CHAPTER – 2

Literature Review

The review of literature based on the similar theme has led to the need for the study. The developed countries like US, Canada, Japan, New-Zealand and Europe have already adopted the multi-hazard approach in planning multi-storied buildings. Even though India is vulnerable to many hazards based on the location and physical topography, till date we have been considering the effect of a particular hazard on a given multi-storied building in isolation only. But generally some of the hazards happen simultaneously e.g. earthquake followed by fire, flood followed by epidemic and earthquake followed by landslides. The research is focussed on the multi-hazard risk assessment of multi-storied buildings and practices adopted in developed countries in mapping multi-hazards on buildings.

2.1 Multi-hazard Risk Assessment: A New Methodology

Multi-hazards pose a serious threat to human life. It can cause considerable damages. The evaluation of the expected losses due to multi-hazards requires a risk assessment (Eshrat, Mahmoudzadeh, Taghvai, 2015). Multi-hazards risk assessment allows the identification of the most endangered areas and suggest where further detailed studies have to be carried out. This study aims to give a new methodology for Multi-hazard risk assessment that makes easier the comparability analysis of vulnerability for different hazards and accounts for possible triggering effects. Methods used in this research are based on theoretical approach and documentation. Two types of hazards will be assessed, namely earthquake and fire following earthquake. Semi-quantitative and quantitative approach would assess risk rates at both regional and local levels. In this study, representation of a new methodology for multi-hazards risk assessment includes determination of a model with parameters, consideration of the indicator-based pattern of vulnerability assessment that selected of all the relevant indicators and presented new classification of indicators based on comparison to different hazards and possible triggering effects. This means a potential multi-hazard indicator could be higher than the simple aggregation of single risk indicators.
Literature Review

calculation. The focus is on establishing a general overview of the emerging issues, and indicating how hazard relations can be considered in multi-hazard studies. The hazard relation is identified and studied by means of a new method and the overlay of hazard areas to determine overlaps in final multi-hazards map \[14\].

2.2 Quantitative Multi-Hazard Risk Assessment with Vulnerability Surface

Risk assessment plays an important role in disaster risk management. Existing multi-hazard risk assessment models are often qualitative or semi-quantitative in nature and used for comparative study of regional risk levels \((Ming, Xu, Ying, Juan, Baoyin, Peijun, 2015)\). They cannot estimate directly probability of disaster losses from the joint impact of several hazards. In this research, a quantitative approach of multi-hazard risk assessment based on vulnerability surface and joint return period of hazards is put forward to assess the risk of crop losses in the Yangtze River Delta region of China. The impact of strong wind and flood, the two most prominent agricultural hazards in the area, is analyzed. The multi-hazard risk assessment process consists of three steps. First, a vulnerability surface, which denotes the functional relationship between the intensity of the hazards and disaster losses, was built using the crop losses data for losses caused by strong wind and flood in the recent 30 years. Second, the joint probability distribution of strong wind and flood was established using the copula functions. Finally, risk curves that show the probability of crop losses in this multi-hazard context at four case study sites were calculated according to the joint return period of hazards and the vulnerability surface. The risk assessment result of crop losses provides a useful reference for governments and insurance companies to formulate agricultural development plans and analyze the market of agricultural insurance. The multi-hazard risk assessment method developed in this research can also be used to quantitatively assess multi-hazard risk in other regions \[15\].
2.3 Decision Support System for Routing Urban Utilities

Osman, Diraby (2011) presents a Web-based system for supporting the selection of the most suitable routes for buried urban utilities. The aim of the proposed system is to support (not make) decisions through a collaborative semi-automated environment, in which stakeholders can share information and/or study the impacts of different routing alternatives with respect to decision constraints. First, the knowledge relating to route selection for urban utilities is represented through ontology. The ontology defines the types and attributes of infrastructure products and the surrounding areas. It also defines the impacts of routing options on surrounding areas through a set of decision criteria adopted to evaluate the effectiveness of any route in terms of its potential impacts. A set of constraints are also defined to help represent/study the decision criteria. Second, a GIS-based system has been created to help visualize route data, interact with users, and support the needed discussions among stakeholders. Finally, a set of reasons have been created to help quantify/augment some of the constraints.

This system is capable of

1. Extracting the attributes of each routing option,
2. Testing the interaction/conflicts between route attributes and the constraints of the surrounding area,
3. Studying the impacts of a route as stipulated in the ontology,
4. Referring users to existing best practices to help enhance routes or address conflicts and, when needed,
5. Developing objective measures for comparing different routes.

On the micro level (street level), route options are evaluated through a “constraint-satisfaction” approach. On the macro level (city level), route options are evaluated through a fuzzy inference scoring system. The system focuses on facility life cycle, sustainability, and community impacts. Construction costing, scheduling, labour, and equipment along with other management issues can either be added to the system or, better, analysed through integrating the system with four-dimensional (4D) modelling tools [16].
Literature Review

2.4 Multi-hazard Risk Assessment Framework for West Sudanian Savanna Zone

West Africa is a region considered highly vulnerable to climate change and associated with natural hazards due to interactions of climate change and non-climatic stressors exacerbating the vulnerability of the region, particularly its agricultural system (Kloos, Asare-Kyei, Pardoe Renaud, 2012). Taking the Western Sudanian Savanna as our geographic target area, this research seeks to develop an integrated risk assessment framework that incorporates resilience as well as multiple hazards concepts, and is applicable to the specific conditions of the target area.

To provide the scientific basis for the framework, the researcher has first defined key terms of risk assessments in a climate change adaptation context: risk, hazard, exposure, vulnerability, resilience, coping and adaptation. It further discusses the ways in which they are conceptualized and employed in risk, resilience and vulnerability frameworks. When reviewing the literature on existing indicator-based risk assessment for West African Sudanian Savanna zones, it becomes apparent that there is a lack of a systematic and comprehensive risk assessment capturing multiple natural hazards.

This research suggests an approach for linking resilience and vulnerability in a common framework for risk assessment. It accounts for societal response mechanism through coping, adaptation, disaster risk management and development activities which may foster transformation or persistence of the social ecological systems. Building on the progress made in multi-hazard assessments, the framework is suitable for analysing multiple-hazard risks and existing interactions at hazard and vulnerability levels. While the framework is well grounded in theories and existing literature, and advances the knowledge by including and linking additional elements, it still remains to be tested empirically \[17\].

2.5 Urban Hazard Mitigation

Cities are complex and interdependent systems, extremely vulnerable to threats from both natural hazards and terrorism (Godschalk – 2003). Cities interact with both technological components and social components. The researcher proposes a comprehensive strategy of urban hazard mitigation aimed at the creation of resilient cities, able to withstand both types of threats. Planning for resilience in the face of urban disaster requires designing
cities that combine seemingly opposite characteristics, including redundancy and efficiency, diversity and interdependence, strength and flexibility, autonomy and collaboration, and planning and adaptability. The paper reviews hazard mitigation practice, defines a resilient city, considers the relationship between resilience and terrorism, and discusses why resilience is important and how to apply its principles to physical and social elements of cities. The researcher has tried to conceptualize the scope and magnitude of the challenges inherent in making our cities resilient to threats from natural hazards and urban terrorism. Contending that current hazard mitigation policy, practice, and knowledge fail to deal with the unique aspects of cities under stress, the paper recommends a major resilient cities initiative, including expanded urban systems research, education and training, and increased collaboration among professional groups involved in city building and hazard mitigation. To meet these challenges, the researcher proposes a national resilient cities initiative, aimed at the vision of the resilient city as the goal that bridges natural hazard mitigation and counter terrorism practice. To succeed, this initiative will require changes in national disaster policy, funding for basic and applied urban systems research, support for advanced education programs, and active collaboration among the city planning, design, and construction professions [18].

