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Earthquake resilience at district level hospital in bangladesh. tactic of non- structural elements and social awareness

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Abstract

Earthquake is one of those disasters which have a direct and acquit effect on human lives and settlement. At any disaster event, the importance of hospitals is out of question. Functional hospitals are a cornerstone in a coordinated national disaster response and without it the health consequence could be disastrous. Vulnerability assessment for non-structural elements of a hospital is very important to keep it functional during and after a disaster event. By taking mitigation measures according to vulnerability assessment of non-structural elements of a hospital it is very easy to serve during the time of emergency. Bangladesh is one of the most earthquake vulnerable countries in the world. Moreover, the north-east region of the country is lying on most threatening zone of seismic hazard. Lalmonirhat Sadar hospital is a district level tertiary hospital, similar to other district level hospitals in structural and service facilities. As lacking in proper non-structural vulnerability assessment process, mitigation system to reduce disaster impact developed not so far. In methodology the non-structural elements were assessed by WHO guidelines and questionnaire survey were conducted amond 400 hospital users and employees to assess the social awareness under 5 category with 25 subcategory. There are 58 types of medical facilities in Lalmonirhat hospital and most of them are in vulnerable situation during the earthquake in Modified Mercalli Intensity (MMI) scale measures. The continuous values derived from the sub-variables under 5 variables of social awareness factors is compounded into a total score which has the range of 25. The final score out of 25 is 7.93 which indicate low level of social awareness of the hospital users for the earthquake awareness. This lower score encourage to develop an effective vulnerability mitigation plan for non-structural elements of a hospital to reduce hazard impact on health facility.

Key words: Resilience, Non-structural elements, Health facility, Sadar Hospital, Modified Mercalli Intensity (MMI) scale, Mitigation plan

1 Introduction

Bangladesh has the 8th largest population in the world with more than 163 million or 2.11 % of the Earth's inhabitants living there in 2019 [1]. Bangladesh is one of the most earthquake prone countries in the world [2]. Bangladesh is vulnerable to earthquake because of the existence of several fault lines and tectonic plate boundaries [3]. Previous experience of earthquake and rapid urbanization, high population growth rate, high density and development of economic arrangements increasing the vulnerability for earthquake [3].

A building may remain standing after an earthquake, but it might be functionless due to nonstructural damage to the equipment, lifeline conduits and other non-structural elements like partition walls, veneers, ceilings, window panes etc. Assessment of non-structural vulnerability is made in order to estimate the expected damage that these elements may suffer when subjected to earthquake shaking at different levels of intensity and the consequence to the functionality of the hospital. The cost of the nonstructural elements in a hospital may be much higher than that of the structure. Particularly in hospitals, it may reach up to 90 % of the total facility value. Moreover, the susceptibility to non-structural damage would be high even in a moderate level earthquake (MMI VI-VII). This can affect or destroy vital aspects of a hospital including those directly related to its function, without significantly affecting the structural components. Thus, in an earthquake, the external appearance of a hospital might be unaffected, but it may not be able to care for patients if the internal facilities have been damaged [4]. So, considering these the study was lead to find out nonstructural elements of Lalmonirhat Sadar Hospital to assess the the earthquake vulnerability and also to know about the social awareness of the hospital user and employee of the hospital to reduce the warthquake vulnerability in Hospital with nonstructural mitigation plan.

2 Methodology

One of the objectives of the study was to investigate the Non-structural elements and their vulnerability by an earthquake in Lalmonirhat Sadar Hospital of Bangladesh. For he investigation of non structural and structural vulnerability by an earthquake many studies were carrioed out as like as Johnson [5], WHO [6], NZS [7], NZS [8], FEMA [9] and FEMA [10]. The methodology is developed in this study according to general availability of non structural elements of hospitals and the primary data are taken into account in developing the methodology.

