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RISK ASSESSMENT OF ACCIDENTAL FIRE BREAKDOWN: A STUDY ON AN URBAN AREA, KHULNA CITY CORPORATION

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ABSTRACT

The aim of the project is to determine the risk of fire hazard in a specific portion of Khalishpur area, Khulna. The residential areas close to the three oil depots and two power stations are considered to be the most vulnerable and the deliverable of this project is to assess the risk of these settlements at different distances from the risky land-uses. At present, the number of accidents due to fire are rising year to year at a very ascending rate which is a huge threat for the urban environment. Not only in Bangladesh but fire hazard is now a concern for all the nations across the globe. According to the World Disaster Report, about 1 billion people are residents of urban area over the world and are yet the most vulnerable towards disasters as cyclones, earthquakes, fire, flood, crime, industrial accidents and many more. Considering the fact that maintaining land use zonal variance is completely absent in Ward no. 07 of Khulna City Corporation, is the selected areas for conducting the study. The study area is of 0.404sq. km, having a population of 18,000.To determine the risk of the residents of the area, a sample size of 20 households were taken and then for primary data source questionnaire for the local residents were prepared including the factors to be considered to assess the risk. After that the field survey was conducted for data collection and also consulted some local political influencers for more supporting data. Also distance from the depot, distance from the power station, distance from the hospital and fire service station these data were collected by field survey. Other secondary data such as population, ward boundary area were collected from website of KCC and some from BBS. To analyze the data to get the expected outcome AHP method was used. Five sub factors considered for hazard were distance from depot, smoker by habit, electric connection status, cooking system and distance from power station. Six sub factors considered for vulnerability were Building type, surrounding land-use, Fire station distance, hospital, Building Storied and Fire Management System. And for Elements of risk 4 sub factors considered are population size, population distribution, health condition and monetary property value. Using the AHP method the weightage to the sub components were identified. And finally using the Risk Function, the risk status of the 20 sample buildings was determined. It is found that 25% of the buildings are at low risk, 55% of them are at medium and 20% of the buildings are at an extreme risky condition. After assessing the risk of the buildings the coordinates of the building were used to point those out in the map produced using ArcGIS 10.5. There will be 3 risk levels (Low, Moderate and High) for the building and will be displayed by 3 different shapes. Finally a map was generated showing the position of the buildings and its risk statues using different points of different shape on the map.

Keywords: *Accidental fire breakdown, Land use zonal variances, Analytical hierarchy process and focus group discussion.*

1. INTRODUCTION

At this edge of 21st century, urbanization has accelerated to such a rapid pace. About 1 billion people are residents of urban area over the world and are yet the most vulnerable towards disasters as cyclones, earthquakes, fire, flood, crime, industrial accidents and many more (Disaster Report 2013, 2014). According to the world disaster report, 2010, flood, earthquakes, cyclones are categorized as urban disaster whereas fire hazard or explosions are more of a technological hazard (International Federation of Red Cross and Red Crescent Societies, 2016). Talking about Bangladesh, in recent years Bangladesh has faced several massive fire and explosion hazards and has very poor management quality to meet the necessary qualification to prevent the hazards. A statistics state that on an average 53 fire accidents were occured daily in Bangladesh in the year 2018 (Hossain, 2019). Among the cities of Bangladesh, Dhaka faced 2334, Chittagong faced 1735 and Khulna faced 1041 occurrences in the same year (Disaster Report 2013, 2014). In a study it is found that most of the accidental firebreakdowns arise in Bangladesh due to unplanned development of urban areas, lack of fire management system and the amount of losses heightened because of ineffectiveness of mitigation measurs like narrow roads, absence or narrow emergency exits point, inadequate number of fire stations etc (Islam & Hossain, 2018). An accident was triggered by the explosion of electric tranformer and was then fanned due to thr explosive liquids that are stored nearby in in the Nimtali area of Old Dhaka in 2010. This incident was named as Nimtali Tragedy and results in the death of 117 local residents and injury of more than 100 people (Imam, 2010).