2.6 Urban Habitat Constructions under Catastrophic Events

COST, an intergovernmental framework for European Cooperation in Science and Technology, allows the coordination of nationally-funded research on a European level. The main objective of the COST Action (Mazzolani, 2010) is to increase the knowledge of the behaviour of constructions in urban habitat under catastrophic events, when exposed to extreme events arising from earthquakes, fire, wind, impact, explosions etc., in order to predict their response when both the applied loading and the inherent structural resistance are combined in such a way as to reduce the safety level below acceptable values, leading in some cases to a premature collapse [19].
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2.7 Multi-hazard Risk Mapping of Natural Disasters

A research project coordinated by *T6 Societa of European Union, Italy* (2007) is focused to develop a new approach to produce integrated multi risk maps to achieve more effective spatial planning procedures in areas prone to natural disasters in Europe by DSS. The project was conceived to harmonize the methodologies for various hazard and risk assessment, different processes of risk mapping to standardised data collection, data analysis, monitoring, outputs and terminology in form useful to end users leading to a new guideline for regional, local and local site \[^{20}\].

ARMONIA achieved outcomes that mitigate the adverse effects of natural phenomena, through the joint effort of the scientific community, technology experts and end users. The target was therefore not a solely scientific output, but a measurable impact on policies and practice for disaster mitigation which could be initiated within the period of the project. The project consortium consisted of eleven partners from Canada, the Czech Republic, Finland, Germany, Greece, Italy, and the United Kingdom. Additionally, the Joint Research Centre of the European Union participated as well. This type of research which takes into account the effect of multi hazard and formulation of harmonised integrated maps is missing in the Indian context \[^{20}\].

2.8 Multi-hazard Mitigation Plan

*Goettel (2008)* developed a multi-hazard mitigation plan that covers each of the major hazards that pose risks to Columbia County, Oregon. The objective of mitigation is to reduce negative impacts of Future Disasters on community, to save lives, minimise damage to buildings, and infrastructure, and minimise economic losses. The mitigation is a planning document and meets FEMA’s planning requirements. The mitigation activities include a range of options including the following six types of categories:

1. Prevention: apply administrative or regulatory actions or processes that influence the way land and buildings are developed and built. These actions also include public activities to reduce hazard losses such as zoning, capital improvements and the like.
Multi-hazard Risk Mapping of Natural Disasters

2. Property Protection: modify existing buildings or structures to protect them from a specific hazard or removing structures from the area of impact for a specific hazard.

3. Public Education and Awareness: inform and educate citizens, elected officials, and property owners about hazards and potential mitigation strategies.

4. Natural Resource Protection: minimize losses from hazard impacts and also preserve or restore the functions of natural systems.

5. Emergency Services: protect people and property, during and immediately following a disaster or emergency event.

6. Structural Projects: establish structural construction projects that reduce the impact of a specific hazard such as retaining walls or culverts.

MAP – 2.1: Provincial Boundaries of Columbia County for MHM (Goettel, 2008)

The County has chartered the formation of a team to lead the implementation of the Hazard Mitigation Plan and the incorporation of the plan into existing comprehensive plans, capital improvement plans, zoning and building codes, site reviews, permitting, job descriptions, staff training and other planning tools where appropriate. So Far as Indian Scenario is concerned, we have been formulating the guidelines in isolation of one hazard to another [21].
Literature Review

2.9 Disaster Prevention in Urban Environment

*Voogd (2004)* focuses on disaster prevention policy in Netherland, implementation issues and gaps and failure of local and national authorities’ preventative policies. Comparisons are also made with the implementation of Strategic Environmental Assessment. The research lays emphasis on understanding the disasters better and giving more attention to risk oriented planning. It also highlights on failure of command and control disaster prevention and inadequate enforcing component. Three main approaches are presented in research study that is considered for disaster prevention. These approaches differ in their emphasis on the two components of prevention, *viz.* mitigation and preparedness.[22]

<table>
<thead>
<tr>
<th>TABLE – 2.1: Disaster Prevention by Mitigation and Preparedness (Voogd, 2004)</th>
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<tbody>
<tr>
<td>Collective Approach</td>
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<tr>
<td>Command and Control</td>
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<tr>
<td>Acquiescent Approach</td>
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<tr>
<td>Liberal Approach</td>
</tr>
</tbody>
</table>

In essence two extreme approaches to disaster mitigation were distinguished: a collective approach focusing on rule enforcement by strict governmental control; and a ‘liberal’ approach focusing on differences of judgement and individual responsibility. In addition, a ‘middle way’ also approach is also considered. Such an approach is termed as ‘the acquiescent approach’. This approach acknowledges that disasters are inevitable in our ‘risk society’ and most attention should be paid to our preparedness for such disasters. The research of the kind focussed on the implementation issues is required to be made for Indian subcontinent.[22]

2.10 Multi-hazard Risk Assessment using GIS

In the framework of the UNESCO sponsored project on “Capacity Building for Natural Disaster Reduction” a case study was carried out by *Westen, Lorena, Boerboom and Badilla (2002)* on multi-hazard risk assessment of the city of Turrialba, located in the central part of Costa Rica. The city with a population of 33,000 people is located in an area, which is regularly affected by flooding, landslides and earthquakes. In order to assist
**Disaster Prevention in Urban Environment**

the local emergency commission and the municipality, a pilot study was carried out in the development of a GIS–based system for risk assessment and management [23].

The work was made using an orthophoto as basis, on which all buildings, land parcels and roads, within the city and its direct surroundings were digitized, resulting in a digital parcel map, for which a number of hazard and vulnerability attributes were collected in the field.

The cadastral database of the city was used, in combination with the various hazard maps for different return periods to generate vulnerability maps for the city. In order to determine cost of the elements at risk, differentiation was made between the costs of the constructions and the costs of the contents of the buildings.

The resulting database is a tool for local authorities to determine the effect of certain mitigation measures, for which a cost-benefit analysis can be carried out. The database also serves as an important tool in the disaster preparedness phase of disaster management at the municipal level.

![Figure 2.1](image)

**FIGURE - 2.1:** Different views of the large-scale database for the city of Turrialba. A: orthophoto, B: vector overlay of parcels, C: polygons displaying landuse type, D: reading information from the attribute database. (Westen, Lorena, Boerboom and Badilla, 2002)

It is important to stress here that the work presented here was aiming primarily on the development of a methodology for GIS-based risk assessment in urban areas, with relatively little basic information available. In such cases the analysis relies heavily on
Literature Review

historical information, and expert judgment, also regarding the relationship between magnitude and return period of the different events \[^{[23]}\].

Due to these limitations, the resulting risk values are only indicative, and should not be taken as absolute values for individual buildings. But they do serve to indicate the relative importance of each type of hazard, and the degree of impact it is likely to have. Formulation of the digitized map for the city of Ahmedabad based on historical information is not available till date for mapping hazards.

2.11 Urban Habitat Construction under Natural Disasters

A research conducted by Indirli (2007) provides an overview on risk assessment approaches in case of natural hazards, suggesting some basic work steps for the future development of innovative and integrated tools. Examples of already implemented digitized databases and on-going projects are also mentioned, in order to identify a starting point for a useful discussion in the framework of the COST Action C26 “Urban Habitat Constructions under Catastrophic Events” \[^{[24]}\]. The basic steps for a correct risk assessment (Table – 2.2) are discussed in the following paragraphs (FEMA 386-2 2001).