2.1 Assessment of Individual Components

Individual non structural components and equipments were visited to evaluate the vulnerability of the hospital. All equipment and components were rated against two earthquakes, i.e. a medium size earthquake (MMI VI-VII) and a severe earthquake (MMI

VIII-IX), in terms of different levels of damage. Four levels of damage - very high, high, medium and low were taken in this case.

2.2 Identifying Critical Systems and Facilities

Identification of critical systems and essential functions of hospitals was carried out based upon the functional requirements of the hospital during and after an earthquake. The main critical systems and facilities, which are important for continued functionality, were identified after visiting the hospital. The following steps were followed to identify the critical systems.

2.3 Steps for Identifying the Critical Systems and Facilities

Step 1 Visit the hospital and explain the scope of work to the hospital administration.
Step 2. Collect information.
Step 3. Visit essential and critical facilities (after collecting information).
Step 4. Visit lifeline facilities (after collecting information).
Step 5. Cross correlation among structural system, medical facilities and lifeline systems.

2.4 Assessment of Social Awareness and Emergency Evacuation Preparedness for Hospital

Interview of hospital user and employee of hospital has been done through questionnaire having close ended questions. It was focused on the variables related to social awareness and emergency earthquake preparedness. The sampling method is purposive sampling. With 95 % confidence level and confidence interval of 5, the calculated sample size was 400.

3 Non-structural Vulnerability Scenario of the Hospital

The most important component among three of Non-structural element of hospital building is lifeline facilities, then comes the medical equipment facilities and architectural elements. All the components of lifeline systems, medical facilities and architectural elements were studied on an individual basis. However, the assessment done system by system according to the guideline, The simplified questioner helped studying all individual components of a specific system before moving to the next.
All equipment and components were rated against MMI VI- IX levels of earthquakes (6.0 – 6.9 magnitude), if they are vulnerable, vulnerability reduction options and mitigation options were identified for all equipment and contents. Major lifeline facilities of Lalmonirhat Sadar Hospital is.

a. Emergency Exit System
b. Fire System

c. Electricity System
d. Water Supply System
e. Medical Gas Supply System
f. Communication System

3.1 Present Status

ield survey shows that the number of staircases in the hospital is about 4 (including one ramp) which are the element of emergency exit system. Field survey reveals that this non-structural system is well-built and not vulnerable in MMI VII-IX level earthquake (6.0 – 6.9 magnitude). The number of Fire safety System in the hospital is about 4 no's fire extinguisher. Those are strongly hooked with the wall. There are 2 diesel generators and a 200kV Bangladesh Power Distribution Board (BPDB) transformer to serve the hospital. The transformer is strongly anchored stable poles, but the generators are revolving and not an chored with floor or wall. Two 6 HP water pump used for water supply of the hospital. There are eight RCC water tank and one plastic tank in the roof top of the hospital building. Approximate capacity is 19000 liters. There is no provision of medical gas supply line. Gas supplied through portable cylinders. Two BTCL land phone used inner-outer communication of the hospital. Broadband internet connection is used in statistics room. There is no internal network or other mode of communication technology is available in the hospital.

Figure 1. Ramp of the exit system, Fire fighting system, Generators and Transformer and Water Supply (Source. Field Survey, 2019)

The following figure 2 shows the lifeline non-structural elements available in the Lalmonirhat Sadar Hospital. From the lifeline non-structural elements the emergency exit and fire system contains the more percentage of available system and both of them are 27 %.

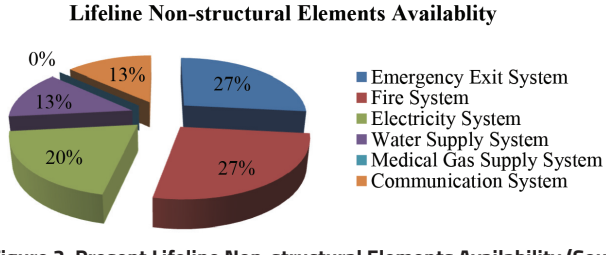

Figure 2. Present Lifeline Non-structural Elements Availability (Source. Field Survey, 2019)

3.2 Available Medical Facilities

A complete Non-structural Vulnerability assessment required identification of all medical facilities; field observation listed all of the medical facility equipment of lalmonir sadar hospital as follow; with their quantity.

