. GreenSL Rating Systems [16].

Finally, comparing the suggested strategies and actual context an analysis was carried out to highlight the prevailing gaps in coastal city planning in Sri Lanka.

Table 1 Inclusion and exclusion criteria

	Inclusion	Exclusion
Criterion 1	Original studies and reviews	Not based on Sri Lanka
Criterion 2	Articles and book chapters	General disaster preparedness/not specific for Tsunamis
Criterion 3		Post-tsunami/recovery stage

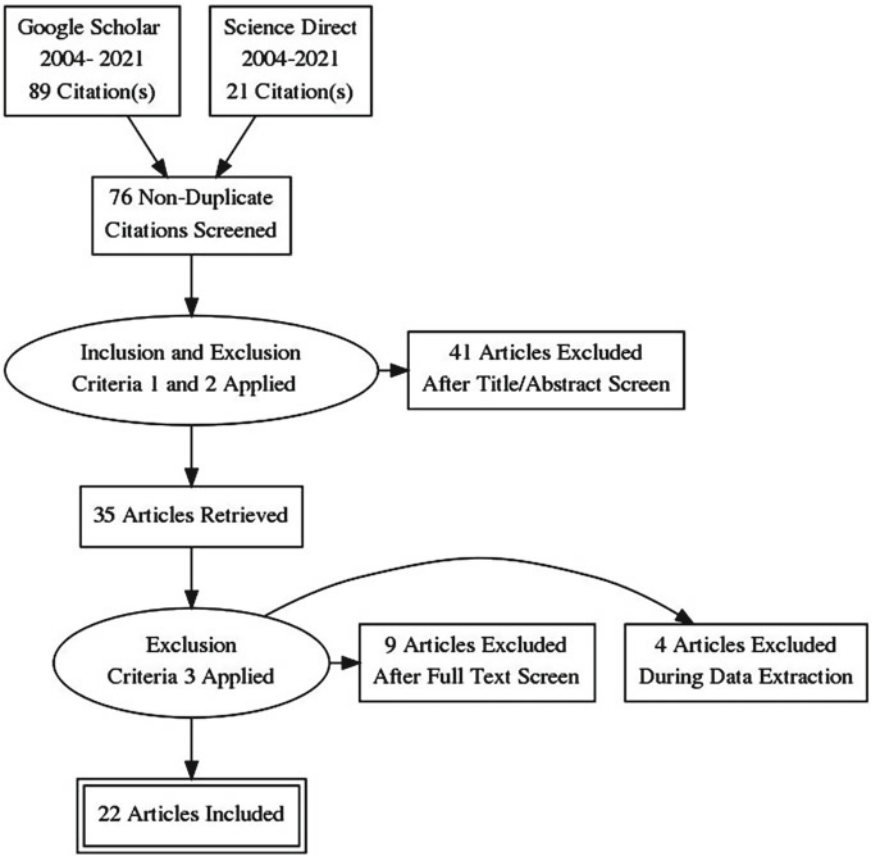

Fig. 1 Prisma flow diagram of the systematic review

3 Results and Discussion

3.1 Review of Scholarly Articles

Key aspects discussed in the reviewed scholarly articles and the recommendations and feasible strategies to Sri Lanka suggested by them are listed in Table 2.

The above aspects were grouped into 6 main parameters/indicators and were selected as the parameters defining tsunami and multihazard preparedness in coastal cities.

1. Spatial Planning
2. Communities and key stakeholder groups
3. Resilience Thinking' approaches
4. Soft engineering structures

Table 2 Recommended strategies in literature to incorporate into urban planning in Sri Lanka

Key aspect	Recommendation	Source
Inundation modeling and vulnerability assessments	Understanding possible vulnerable areas of future Tsunamis to prepare and implement disaster mitigation and management plans Use of dashboard tools for wave propagation modeling Inundation Modeling with primary considerations as inundation depth and recommended story heights	[17] [18]
Bathymetric assessments	Continuous assessment of bathymetric changes that have taken place in near shore areas	[19]
Evacuation	Availability and functionality of the vertical and horizontal tsunami evacuation facilities with safe evacuation routes	[18, 20]
Awareness	Increasing and monitoring continuous awareness of the exposed population	[21]
Design of buildings	Overall design guidelines providing advice on location, layout, orientation, structural configuration, geotechnical, and other considerations Detailed design guidelines leading to hydraulic and structural loads and geotechnical issues	[19]
Public open spaces (POS)	The locations of POS according to risk zonation Terrain quality and the Topographic character-guided allocation Determining the DRR use based on the location and size of POS Multipurpose uses of POS Networking of POS as a DRR passage Network of public open spaces linked with green corridors	[22, 23]
Key stakeholder engagement	Planning regulations should provide a strong institutional basis to clarify the role and requirements of vulnerability and risk information in the planning process A clarification of the roles of various stakeholders Coordination between authorities	[21, 24]
Buffer zones	Buffer zones have to be developed consistently and transparently while considering the needs of different household types as fishermen	[21]