<table>
<thead>
<tr>
<th>Process</th>
<th>Outputs</th>
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</thead>
<tbody>
<tr>
<td><strong>Step – 1: Identify Hazards</strong></td>
<td></td>
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<tr>
<td>Definition of study region</td>
<td>Study Region</td>
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<tr>
<td>Creation of a region base map</td>
<td>Base Map</td>
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<tr>
<td>Hazard of interest identification</td>
<td>Hazard of interest list</td>
</tr>
<tr>
<td><strong>Step – 2: Profile Hazards</strong></td>
<td></td>
</tr>
<tr>
<td>Hazard database construction</td>
<td>Updated and completed hazard profiles</td>
</tr>
<tr>
<td>Performing a data gap analysis</td>
<td>Map of hazard areas</td>
</tr>
<tr>
<td>Profile and priority of hazards</td>
<td>Hazards prioritized list</td>
</tr>
<tr>
<td><strong>Step – 3: Inventory Assets</strong></td>
<td></td>
</tr>
<tr>
<td>Inventory database construction</td>
<td>Inventory data tables and maps</td>
</tr>
<tr>
<td>Performing a data gap analysis</td>
<td>Inventory data, data sources list</td>
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</tbody>
</table>
Management/Evaluation of Urban Disaster Risk

<table>
<thead>
<tr>
<th>Step – 4: Estimate losses and risk assessment tools</th>
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<tbody>
<tr>
<td>Construction of estimate losses scenarios and risk assessment tools</td>
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<tr>
<td>Evaluation of the results</td>
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</table>

<table>
<thead>
<tr>
<th>Step – 5: Consider Mitigation options</th>
</tr>
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<tbody>
<tr>
<td>Mitigation options identification</td>
</tr>
<tr>
<td>Mitigation options list</td>
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</table>

MAP – 2.2: Seismic hazard and Risk Map; MAP – 2.3: Building Vulnerability Inventory, Source: University of Ferrara, Department of Architecture (Indirli, 2007)

Risk assessment in case of natural hazards can be managed by using innovative and integrated tools (like standard loss and estimation methodologies GIS-based software) implemented in digitized databases, also provided by huge inventories and interactive import-export capabilities [24].

2.12 Management/Evaluation of Urban Disaster Risk

Okada (2004) focuses to develop a methodology of urban diagnosis for urban disaster risk management, to provide necessary information based on spatial GIS and formation of research partnership network as well as development of methodologies for evaluation of UDR and effective utilization of spatial GIS. This research group has been carrying out research with a focus on management of urban disaster risk within the framework of the EQTAP project. This research provides digested outcomes of what
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have been achieved so far. The achievements also include the formation of a research partnership network as well as the development of methodologies for evaluation of urban disaster risk and the effective utilization of spatial-temporal GIS as demonstrated in figure – 2.2 [25].

This research is focussed on EQ and takes into consideration concept of performance evaluation, long term and short term gains, economic evaluation, water resource planning and management [25].

2.13 Multi-hazard Assessment & Design on Built Environment

The notion of risk is reported on local and transitory phenomenon that through them actions is remodelling the ecological system, affecting the built environment and endangers the human life (Oprita, 2010). Risks are nature generated like earthquakes, floods, winds and fires; and human generated like terrorism. Defining and understanding risks and the problems that each of them raises on built environment is essential because they are changing human environment and the way of life. Each risk has its own characteristics and raises specific problems. A multi hazard approach of design teams is required for a proper mitigation assessment of the impacts on built environment. An investigation of built environment affected by risks leads to definition of specific
Built Environment Hazards in Urban Habitats

measures for each risk category as well as commune measures for mitigation. Structural modification of the built environment can lead to remodelling of urban landscape with beneficial effects on socialization needs and protection of humans [26].

The urban environment and landscape defined by the above-mentioned characteristics may gain social and environmental valences, where people can develop themselves protected against any risk. The author focuses on risks related to the hazards like EQ, fire, wind, flood and terrorism. A multi hazard approach of design team is required for proper mitigation assessment of the impacts on the built environment. It emphasises on the structural modification and also takes into consideration modern human needs [26].

2.14 Built Environment Hazards in Urban Habitats

Naeim, Lew (2000) provides a basic understanding of major earthquake performance issues and importance of multi-storied building performance worldwide. Major earthquake disasters and building performance provide valuable insight to design professionals, owners and public officials for development of planning guidelines and building design and construction mitigations that may be utilized to minimize death and destruction of the urban habitat caused by future seismic events. It is imperative that we do not ignore the recent lessons learned and press on to implement needed changes to current societal, design, and construction practices. This paper provides a basic understanding of the major earthquake performance issues of importance worldwide, the lessons we have learned during the recent past, and the promising paths to a less risk-prone future [27].

The major known structural issues causing devastation of the built environment include:

1. Soft and weak story building configurations
2. Poor material quality and workmanship
3. Poor structural detailing
4. Unaccounted for torsional response
5. Weak column strong floor configurations
6. Lack of adequate load paths
7. Influence of “non-structural” components on building response
Literature Review

8. Lack of adequate correlation between the building as analysed and designed and the building as built.

The important lessons learned from old and new earthquakes were reviewed. It is unfortunate that these lessons which have been learned many times over have to be re-learned following each major earthquake. This research contributes to the general understanding of critical issues and results in a coordinated course of action to reduce the damaged caused by them during the future earthquakes. Let us learn only new lessons from future earthquakes and avoid re-learning the old lessons again [27].

2.15 Geologic and Seismic Hazards in Urban Habitats

Strong ground shaking presents the greatest hazard to property and personal safety in the urban habitat in the seismically active regions of the world. However, there are geologic and seismic hazards that threaten a smaller population in the urban habitat. These hazards include the effects of surface fault rupture, liquefaction, and landslide (Lew, Naeim, 2001). With proper precautions, the exposure to these hazards could be avoidable.

Liquefaction in saturated soils can occur during an earthquake if the strong ground shaking causes a loss of strength in the soil. Liquefaction usually requires the presence of shallow ground water and loose sandy soils. The effects of liquefaction can range from subtle to very dramatic [28].

The economic costs of identifying the sources of geologic and seismic hazards can be large and large public sector funding will most likely be needed to accomplish the required research. Once the hazards are identified, new construction can be protected by proper mitigation techniques. Strong enforcement of the building codes and proper construction techniques will also be needed to provide assurance that the mitigation techniques will be effective in the new construction. However, existing construction will likely continue to pose a threat for severe economic losses and life safety concerns as it will be unlikely that there will be sufficient capital or will to deal with the complex social and economic issues [28].
Regional Scale Multi-hazard Susceptibility Assessment

2.16 Regional Scale Multi-hazard Susceptibility Assessment

Natural disasters are the major economic, social and environmental Problems of concern to many countries. Mass movements, as one of the major disasters, post great threat to people’s life and property. Assessing the susceptibility of mass movements could help to mitigation the loss they brought (Yewen Ma, 2011). However, due to the limitation in available historical data, regional scale mass movement susceptibility assessment is not easy to operate. This research aims to apply a method for multi – hazard mass movement susceptibility assessment with run out in a mountainous area with limited information on past events at a regional scale. Here multi –hazard indicates different mass movements including debris flow, landslide, rock fall and snow avalanche. First, susceptibility for each type of mass movement is evaluated using Spatial Multi Criteria Evaluation (SMCE) in ILWIS. Then the cells with high susceptibility value are selected as source area to model the run out with software flow – R. The run out maps are combined together to make a multi – hazard susceptibility map. Different scenarios of major trigger, moderate trigger and minor trigger are modelled. The results indicate that a heuristic susceptibility assessment can generate good results if the knowledge about the local environmental situation is well known. The run out included in the susceptibility assessment can delineate the susceptibility zone more realistically than an initiation susceptibility assessment only [29].

The conclusion is related to the property of the study area, of which the land cover type is quite uniform that more than 90% of the area is made up of grassland and forest. Linear factors such as roads and drainage network influence the results a lot in SMCE. The highest susceptibility – value cells are mostly along linear segments. Though it is similar to the reality, for example, debris flow mostly happens along drainage [29].