Table 1. Available Medical Facilities (Source. Field Survey, 2019)

S.N.	Name of Equipment	Quantity	S.N.	Name of Equipment	Quantity
1	Anesthesia machine & ventilator	5	30	Osmometers	1
2	Autoclave	7	31	Ovens	2
3	Automatic cell counter	1	32	Oxygen concentrator	1
4	Bilirubin meter	1	33	Nebulizer	7
5	Biochemical analyzer	1	34	Oxygen cylinders	41
6	Blood bank freezer	2	35	Pavilion lamp	2
7	Boilers	2	36	Power generator	2
			37	Pulmonary function analyzer	1
8	Centrifuge	3	38	Pulse oxymeter	1
9	Culture incubator	1	39	Respirators	5
10	Dialysis unit	1	40	Shelves	23
11	Dryers	3	41	Sterile and non-sterile material storage	4
12	Electrical photometer	1	42	Suction machine and pumps	9
13	Electrocardiogram monitor	2	43	Transformer	1
14	Electro diathermy	3	44	Ultrasound	3
15	Electro stimulator	2	45	Urine analyzer	1
16	ELISA analyzer	1	46	Vital signs monitors	2
17	Emergency power generator	2	47	Water pump system	3
18	Sterilizer	8	48	Water tanks	9
19	Flame photometer	1	49	X-ray equipment	4
20	Hemodialysis machines	1	50	Equipment trolley	14
21	Image intensifier	1	51	Fridge for Dead body	1
22	Incubator	10	52	Non-wheeler Patient bed	43
23	Nitrogen Cylinder	36	53	Wheeler Patient bed	25
24	OT Lamp	6	54	Cupboard	22
25	Laparoscopy equipment	1	55	Revolving chair	15
26	Micro centrifuge	1	56	Dental Table	1
27	Microscopes	3	57	Water Filter	4
28	Miscellaneous equipment	13	58	X-ray View board	5
29	Operating table	6			

3.3 Assessed Architectural Elements

As the hospital established in 1981 and the building renewed in 2006 the Architectural Elements poses a little risk compared to other system. About 100 sq. feet's of total glass paneled partition found. 60 sq. feet of them are required modification.

Figure 3. Medical Facilities (Anesthesia, Operating Room and Incubator) and Architectural Elements (Laminated glass panel in pediatric ward), Source. Field Survey, 2019

4 Performance Analysis of Existing System

The major three elements of the non-structural components of the hospital were surveyed. By comparing them with WHO guideline following vulnerability of those system calculated.

4.1 Availability of Resilience of lifeline system

Table 2. Vulnerable system, Source. Field Survey, 2019

System	No. of system	Percentage of Vulnerable system	Percentage of Safe System
Emergency Exit System	4	0%	100%
Fire System	4	0%	100%
Electricity System	3	67%	33%
Water Supply System	2	50%	50%
Medical Gas Supply System	0	0%	0%
Communication System	2	50%	50%
Lifeline System	-	60%	40%
Medical Equipment	377	79%	24%
Architectural Element and Glass Panel	10	38%	62%

5 Mitigation Options

All fifteen of mitigation options stated in the WHO guideline are useful to increase systems performance. After conducting field survey 10 of the options are found usable among 15 of total to reduce vulnerability of the hospital.

Table 3. Vulnerability Mitigation Count

No.	Mitigation Option Name	Recommended	Total Number
1.	Removal	**Yes**	16
2.	Relocation	**Yes**	9
3.	Restricted Mobility for Certain Objects	**Yes**	32
4.	Anchorage	**Yes**	66
5.	Hooking	**Yes**	44
6.	Strapping	**Yes**	48
7.	Flexible couplings	**Yes**	27
8.	Supports	No	0
9.	Substitution	No	0
10.	Modification	**Yes**	6
11.	Reinforcement	No	0
12.	Redundancy	No	0
13.	Rapid Response and Repair	No	0
14.	Improving Safety of Operation Theatres	**Yes**	14
15.	Development of Chaining System on Beds	**Yes**	25

5.1 Vulnerability Mitigation Count

The following figure 4 shows the mitigation options stated in the WHO guideline to increase systems performance and here are the total mitigation option for the hospital nonstructural elements.