Oil depots are the store house to a lot of flammable petroleum products. By chance the fuel and air comes in contact or stored fuel gets ignited somehow there is a high possibility that in may turn to a huge fire explosion. Also while regular maintenance like cleaning or nearby activities like cooking, welding, industries etc. these might be a reason to accidentally trigger a fire explosion causing great casualties, heavy environmental pollution and massive economic losses as well. . For the past few years, a series of large fire and explosion accidents were happened in oil depots all the world around, such as the Buncefield oil depot explosion in London (Zhou et al., 2016). In December 2005 an accident was occur in Buncefield, 40 km northwest of London, which caused a drastic disruption in the environment as well as in the economy. This accident cause resettlement of about 2000 people, reconstruction of about 29 km of road, relocation of nearby businesses, pollution of groundwater and many other environmental impacts (Atkinson, 2014).

Khulna City being the heart of the south-western part of the country and due to the recent communication development with the south west, rapid pace in urbanization in Khulna city is being seen in recent years. Therefore, the risk of fire hazard is increasing day by day. The way to reduce such risk is to assess the vulnerability of areas with heavy industries, oil depots, densely populated areas etc. In this study, Analytical Hierarchy Process (AHP) is used to weight the factors considered responsible to trigger a fire hazard and Geographic Information System (GIS) is used to overlay those and generate a map showing the radius of area under risk due to the presence of the fire risk factor.The Analytic Hierarchy Process (AHP) is widely used by decision makers and researchers. The definition of criteria and the calculation of their weight are central in this method to assess the alternatives. However, there are few studies that focus on them (FSM Russo & Camanho, 2015).
This study is conducted in Khalishpur, Khulna as there are presence of oil depots and also residential and commercial mixed land-use at a very low distance making them the most vulnerable group. As a whole the study is conducted to determine the risk under which currently the residents of ward no. 07 and 08 are in due to not maintaining the land use zonal variance and still growing residence beside such a risky land use zone.

2. METHODOLOGY

The project focuses at risk assessment for fire hazard in word no 7. At first the risk function was studied and then the sub factors and element under the main factors were fixed.

2.1 Study Area

At a present scenario Khulna is the third largest city in Bangladesh and one of the largest economic hub of the country, therefore fire hazard assessment to be able take necessary measures is un avoidably important. Khulna has faced a total of 190 massive fire incidents from years 2014-2017. In 2014 there were 29 incidents. In 2015 it was 27, in 2016 it was 67 and in 2017 it was 69, which shows the fire hazard is occurrence rate is increasing at an alarming rate (Bangladesh Fire Service and Civil Defense Authority, 2018). Due to mixed and unplanned land-use, the study area selected is Ward no 7 of Khulna city, having 3 massive oil depots and 1 power station just adjacent to residential area. A 225MW power station close to an oil depot, a simple shot circuit fire will be able to create a massive disaster.The study area is of 0.404sq. Km (Source: Khulna City Corporation), having a population of 18,000 (Bangladesh Bureau of Statistics, 2001).Figure:1 represents the map of the study area.