2.17 Risk Habitat Megacity

A research initiative, conducted by about 40 natural and social scientists and engineers of five research centre of German Helmholtz Association (2007 – 2012) focuses on the correlation between the urban habitat as a space of risk and a space of opportunity. Because megacity risks are frequently the result of interaction between natural conditions
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and human activity (settlement, economic activity, use of natural resources, etc.), leading to multiplication, propagation and reinforcement, research must capture risk interdependencies. The research methodology makes the network of interdependencies explicit, visible and open to analysis. This demands a holistic analysis approach to the complex system of interdependencies, avoiding partial improvement in some subsystems at the expense of worsening the situation in others. To make solutions convincing, analysis will be based on empirical evidence and appropriate simulation models. The research initiative intends to go beyond the generation of orientation knowledge; it aims to develop workable implementation solutions for risk management, which include new forms of urban governance[30].

FIGURE – 2.3: Program Architecture for various researchers (Source: German Helmholtz Association)

The initiative applies these analytical concepts to several typical megacity issues, such as Land use management, Socio-spatial differentiation, Energy, Transportation, Air quality and health, Water resources and services, and Waste management (Figure -2.3). Hence, the programme encompasses ten topics: three “cross-cutting concepts” – Sustainable Development, Risk, and Governance – and seven “fields of application”[30].
Urban Risk Reduction

2.18 Urban Risk Reduction

This thematic review report on urban risk reduction in Asia has been prepared by Srinivas, Sharma, Shaw, (2009) in the context of progress review in the implementation of the Hyogo Framework. It provides thematic analysis as input to the production of the Global Assessment Report on Disaster Risk Reduction (GAR/DRR) to be launched at the second session of the Global Platform on Disaster Risk Reduction in 2009. Urban risk reduction in Asia need a balanced mix of policy implementation, regulatory measures and education-awareness programs through community based approaches [31]. A few conclusive statements are as follows:

1. Urban risk reduction poses a challenge for effective distribution and management of global resources.

2. For effective urban risk reduction, there is a need to strike a balance between natural and built environments and between ecological and economic objectives.

3. There is a need to develop a structure of goals/visions and a methodology to achieve urban risk reduction in order to identify the action that has to be taken.

4. Steps need to be taken that are relevant in the short term in order to gain wider acceptability, but keeping long term goals in mind.

5. Access, sharing and dissemination of information has to be a priority to achieve greater understanding of the issues involved.

6. Collaborative efforts in 'knowledge transfer' at the community-to-community level and city to city level has to be encouraged, particularly between developed and developing cities.

7. There is a need to understand and enact the concept of sustainable development and sustainable living, in all its varied definitions, to achieve urban risk reduction objectives.

8. Development of new technologies that are clean, green, and practical has to be encouraged and exchanged between national and city/local governments to combat environmental problems.
Literature Review
The urban risk issue in Asia is being addressed by various institutions at various levels through regional programs by regional entities, through national programs by country governments, and through city-level and local level activities by community level entities. The Asia Region is uniquely positioned to have a synergy of activities of UN, bilateral donors, governments, and specific activities by civil society organizations and academic institutions [31].

With the increasingly complex and urbanizing world, sustainable urban development and management present considerable challenges and potentials for reducing urban vulnerabilities and risks. The Asia Regional Task Force on Disaster Risk Reduction will expand its network and partnership, work together to cope with these challenges through the concerted and collaborative efforts among partner organizations, and contribute to creating an enabling environment to reduce urban risk in the Asia region [31].

2.19 Seismic Microzonation for Cities of South Asian Countries

Research conducted by SAARC Disaster Management Centre (Bhandari, 2011) for South Asia is one of the most earthquake prone regions in the world. Six out of the eight countries of South Asia - Afghanistan, Pakistan, India, Nepal, Bhutan and Bangladesh are located within seismically active Himalayan - Hindukush belt which has seen some of the worst earthquakes recorded in history. Large part of peninsular India is prone to earthquakes of varying magnitudes. Sri Lanka, Maldives and parts of the coastal areas of Bangladesh, India and Pakistan are vulnerable to tsunami earthquake in the Indian Ocean [32].

Most of the countries developed their respective macro-seismic zonation maps based on critical evaluations of historic evidences of earthquakes, published and unpublished literature and systematic seismo-tectonic mapping. These small scale zonation maps provide a broad-brush picture of the levels and distribution of earthquake hazards to which a particular country is subjected. They also provide a scientific basis for earthquake resistant design codes. These small scale maps are, however, not much of a use in assessment of area specific seismic risks, uncompromisingly requiring large scale seismic micro zoning with care for detailing far beyond the standards of routine practice. It was, therefore, only natural that attention gradually turned to seismic microzonation of urban

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centres where perceived threat levels are very high and seismic risks are clearly unaffordable. Figure – 2.4 shows the structural framework for seismic microzonation and risk assessment due to earthquakes.

FIGURE – 2.4: Recommended framework for seismic Microzonation: From seismicity to risk assessment (Bhandari, 2011)
Figure – 2.5 depicts the Microzonation action plan suggested by Mohanty, 2005. Seismic Microzonation programmes in the various cities and urban centres of SAARC countries will likewise have to draw road maps suited to their specific situations, the broad approach and items of concern remaining the same. It should usually be the task of national or local authorities in a country to identify sites, and assign priorities for seismic micro zoning and such decisions are usually based on the scientific inputs from experts on risk and vulnerability of urban centres. Socio-economic and strategic importance of the various urban centres and consequential impact of disasters on national economy usually weigh high in the decision making process. There is no other subject of equal importance in which we can gain more by working together.  

2.20 Using Geographic Information System (GIS) for Planning

ACF Disaster Risk Reduction (DRR) Project has been implemented in Camarines Sur and Catanduanes with the objective of reducing the population’s vulnerability of population to natural disasters. Hazards like typhoon, landslide, flood, storm surge, tsunami, and
Using Geographic Information System (GIS) for Planning

earthquake poses risks to life, property and livelihood compounded by physical exposure and proximity to hazard-prone areas, socio-economic, and cultural and behavioural conditions (lidija, Ivan, 2009) [33].

Using GIS, maps are produced through the integration of spatial data and local community knowledge. GIS aids in efficient development, storage, updating, access and sharing of multi-hazard mapping information. The availability of reliable multi-hazard maps are important risk assessment tools providing relevant information essential for community planning and decision making, especially in emergency response, and disaster preparedness and mitigation [33].

FIGURE – 2.6: Process of Multi-hazard Mapping (lidija, Ivan, 2009)

Following are the uses of Multi-hazard Maps

1. Hazard and Risk Identification
   Impact of natural disasters can be minimized significantly if proper and timely information is available. Multi-hazard mapping process supports the requirement of availability of relevant information since the first step in producing multi-hazard maps is the identification of hazards and risks.

2. Emergency Response
   During disasters, local government units (LGUs) are under extreme pressure to make abrupt decisions affecting thousands of people, often with limited time to analyze situations and undertake actions. Maps are cartographically simple with information to make prompt and appropriate responses especially in emergencies.
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3. Risk Management and Local Development Planning

Hazard mapping is a crucial guide in optimizing development gains and minimizing potential loss of physical assets, human resources, and environmental capital. Mainstreaming multi-hazard mapping into local development planning is essential to effective disaster risk management.

Spatial planning enables detecting and avoidance of the areas prone to hazards, i.e. decreasing risks of occupying those areas. The MHM is an excellent tool to create awareness in mitigating multiple hazards. It becomes a comprehensive analytical tool for assessing vulnerability and risk, especially when combined with the mapping of critical facilities. The adoption of a multiple hazard mitigation strategy also has several implications in emergency preparedness planning. For example, it provides a more equitable basis for allocating disaster planning funds; stimulates the use of more efficient, integrated emergency preparedness response and recovery procedures; and promotes the creation of cooperative agreements to involve all relevant agencies and interested groups:

It must be emphasized that the MHM will not meet the site-specific and hazard-specific needs of project engineering design activities [33].