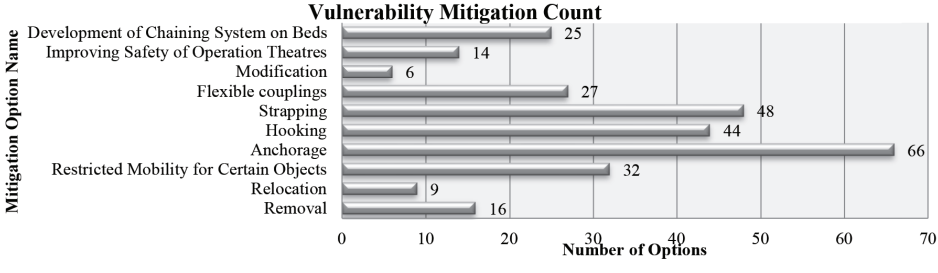

Figure 4. Vulnerability Mitigation Option Counts (Source. Field Survey, 2019)

6 Social Awareness and Emergency Evacuation Preparedness Analysis for Hospital

The awareness condition of the hospital users and the employees are done through a scoring system. There are five variables under the emergency evacuation preparedness and the awareness condition in a hospital. They are:

- Earthquake risk awareness

- Emergency evacuation knowledge
- Provision for elderly/disabled
- Vulnerability of nonstructural elements
- Self-protection ability

Each variable has five sub variables under it. The negative and positive responses of the sub variables are coded from 0 -1. The mean values of each sub-variable describe the condition of each sub-variable. The sum of sub-variable mean scores show the condition of each variable.

6.1 Earthquake risk awareness

The earthquake risk awareness variable has five sub-variables. The highest score of 0.8 belongs to the sub-variable earthquake probability in the area/hospital. Have earthquake safety plan have the lowest score of 0.14. The total score is 1.92 out of 5.

Table 4. Earthquake Risk Awareness of the Hospital Users, Source. Field Survey, 2019

Earthquake Risk Awareness of the Hospital Users	Mean	Total Score (out of 5)
Earthquake probability in the area/hospital	0.8	1.92
Taken steps to increase earthquake knowledge	0.18	
Hospital is safe for earthquake	0.48	
Have earthquake safety plan	0.14	
Safety measures taken by Hospital	0.32	

6.2 Emergency evacuation knowledge

Under this variable, the lowest scoring sub variable is 'Participation in earthquake drills', with score of 0.23. 'Post-earthquake meeting place' sub-variables have the highest score of 0.92. The total score is 2.54 out of 5.

Table 5. Emergency evacuation knowledge of the responders, Source. Field Survey, 2019

Emergency evacuation knowledge of the responders	Mean	Total Score (out of 5)
Know the quick route out of hospital	0.78	2.54
Post-earthquake meeting place	0.92	
Participation in earthquake drills	0.23	
Know earthquake emergency evacuation procedure	0.34	
Know the number of emergency services	0.27	

6.3 Provision for elderly/disabled

The sub-variables under Provision for elderly/disabled variable have poor scores to them. Among them, the highest scoring sub-variable is 'Assistive devices for elderly/ disabled at hospital' with a score of 0.72. The lowest scoring sub-variable is 'Training for the elderly/disabled for emergency evacuation' with score of 0.04. The total score is 1.16.