(continued)

Table 2 (continued)

Key aspect	Recommendation	Source
Regulations for coast protection	Legal actions against mining activity	[25]
Flood prevention	Protect the flood-prone areas from land encroachment Keeping flood-prone areas for open space purposes to control the future development	[23]
Sand dunes	Combination of the sand dune followed by vegetation toward landside to retard Tsunamis Sand dunes (with or without vegetation)	[25] [26]
Education strategies	Public education strategy in collaboration with media institutions to enhance public engagement with early warning mechanisms Community mobilization	[27, 28]
Vegetation schemes	Use of a complex aerial-root structured specie in the frontline to dissipate energy when a tsunami hits. (Pandanus odoratissimus) Two layers of vegetation (odoratissimus and equisetifolia) in the vertical direction have a greater ability to lower the damage	[29]
Blue spaces	Water body/lakes (blue spaces)	[25]
Mangroves and plantation	Features such as dense vegetation and sand dune/beach and aquaculture pond/saltpans Sparse vegetation with some paddy fields plantations (e.g., coconut) and multi-species vegetation (e.g., mangrove) mixed with settlement areas When there is limited mangrove cover, vegetation like Casuarina, Cocos, Pandanus, etc., can be propagated in the coastal zone (with a prior knowledge on the consequences, if any, in relation to the local eco-socioeconomic conditions)	[25]
Urban forests	Urban forests and green spaces are resilient to rising heat and the threat of extreme weather hazards of changing climate, improve health and well-being, and promote resilience of urban dwellers	[30]
Marginalized communities and patterns of urbanization	Assess and prioritize vulnerable and marginalized people in the cities in urban land use planning The patterns of urbanization play more important role in the speed of urban land expansion which make more contribution for climate change	[30]

(continued)

Table 2 (continued)

Key aspect	Recommendation	Source
Ecosystem	Invest in ecosystem-based integration of disaster risk reduction (DRR) in urban planning	[31]
Green belt	Multipurpose green belt along the coast	[30]
Network of elements	Green elements including street trees, gardens and parks that support the connectivity creating a network	[32]
Local authorities	Effective utilization of local authority resources (physical/human/capital) in provision of services and good governance which increases planning capacity and responsiveness Establishment of disaster management unit Practice building application approval from national building research organization Climate change adaptation strategies Control the development activities in hazard prone areas through development permits Providing an adequate number of public toilets and urinals Daily sweeping and scavenging of streets Obtaining community participation for maintenance of road and storm water drainage	[33]
Data and technology	Using big data for urban planning	[34]
Key Stakeholders	Increase Institutional capacity and resources and address cognitive and cultural factors	[35]
Human Settlement planning	Planned human settlement through the adoption of new parameters based on population density, land suitability, and environmental sustainability, including adoption of the vertical development approach in high and medium population density areas	[36]
Drainage	Plan, construct, and maintain the city's drainage system to avoid or limit the risk of floods	[36]
Building standards	Development and enforcement of building standards	[37]
Waste management	Solid waste management	[38]
Catchment management	Catchment and integrated water resource management	[38]

(continued)

Table 2 (continued)

Key aspect	Recommendation	Source
DIA and EIA	Disaster impact assessment to be integrated to environmental impact assessment	[38]
Coastal structures	Structures with co-benefits, e.g., revetments and railway embankments	[39]

5. Hard engineering structures
6. Nature-based solutions.

3.2 Review of Urban Planning Frameworks

The Urban Development Authority Law, No. 41 of 1978, of the National State Assembly governs the Regulations made by the Minister of Urban Development and Housing, and it recently underwent a revision and the regulation will be cited as the Urban Development Authority Planning & Development Regulations 2020 henceforth. Even though it has introduced its own Green Rating System to assess buildings for the implementation of sustainable and green measures, neither the rating system nor the general guidelines include measures to reduce tsunami or coastal hazard risks, except for fire hazard.

Tsunami resilient building planning aspects have been demonstrated in NBRO guidelines in terms of site selection, shape and orientation of buildings, design of the structure, and also the external adjoining structures to the buildings.

Guidelines for buildings at risk from natural disasters by Society of Structural Engineers—Sri Lanka came about as a response to the tsunami of 26/12/2004 and as a contribution to the task of reconstruction. It discusses the following aspects shown in Table 5 regarding tsunami resilient housing construction. According to the framework, any building within 500 m of the coastline or 3 m elevation from mean sea level (which we shall call the "Coastal Zone") should be designed according to these guidelines; the above limits should read as "1 km of the coastline or 5 m elevation from mean sea level" for the East Coast. However, the scope is limited to the structural measures for buildings.