2.21 Structure Specialist Training Manual

The objective of this training module developed by FEMA US & R Response system / U. S. Army Corps of Engineers (2009) is to systematically summarize:

1. The various types of events that may lead to a US&R deployment,
2. The failure modes that may be expected from those events for common building types,
3. The practical significance of those failure modes for US&R operations.

The US&R program was initially developed to respond to a major urban earthquake disaster. Much of the early structure training therefore focused on expected earthquake damage patterns. However, the short history of the program has demonstrated that US&R resources may be called upon to respond to structural collapses triggered by a wide variety of causes. Each of the US&R deployments to date has presented unique challenges to the Structures that went well beyond what had been covered in early Structure training. The intent of this module is to increase the experienced Structure’s understanding of both the
commonalities and unique aspects of this wide variety of potential events so that they are better prepared to respond effectively to the unique circumstances of the next event [34].

Three major factors that influence risk assessment and mitigation strategies are:

1. Cause of the collapse,
2. Nature and extent of damage (damage zone), and
3. Construction type.

Thus, the Structure must consider those three major factors, as discussed in the balance of this module, in their on-going assessment of failed structures and re-evaluation of the risk/reward balance as rescue operations proceeds and circumstances change [34].

2.22 Assessment, Design and Mitigation of Multiple Hazards

Large parts of the world are subjected to one or more natural hazards, such as earthquakes, tsunamis, landslides, tropical storms (hurricanes, cyclones and typhoons), costal inundation and flooding (Ahuja, 2011). Virtually the entire world is at risk of man-made hazards. In recent decades, rapid population growth and economic development in hazard-prone areas have greatly increased the potential of multiple hazards to cause damage and destruction of buildings, bridges, power plants, and other infrastructure; thus posing a grave danger to the community and disruption of economic and societal activities. Although an individual hazard is significant in many parts of the United States (U.S.), in certain areas more than one hazard may pose a threat to the constructed environment. In such areas, structural design and construction practices should address multiple hazards in an integrated manner to achieve structural performance that is consistent with owner expectations and general societal objectives. This report provides a review of literature and the current state of practice for assessment, design and mitigation of the impact of multiple hazards on structural infrastructure. It also presents an overview of future research needs related to multiple-hazard performance of constructed facilities [35].
### Literature Review

**TABLE – 2.3: History of Multiple Hazards with Assessment of Damage (Ahuja, 2011)**

<table>
<thead>
<tr>
<th>Multiple Hazards</th>
<th>Mode Of Damage</th>
<th>Occurrences</th>
<th>Examples Of Multi – Hazard Damage</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Hurricane (Wind and Rain)</strong></td>
<td>High Speed winds damage doors and windows and when followed by heavy rainfall. Causing interior property damage to the structure.</td>
<td>Hurricane Ike(2008) Hurricane Katrina and Rita (2005) Hurricane Andrew (1992)</td>
<td>During Katrina Complete structural damage was observed when the roofs were blown away by high speed winds and the interior damaged by heavy rainfall that followed.</td>
</tr>
<tr>
<td><strong>Hurricane (Wind, Wave and Storm Surge)</strong></td>
<td>Waves cause extensive damage when they strike coastal structures after wind has caused external structural damages.</td>
<td>Hurricane Ike (2008) Hurricane Katrina and Rita (2005) Hurricane Andrew(1992) Hurricane Opal(1995)</td>
<td>Waves as high as 25 ft. were observed during Katrina, which caused large scale structural damage (buildings, bridges, etc..)</td>
</tr>
<tr>
<td><strong>Earthquake and Tsunami</strong></td>
<td>Tsunamis are high speed and height waves triggered by an underwater earthquake. The combined damages are caused first by ground shaking followed impact of high speed waves.</td>
<td>Indian Ocean Tsunami(2004) Japan Tsunami (2011)</td>
<td>Indian Ocean Tsunami killed about 283000 and displaced more than 1.1 million people. The Japanese tsunami damaged the electrical power lines of Fukushima Daiichi nuclear power plant creation a meltdown threat.</td>
</tr>
<tr>
<td><strong>Fire following an Earthquake</strong></td>
<td>Fire caused after damages to oil and gas pipelines and to electrical power transmission lines damaged by an earthquake</td>
<td>San Francisco (1906) Tokyo (1923) Kobe (1995) Northridge (1994) Japan (2011)</td>
<td>Around 3000 people were killed in the 1906 San Francisco (Varnes and Pielke Jr.2009) and around 142.000 people were killed in Tokyo in 1923 from fires following and earthquake (James 2002). The cities of Kesennuma and Sendai of Japan were under heavy files after the earthquake of 2011 (Reuters 2011).</td>
</tr>
</tbody>
</table>
TABLE – 2.4: Current Mitigation Strategies for Multiple Hazards (Ahuja, 2011)

<table>
<thead>
<tr>
<th>Mitigation Strategies</th>
<th>Description</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forecasting</td>
<td>Forecasting specifies in advance the location, size and time of occurrence of a natural hazard.</td>
<td>SLOSH used to is estimate storm surge heights and wind intensities resulting from historical, hypothetical, or predicted hurricanes (NHC 2003).</td>
</tr>
<tr>
<td>Land Use Planning</td>
<td>An effective tool for development of hazard prone areas.</td>
<td>Coastal Barrier Resources Act (CBRA) protects coastal areas from development and thus limits property damage (FEMA 2010). Disaster mitigation Act, 2000 makes it mandatory for public sector organizations to prepare multi hazard mitigation plans to eligible for federal funding.</td>
</tr>
<tr>
<td>Improved Building codes and Standards</td>
<td>Provide minimum design specifications necessary for new construction and retrofitting.</td>
<td>International Building Code includes instructions for designing structures for wave and wind load simultaneously (ASCE —7 2010). National Flood Insurance program (NFIP) has created performance standards for structures in the coastal areas.</td>
</tr>
<tr>
<td>Risk Communication and loss estimation</td>
<td>Creating public awareness about the ways a hazard can affect people.</td>
<td>Building trust among people so that every warning (flood, tsunami, winds) is treated as a real threat. Local hazard information centers to educate people about multi – hazard risks and mitigation strategies.</td>
</tr>
</tbody>
</table>

The Multidisciplinary Centre for Earthquake Engineering and Research (MCEER 2007) symposium emphasized the need for resilience towards multiple hazards in the future and identified needs. Bruneau proposed a 4R (Robustness, Redundancy, Resourcefulness and Rapidity) approach towards enhancing the disaster resilience of the communities through multi-hazard engineering. Additionally, the Consequence Based Engineering approach concentrates on the consequences of the hazard and the mitigation strategies employed (Abrams 2002), emphasizing impacts ranging from damage to socio-economic effects. This framework offers an alternative lens through which multi-hazard mitigation can be evaluated, yet its application to integrating different hazards has been limited to date [35].

This report provides examples of damages realized from multiple hazards, and provides an overview on the different perspectives of multiple hazards. Experimental tests performed to assess damages, to validate new designs and to evaluate the performance of structures are discussed. A review of current risk assessment methods, design and mitigation strategies for multiple hazards are summarized. In addition, potential impacts of climate
Literature Review

change on natural hazard patterns and building/infrastructure damages are presented. Despite the stringent building codes and advanced warning systems, the 2011 earthquake and tsunami in Japan caused unprecedented damages, deaths and economic and societal losses. This type of event underscores the importance of multi-hazard mitigation and the challenge of designing and building structures capable of withstanding the impact of such an event in a technically sound and cost-effective manner [35].