Table 6. Provision for elderly/disabled, Source. Field Survey, 2019

Provision for elderly/disabled	Mean	Total Score (out of 5)
Nonstructural provision for evacuation of elderly/disabled from hospital	0.12	1.16
Access to vehicles for evacuation of elderly/disabled	0.17	
Training for the elderly/disabled for emergency evacuation	0.04	
Assistive devices for elderly/ disabled at hospital	0.72	
Training of caregivers for elderly/ disabled for emergency evacuation	0.11	

6.4 Vulnerability of nonstructural Elements

In case of vulnerability of nonstructural elements, 'Concerned about the Anchorage, Hooking and Strapping for safeness of medical equipment's' got the lowest score of 0.02. The total score is 0.89.

Table 7. Vulnerability of structures, Source. Field Survey, 2019

Vulnerability of Nonstructural Elements	Mean	Total Score (out of 5)
Concerned about safety due to nonstructural elements of the hospital	0.12	0.89
Concerned about Removal and Relocation system for safety of medical equipment's	0.08	
Accessibility of the safety elements as like as firefighting system	0.51	
Concerned about the Anchorage, Hooking and Strapping for safeness of medical equipment's	0.02	
Knowledge and concerned about Supports and Modification of nonstructural elements of hospital for earthquake safety	0.16	

6.5 Self-protection ability

The self-protection ability variable has the Highest scoring is 'Formal savings for general purposes', with score of 0.68. Total score is 1.42 out of 5.

Table 8. Self-protection ability, Source. Field Survey, 2019

Self-protection ability	Mean	Total Score
Savings for emergencies	0.32	1.42
Bring safety instruments to hospital for emergency	0.02	
Health Insurance	0.06	
Formal savings for general purposes	0.68	
Ability to shift another hospital	0.34	

6.6 Total social awareness and Emergency Evacuation Preparedness Score

The continuous values derived from the sub-variables under 5 variables of emergency evacuation preparedness factors is compounded into a total score which has the range of 25. The final score out of 25 is 7.93 which indicate low level of social awareness of the hospital users for the earthquake preparedness.

Table 9. Total Score of Social Awareness and Emergency Evacuation Preparedness Factors

Emergency Evacuation Preparedness Factors	Score
Earthquake Risk Awareness of the Hospital Users	1.92
Emergency evacuation knowledge	2.54
Provision for elderly/disabled	1.16
Vulnerability of Nonstructural Elements	0.89
Self-protection ability	1.42
	Total: 7.93 (out of 25)

7 Recommendation about mitigation options on Non-structural vulnerability resilience

7.1 Removal, Relocation, Restricted Mobility for Certain Objects, Anchorage, Hooking, Strapping, Supports, Modification and Safety of Operation Theatres

Removal is probably the best mitigation option in many cases. Relocation would reduce the danger in many cases. For example, a very heavy object on top of a shelf could fall and seriously injure someone as well as break thereby causing economic losses. Restricted mobility for certain objects such as gas cylinders and power generators is a good measure. Anchorage is the most widely used precaution. It is a good idea to use bolts, cables or other materials to prevent valuable or large components from falling or sliding. Development of a proper hooking system using chains and hooks can protect medical equipment and can decrease the impact hazard during use and storage respectively. To mitigate the risk the medical elements can easily be secured by using strapping, thus preventing chemical bottles and medicine stored on the shelves from falling

down. Supports are suitable in many cases. For example, ceilings are usually hung from cables that only withstand the force of gravity. Modification is a possible solution for an object that represents a seismic hazard. For example, earth movements twist and distort a building possibly causing the rigid glass in the windows to shatter and launch sharp glass splinters onto the occupants and the passers-by around the hospital. The OT system should have a number of chains, straps, hooks and guide bars in the rack for fixing and securely placing the equipment in the rack [4].

Figure 5. Mitigation technique for Removal, Relocation, Restricted Mobility, Anchorage, Hooking, Modification and Safety of Operation Theatres, Source. Field Survey, 2019 and [4]

8 Conclusion

Non-structural earthquake vulnerability assessment is a small part huge system to combat earthquake disaster. The goal of this study is to assess functionality of the facility and to assess the social awareness to increse the level of awareness in the earthquake situation. According to the guideline of the WHO this gradual process be obtained by all the hospitals of the country

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