Coast Conservation act, 1981, along with the coastal zone management plan only seems to bring out the nature-based solutions for the protection of coast minimizing the erosion and other issues in beaches where most of the measures indirectly contribute to tsunami and coastal hazard prevention.

Guidelines for housing development in coastal Sri Lanka brings out statutory requirements and best practice guides to settlement planning, housing design, and service provision for hazard preparedness in general.

Both the GreenSL rating systems for Built Environment and Transportation Infrastructure lacks measures for prevention and preparedness for any kind of natural

hazard while the GreenSL rating system for Sustainable Cities addresses few aspects for general disaster resilience. However, the integration of tsunami and other multi-hazard (including the pandemics) preparedness into thee rating systems is vital and a separate rating system can be introduced for coastal zones if addition of tsunami prevention measures to the general building and city tool might cause unnecessary point reduction in unaffected areas.

After analyzing the local literature referred under Sect. 3.1 and their considered aspects in regard to tsunami and multihazard preparedness in tsunami prone areas, when moved on to analyze the consideration of above aspects to the actual planning context in Sri Lanka (discussed in Sect. 3.2), the following comparison shown in Table 3 can be reached.

The aspects that should be ideally addressed or the pre-identified main 6 indicators have been listed as column headings in Table 4. A gap analysis of Sri Lankan urban planning frameworks shown in Table 4 confirms that some important aspects have been neglected in most of the local codes while the prominence has been given to the structural aspects of the preparedness measures. The current inclusion of measures is indicated as the darker color shows the deeper integration and the blank cells indicate the absence of any measure under the given aspect.

4 Conclusion

The work intended to study the existing strategies for tsunami and other coastal hazard preparedness in Sri Lankan urban planning frameworks and guidelines. Searching for guidelines under the pre-identified aspects allowed realizing that apart from the guidelines for erecting buildings in tsunami prone areas by National Building and Research Organization (NBRO), Society of Structural Engineers—Sri Lanka, and National Housing Development Authority and other local codes lack the preparedness and planning aspects of a city in regard to tsunami and multihazard resilience. Also lack of proper legal compliance requirements of many of the discussed frameworks creates loopholes and a set of optional manuals which will most likely be violated and not complied in the practical context.

The above local codes can be modified and the integration of tsunami and other coastal hazard preparedness measures can be deepened through mainstreaming the suggested strategies in local literature as well as the globally practiced concepts and guidelines into the local context appropriately. For example, the community engagement in policy and decision-making and other highlighted areas of lack of integration could be improved through the guidelines in global frameworks such as RELi 2.0 (Rating guidelines for Resilient Design and Construction) which bring out certain missing aspects in the local codes. However, relation and impact for fishery and marine products, industry and tourism, financial limitations, and disturbance to the natural environment and resources will be the risk drivers and conflicting factors which need to be handled with care when proposing guidelines.

Table 3 Comparison of measures suggested and measures implemented

Aspects highlighted in research	Actual frameworks/policies
Modeling and assessments	Not recommended
Spatial planning for disaster response	• General spatial planning requirements by UDA and NHDA (not specified for disasters)
Land use planning for risk mitigation	General spatial planning requirements by UDA and NHDA (not specified for disasters)
Public awareness/stakeholders	Participatory (community) approach recommended in NHDA Guidelines Sri Lanka national disaster management plan does not recommend multi stakeholder engagement Coordination between different authorities is lacking • Planning and policy making through DMC and some other organizations—government acts through coastal conservation dept. etc. • Early warning through Meteorological Dept • Enforcing and response mechanisms through local authorities • Non-legally binding guidelines and manuals by several other parties
Design of buildings	Recommended in SSESL guidelines/NBRO guidelines No building code
Design of city infrastructure	Not recommended in any
Vegetation and other soft measures	Specific plantation schemes not recommended in any
Protection of natural buffers	Coast conservation act
Buffer zones and legal compliance/permits	Coast conservation act/UDA general guidelines Clearance from costal conservation department and UDA/local authority (NBRO requirements are not legally binding for coastal districts compliance required only for landslides)
Resilience approaches (Build back better)	Sri Lanka national disaster management policy (governed by disaster management act no 13) has removed build back better aspect in its final version (2014)
Multi-hazard aspect	Only multihazard early warning is highlighted in national disaster management plan (2017)

Table 4 Gap analysis of Sri Lankan urban planning frameworks

Framework	Spatial planning	Communities and key stakeholder groups	Resilience thinking' approaches	Soft engineering structures	Hard engineering structures	Nature-based solutions
Urban development authority (UDA) frameworks and guidelines						
NBRO guidelines						
Guidelines of society of structural engineers Sri Lanka						
Coastal conservation act and coastal zone management plan						
Guidelines of national housing development authority, Sri Lanka						
GreenSL rating system for cities						

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