2.23 Disaster Mitigation in Urban Planning

After the Orissa super-cyclone in 1998, the Gujarat earthquake in 2001 and the most recent tsunami in 2004, and the devastating floods in Mumbai last year, the government has recognized the need for comprehensive disaster management. The current disaster management paradigm lays emphasis solely on response – rescue, relief and rehabilitation. To bring about a paradigm shift towards long-term disaster risk reduction, it is necessary to increase emphasis on disaster mitigation in all disaster management initiatives. Till recently, disaster management has been perceived as an independent subject requiring independent institutional structures to deal with it. It is now accepted that disaster management is a crosscutting theme that needs to be integrated in all aspects of mainstream urban and regional planning. The impact of disasters is accentuated by flaws in urban planning and poor quality of existing building stock. Disaster risk reduction requires improvement in quality of building stock necessitating high levels of compliance and, spatial planning that adequately incorporates disaster risk reduction. The purpose of this project is to present an approach that integrates disaster mitigation into mainstream urban planning – both: physical planning and its implementation; and, legal provisions/regulations and their enforcement (Byahut, Parikh, 2006) [36].

Local governments being closest to a disaster, have the highest stake in mitigating the risk. However, urban local governments in India largely don’t perceive disaster mitigation as their responsibility. Urban local bodies must be made legally responsible and empowered for undertaking long-term disaster mitigation measures. Multiplicity of agencies and government bodies made responsible for the same leads to complete lack of coordination. While the physical growth of a city is important, it is also equally critical to envisage strategic growth of cities. For instance, almost over half of Mumbai and Delhi live in
Structural and Non-Structural Seismic Vulnerability Assessment

Unauthorized areas and buildings \[^{36}\]. The primary reason for this is that the land supply mechanism in cities is not able to meet the burgeoning demand and is controlled by a few powerful builders’ lobby. Strategic growth components allow planners to look at the overall city environment and plan in accordance with its long menu of needs. This also allows for mitigation to be built in easily into the plans.

Accurate maps and spatial database is critical for decision-making, risk identification and mitigation. Multiple authorities build and maintain infrastructure and databases, with no inter-agency coordination or sharing of database. Vulnerability maps of urban areas are not available at all or at least not very easily. Mapping of inundation areas, hazard-prone areas, vulnerable areas etc. is almost always never undertaken during city planning process.

However, on the other hand, roles and responsibility are not clearly defined in procedure regulations which lead to lack of accountability and ultimately results in non-compliance. They need to take greater responsibilities for compliance of design to regulations and that of construction of the building to that sanctioned design \[^{36}\].

The development regulation system must be able to deliver safe and secure buildings for the people of India. In context to the disaster vulnerability and the extensive damages experienced in recent earthquakes and other disasters, any effective policy for long-term risk reduction should target improvement of development regulation system to ultimately improve the existing and future building stock \[^{36}\].

2.24 Structural and Non-Structural Seismic Vulnerability Assessment

A fast and cost-effective procedure is proposed in order to assess the structural and non-structural seismic vulnerability of hospitals and schools (Lang, Verbicaro, Singh, Prasad, Wong, Gutiérrez, 2010). Through the application of standardized questionnaires, both a structural and non-structural vulnerability index are derived which allow a priority ranking and an identification of the most vulnerable features so that responsible authorities are able to conduct a more targeted investigation using more advanced investigation methods. In contrast to other available approaches, structural and non-structural vulnerability are treated separately. While the structural vulnerability index is generated taking into account
Literature Review

main design failures as well as the age of the building and its general state of maintenance, the non-structural vulnerability index covers all types of installations, secondary structural elements as well as their impact on the functionality of the building. To optimize a realistic selection of survey questions, the questionnaires have been applied to numerous hospitals and school buildings in Northern India and the Central American countries Guatemala, Nicaragua and El Salvador. Based on these results and the experiences gained during these case studies, a calibration of the questionnaires was done through the definition of reliable weighting factors for the different vulnerability-affecting aspects \[37\].

The presented procedure to assess both structural and non-structural vulnerability of hospital and school facilities by the application of standardized questionnaires is an attempt to quickly identify existing structural and non-structural shortcomings, to allow a priority ranking of the most vulnerable structures and to provide a basis to compare different structures with each other \[37\].

The questionnaires were applied to numerous hospitals and schools in Central America and India, thereby developed as well as calibrated. However, a more substantiated calibration of the decided importance factors, age and actual state factors, and derived vulnerability indexes with more thorough analytical studies of selected structures is on-going (Verbicaro et al. 2009) and will be the purpose of future investigations.

2.25 Promoting Safer Building Construction

The maximum loss to life and property in the Asian Region, due to frequent occurrence of natural disasters, dictates the need for the evolution of safer habitat, which can respond and resist the loads, forces and effects due to the natural disasters. This becomes imperative in the context of huge socioeconomic loss to nations. Therefore, all efforts are to be promoted and nurtured for safer building construction to take care of normal loads and forces and the effects of natural disasters. This can only happen when an enabling environment is created for effective techno-legal and techno-financing regime for effective building regulatory mechanism for creating safe habitats (V. Suresh, 2002). With large part of the communities belonging to low income strata, with people driven construction processes, appropriate grass root level technology transfer initiatives should be put in place for creating
Promoting Safer Building Construction

awareness, appreciation and application models for using disaster resistant and cost effective building technologies. The multi-pronged strategies to create safer habitat, as a people's movement would need massive community participation and use of media, governmental and technology back up delivery support.\[38\]

The extent of damages to buildings and infrastructure, in disaster affected areas is colossal. These are primarily due to the fact that the buildings for various uses like residential (housing - individual and group housing), educational (schools, colleges, places of learning), institutional (health centres, hospitals), assembly (community centres, cinemas, auditoria, terminals), business (offices), mercantile (shopping, trade, commerce), storage (warehouses, godowns, sheds), industrial (factories, production units) are all damaged partially or fully due to unsafe design and construction from natural disaster related forces and effects. While these buildings could well be safe from dead and live loads and forces, these are not planned / designed / built to take care of the lateral / other forces due to earthquakes (from below the ground), wind load (forces above the ground), landslides, storm surges / flooding etc.\[38\].

**FIGURE – 2.7: List of Disaster Resistant Cost Effective Technologies (Suresh, 2002)**

In all efforts for promoting safer building construction based on the actual efforts providing for policy / regulatory / financing mechanisms, one of the important application
Literature Review

area is the actual implementation phases. Technology know-how is always available through codes, manuals, standards, brochures, folders etc. But what is more important is the actual grass root level application. This is an area where one of the biggest gaps has been noticed to promote safer building construction for disaster prone areas \[38\].

One of the very significant efforts in this direction has come from India through the establishment of a large network of Building Centres (Nirman Kendras) which are one of the most effective grass root level technology transfer centres for disseminating and propagating appropriate skills to the cutting edge level for transforming the technological know-how through hands-on show-how skill formation systems. The programme started in 1988 in continuation of the work done by Laurie Baker, one of the doyens and eminent master builder in the field of cost effective construction. The institutionalisation of the building centre programme with support from the Government of India / State Governments and with a broad based participation of all stake holder agencies has grown into a very powerful network with over 640 building centres all over the country in the last 14 years \[38\].

The best way to disseminate and propagate technology for use of safer technologies is to use the building itself as a medium. Many state governments and local governments have now taken a lead in constructing public asset buildings of high visibility nature viz. school buildings, health centres, community centres, village offices, multi-purpose centres utilizing cost effective and disaster resistant technological features incorporated in the same \[38\].

The contribution made by V. Suresh lays emphasis on need for evolution of safer habitat which can respond and resist the loads, forces and effects due to natural disasters. The work is focussed on EQ only but it discusses at large on the implementation issues and gaps in our system which acts as a barrier for safer building construction. The cost effective technologies are also discussed at large so that the people of low income strata can be benefitted \[38\].
Urban Multi-hazard Risk Analysis using GIS and RS

2.26 Urban Multi-hazard Risk Analysis using GIS and RS

Many cities develop without any proper urban development planning, let alone that within these development plans natural hazards, such as landslides or earthquakes, and the risk they pose to the city and its inhabitants, are taken into account. Therefore a study on multi-hazard risks in urban areas is of prime importance to be able to implement vulnerability reduction measures, and involve risks as an integral component of development planning. This study gives an example of such as multi-hazard risk assessment, carried out for a rapidly developing city with very limited availability of existing data: the town of Kohima, capital of the state of Nagaland in North eastern India (Khatshu, Westen, 2005). Building footprints, which serve as the basis for the multi-hazard risk assessment, were generated from remote sensing images. The characteristics of the elements at risk, such as building structure, material, condition of buildings, socio-economic aspects, population information, etc. were collected through extensive field surveys with the help of the digital footprint map. Along with the data collected from remote sensing data, field mapping and historical data, individual hazards were analysed in GIS environment using vector operations, and all the individual hazard maps were integrated to prepare a multi-hazard map. The number of households in each building was calculated to derive the population at risk to different individual hazards. Individual buildings with both single and multi-hazard were identified and population at risk was calculated. A comparison of the existing situation in the study area with that of the standards prescribed at the national level was made. The situation in the study area is falling short of the norms and efforts should be made by both local authorities as well as local communities to reduce the high level of vulnerability.

The main objectives of the study is to develop a method for multi-hazard risk assessment in urban areas with limited access to spatial data, using Remote Sensing and (mobile) GIS and to test it in the town of Kohima. Therefore an analysis was made of landslide, earthquake and fire hazards in three wards of Kohima town (New Market, Midland, Hospital Colony wards), based on historical analysis, a mapping survey and a questionnaire survey combined with elements at risk inventory to derive a multi-hazard risk map, which can be used as base map for reallocation of facilities and infrastructure, formulation of plans for future expansion and emergency planning. Kohima town is
Literature Review

characterised by an extreme scarcity of data. Since this area is politically instable, the access to topographic data and aerial photographs for this region is restricted. Other thematic data is also often lacking. For instance, the Geology Department of the Nagaland University, Kohima does not have a geological map and the Directorate of Soil and Water Conservation could not produce a soil map of the city. Data should either be collected using Earth Observation satellite images, by extensive field surveys, or by a combination of both. In addition, data from the Indian satellites are not freely available for this region. Unfortunately, the study area lies between two scenes of IRS data that sometimes it could not capture the study area by either of the scenes \cite{39}. Table – 2.5 depicts the population at risk calculated by some of the methods for effect of Multihazard.

**TABLE – 2.5: Ward-wise distribution of buildings and population at MHR (Khatshu, Westen, 2005)**

<table>
<thead>
<tr>
<th>Wards</th>
<th>MH</th>
<th>No. of Buildings</th>
<th>% of Ward Buildings</th>
<th>Population at Risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>New Market Ward</td>
<td>ELF</td>
<td>69</td>
<td>17.21</td>
<td>306</td>
</tr>
<tr>
<td></td>
<td>EL</td>
<td>9</td>
<td>2.24</td>
<td>68</td>
</tr>
<tr>
<td></td>
<td>EF</td>
<td>72</td>
<td>17.96</td>
<td>356</td>
</tr>
<tr>
<td></td>
<td>FL</td>
<td>78</td>
<td>19.45</td>
<td>423</td>
</tr>
<tr>
<td>Midland Ward</td>
<td>ELF</td>
<td>61</td>
<td>8.24</td>
<td>279</td>
</tr>
<tr>
<td></td>
<td>EL</td>
<td>23</td>
<td>3.11</td>
<td>144</td>
</tr>
<tr>
<td></td>
<td>EF</td>
<td>113</td>
<td>15.27</td>
<td>504</td>
</tr>
<tr>
<td></td>
<td>FL</td>
<td>33</td>
<td>4.46</td>
<td>203</td>
</tr>
<tr>
<td>Hospital Colony Ward</td>
<td>ELF</td>
<td>57</td>
<td>5.91</td>
<td>203</td>
</tr>
<tr>
<td></td>
<td>EL</td>
<td>95</td>
<td>9.85</td>
<td>387</td>
</tr>
<tr>
<td></td>
<td>EF</td>
<td>79</td>
<td>8.20</td>
<td>333</td>
</tr>
<tr>
<td></td>
<td>FL</td>
<td>76</td>
<td>7.88</td>
<td>414</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>765</strong></td>
<td></td>
<td><strong>3620</strong></td>
</tr>
</tbody>
</table>

This study develops a methodology which can be adopted for other towns having similar problems (Landslides, Earthquakes and Fire) but generally it is focussed on Kohima City of Nagaland. This type of study is needed badly so far as the city of Ahmedabad is concerned but the hazard like landslide can be excluded.
2.27 Suitable Site Selection for Seismic Micro-zonation

The ability to undertake seismic micro-zonation can be improved through current advances in GIS technology. Undertaking seismic micro-zonation for large areas is very expensive; hence it is imperative to identify the areas, which are most susceptible to natural hazards (Subramanian, Kaneko, Ranjan, 2005).

The application does an overlay operation and creates separate social and natural hazard maps, along with creating an integrated map of the input parameters and finally divides the area into multiple Seismic zones. Users have the option to increase or decrease the weightage for any of the input parameters. The paper discusses an application that can create micro-zonation maps using the above parameters [40].

2.27.1 Micro-zonation Feasibility

To evaluate the most suitable areas for the seismic micro-zonation, the following natural and social hazard factors were considered:

A) Natural Hazard Factors: The four key natural hazard factors include
   1. Base Rock Motion
   2. Soil Amplification
   3. Liquefaction Potential
   4. Slope Failure Potential

B) Social Hazard Factors: The three key social hazard factors include
   1. Building Vulnerability
   2. Demographic Condition
   3. Economic Condition

These parameters were thus grouped into five grades depending upon the importance of these individual layers [40].
Literature Review

2.27.2 Micro-zonation Viewer

RMSI developed an application named – “Seismic Zone Viewer” to create seismic hazard zone maps of an area. The application allows a user to modify the weightages as well as gives a facility to select or deselect any of the input layers to modify the hazard model for micro-zonation. The objective of this application was to create a user-friendly application to generate seismic hazard zone of any area. The output of the viewer is a map representing seismic hazard zone of the area based on the earthquake hazards and vulnerability factors of that area [40].

![Seismic Zone Viewer](image.png)

FIGURE – 2.8: Screen Shot of Arc View Software of GIS for seismic hazard map formulation of Gujarat (Subramanian, Kaneko, Ranjan, 2005)

All the input data should have similar boundary conditions. Each of the above mentioned input should contain the rank for each of these layers at the administrative boundary.

2.27.3 Viewing Facility

The advantage with this tool is visualization of each hazard layer as an individual, as well as in the combination of input layers. In this application a user can modify weightage of any map layer and can visualize the impact of that in an overall scenario. User has a facility to create the seismic zonation map using different combinations (only natural or only social parameters or a combination of both). User
Risk Micro-zonation of Ahmedabad City

can modify any one of these layers or add new map layers as per their requirement \[40\]. Based on a study undertaken by RMSI, it has been inferred that in normal Indian condition the weightages for each of these layers is as follows:

TABLE – 2.6: Weightage assigned of various parameters for micro-zonation \[40\]

<table>
<thead>
<tr>
<th>Factor</th>
<th>Item</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural Hazard</td>
<td>1. Base rock Motion</td>
<td>3.0</td>
</tr>
<tr>
<td></td>
<td>2. Soil Amplification</td>
<td>1.50</td>
</tr>
<tr>
<td></td>
<td>3. Liquefaction Potential</td>
<td>0.75</td>
</tr>
<tr>
<td></td>
<td>4. Slope Failure Potential</td>
<td>0.75</td>
</tr>
<tr>
<td>Social Factor</td>
<td>5. Building Vulnerability</td>
<td>0.75</td>
</tr>
<tr>
<td></td>
<td>6. Demographic Condition</td>
<td>1.0</td>
</tr>
<tr>
<td></td>
<td>7. Economic Condition</td>
<td>0.50</td>
</tr>
</tbody>
</table>

2.28 Risk Micro-zonation of Ahmedabad City

The study was carried out during 2001-2005, covering an area of 500 sq. km, in and around Ahmedabad city, with an objective of providing input for planning pre-earthquake disaster management (Mathur, Saxena, Prasad, Fulzele, Singh, Regar, 2005). The area is located in the Cambay rift basin and is occupied by south westerly pro-grading deltaic and Aeolian sediments of Quaternary age. These are affected by NW-SE and NE-SW trending faults. The city falls in zone III of seismic zonation map of India. Thematic maps on geology, geomorphology, seismo-tectonic, land use, ground water and soil were compiled. Borehole data and SPT values from 75 boreholes were studied, which indicate that the first 2 to 3 metre consists of sandy / silty dark grey to dark brown humus soil. Within 3 to 10 meters, sediments consist of mainly cohesion less silt and sand with disseminated kankar. 10 meters below, the Quaternary sediments consist of fresh riverine sand and sticky clay horizons. Ground water levels, as recorded from the boreholes, range from 6 to 23 meters below the surface. Based on the inputs from the present multidisciplinary studies, the city of Ahmedabad has been demarcated into four seismic hazards micro zones- A, B, C, and D. Micro-zone D is anticipated to be the most hazardous while micro zone A is the least hazardous zone. Micro zone D, marked by softer sediments, shallow ground water, low ‘N’ value, low shear wave velocity, higher average horizontal spectral amplification (ASHA),
Literature Review

Low resistivity, high amplification factor, and low frequency, covers several residential and commercial areas around Kankaria talav, and Chandola talav and extends in EW directions on either banks of Sabarmati river. Micro-zone C covers major parts of Ahmedabad city. GSI suggested carrying out of site-specific studies at each site during the design stage of high-rise buildings, in order to better evaluate the site-specific conditions by planners, designers, and Ahmedabad Urban Development Authority\(^{[41]}\).

MAP – 2.4: Seismic hazard Micro-zonation map of Ahmedabad city formulated by GSI

(Mathur, Saxena, Prasad, Fulzele, Singh & Regar, 2005)

2.29 Building Design for Fire after Earthquake

The research conducted by Botting, Buchanan, 2000, describes systematic review of fires after major recorded earthquakes throughout the world, reporting ignition sources, fire spread, fire fighting activities, damage to fire protection systems and water supplies. The historical survey is used as a basis for proposed improvements to building design, in order to reduce the impacts of fires in the urban environment after major earthquakes, giving priorities for building owners, territorial authorities and fire services. It has been observed that even if adequate reporting of fires occurs, fire services often have great difficulty
Building Design for Fire after Earthquake

going to the fires for many reasons, including inadequate resources, damaged fire stations
and choked up streets as summarized in Table – 2.7 mentioned below.

**TABLE – 2.7: Damage / Failure to Fire Service and Water Supply System**

<table>
<thead>
<tr>
<th>Earthquake</th>
<th>Reported Damage to Fire Service</th>
<th>Damage / Failure to Water Supply System</th>
</tr>
</thead>
<tbody>
<tr>
<td>San Francisco, 1906</td>
<td>Fire alarm receiving office destroyed. Telephone system failed over wide area. Fire stations damaged but all fire vehicles went into service.</td>
<td>Complete water failure in most of city. Three major water lines failed in marshy ground. Widespread damage to distribution system.</td>
</tr>
<tr>
<td>Tokyo, 1923</td>
<td>Fire station damage prevented the use of some fire vehicles and equipment.</td>
<td>Complete water supply failure.</td>
</tr>
<tr>
<td>Napier, 1931</td>
<td>Fire Station destroyed and fire engines buried.</td>
<td>Complete water supply failure. Fractures in cast iron water pipes. Reservoir damaged and water tower</td>
</tr>
<tr>
<td>San Fernando, 1971</td>
<td>Parts of telephone system disrupted due to physical damage, power cuts, and overloading.</td>
<td>The water supplies devastated. Wells ruptured and reservoirs cracked. Pumping stations inoperative due to electricity failure.</td>
</tr>
<tr>
<td>Managua, 1972</td>
<td>Telephone equipment damage at several exchanges. Three fire stations collapsed. Some portable equipment salvaged. Serious lack of resources.</td>
<td>Underground water system badly damaged in poor ground and across earthquake faults. Many breaks in street mains.</td>
</tr>
<tr>
<td>Morgan Hill, 1984</td>
<td>Telephone overloading but no damage.</td>
<td>Large water losses due to breaks in two transit lines. Many connection failures.</td>
</tr>
<tr>
<td>Mexico City, 1985</td>
<td>Telephone system seriously damaged. Main exchange building collapsed and many others severely damaged. Earthquake damage to Fire Department.</td>
<td>Area of water pipe damage much larger than area of structural damage. Shear failures in large pipes, telescopic failures in smaller pipes.</td>
</tr>
<tr>
<td>Whittier, 1987</td>
<td>Telephone system remained serviceable although saturated with calls.</td>
<td>Water supplies performed well. Peak water pressure only 50% of normal for two days.</td>
</tr>
<tr>
<td>Hokkaido Nanseioki, 1993</td>
<td>The two fire trucks were undamaged but only 25% of the fire fighters were available.</td>
<td></td>
</tr>
<tr>
<td>Northridge, 1994</td>
<td>Significant disruption to telephone and other communications systems. Loss of standby power and computer-aided dispatch. Minor damage to fire stations.</td>
<td>Water loss from many pipe breaks. Pumping stations and tanks damaged.</td>
</tr>
<tr>
<td>Kobe, 1995</td>
<td>Command centre unable to receive calls immediately after the earthquake due to major damage and overloading. Earthquake damage affected fire stations and fire-fighters.</td>
<td>Most hydrants unserviceable. Many breaks in piping. Water from cisterns, but many damaged. Small fire trucks had limited water capacity.</td>
</tr>
</tbody>
</table>
Literature Review

2.30 Research Gap

Review of literature from different sources depicts that countries like US, Europe, Japan, China and New Zealand have provisions in design practices to include the effects of multi-hazards on buildings. The use of GIS, GPS and RS for mapping hazards is also found to be a good tool. Government of India has also formulated hazard maps at macro level [4] but micro-zonation of urban centres is still lacking where population density is increasing day by day. The cities like Delhi, Mumbai, Chennai, Kolkata, Jaipur, Surat, Ahmedabad and others are forced to expand their limits and revise development control regulations owing to the needs of growing population. Thus it is now imperative to plan these cities at micro level to enable them to handle the effects of multi-hazards they can be posed for.

Literature review of the related themes clearly depicts that:

1. In most of the developed and developing countries research has been conducted on hazard planning and authorities take into account the effect of multi hazards for planning of urban habitats.
2. Research has generally been conducted on a particular hazard in isolation. But a hazard is always coupled with other systems failure which exacerbates the disaster. eg. Japan Earthquake, fire ignition and nuclear reactor rapture.
3. Evacuation procedures, routes required and shutdown of other systems in case of multi-hazard for public buildings are not defined.
4. Urban hazard mitigation is not accounted for during the planning stage. e.g. Ahmedabad earthquake, Mumbai bomb blasts, Surat floods.
5. Earthquakes are followed by fires but the effect is not taken into account during the planning stage of multi-storied buildings in India. This effect of multi-hazard leads to premature failures and unnecessary loss of life and property.
6. Zoning guidelines are not formulated to identify areas and localities within urban habitats which may be vulnerable to hazards like earthquake, fire, flooding and chemical hazards.