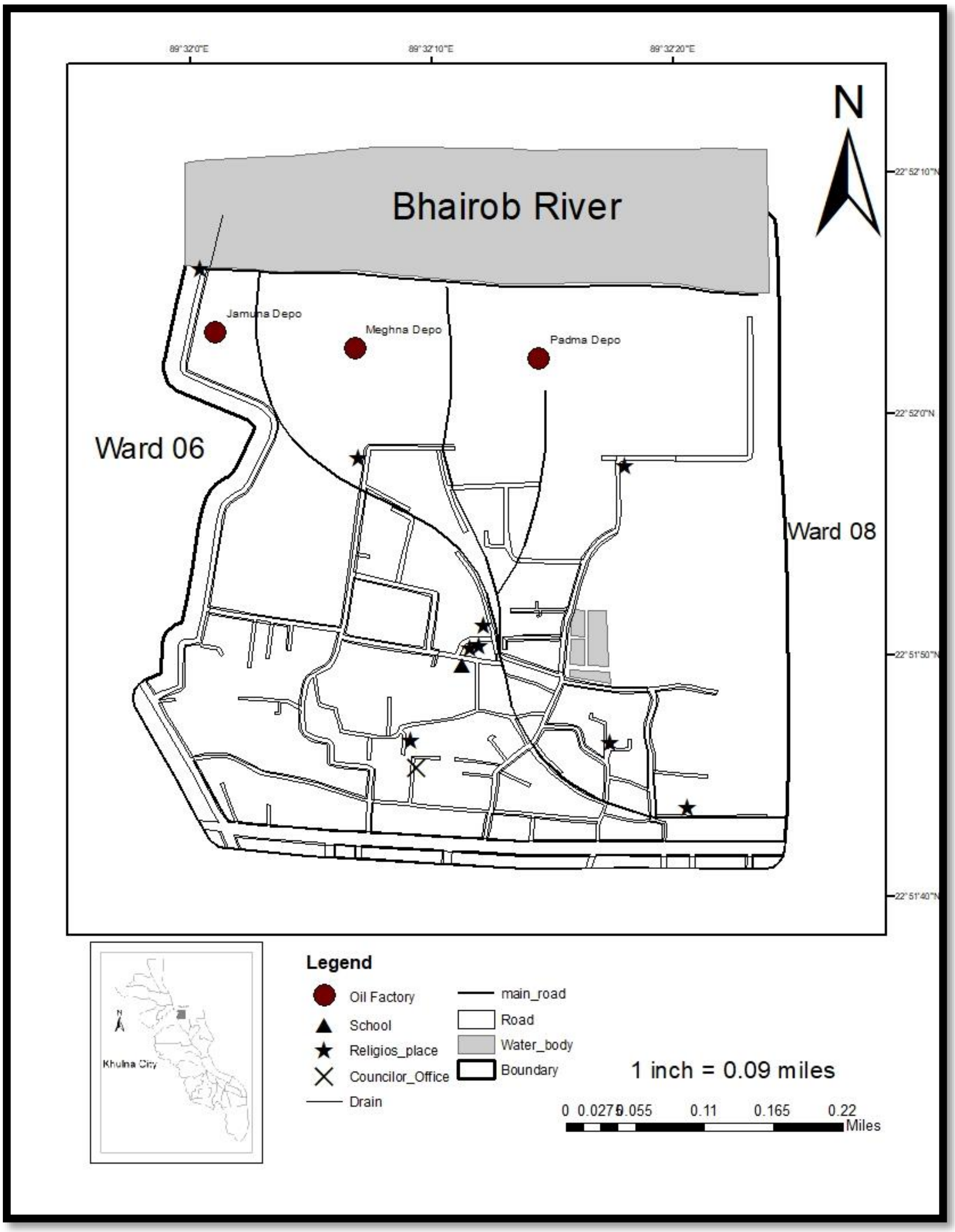

Figure 1: Landuse Map of the Study Area

(Source: Author, 2019)

2.2 Study Design

For data collection primary/ field survey was the main process of data collection. In field data collection two parts were performed

- Questionnaire survey and focus group discussion
- GPS coordinate marking.

Questionnaire survey was prformed at 20 building of different land uses. The local residents were asked about the factors about fire hazard as well as warned to be cautious.Also secondary data were collected from KCC and the population from BBS. The local councilor were interviewed as key in formant. These are the secondary data sources.

The analysis of the collected data are performed in two steps to finally display the output in a map. The main process to be followed, to determine the weightage and in this is were AHP is used to assess risk.

In this case AHP method is used for weighing the factors. Pairwise comparisons are made between the components as well as between the sub-components and the relative importance between each pair of decision alternatives and criteria is rated. Normalization Pair wise comparison matrix are then calculated for the components and each of the sub-components.

$$\text{Normalize Value} = \frac{\text{Column Value of Pairwise Matrix}}{\text{Column Sum of Pairwise Matrix}}$$

From those matrix criteria of the components and sub-components are calculated by using the given formula.

$$\text{Criteria Weight} = \frac{\text{Rowsum of Normalize Matrix}}{\text{No. of Component}}$$

The final step is consistency check to determine the consistency of the calculated weight (FSM Russo & Camanho, 2015).

After the determination of risk status of the buildings, with the help of ArcGIS 10.5 the buildings will be pointed out with points on the map. According to the risk status the color code for the determination of buildings at the highest and lowest possibilities.

3. ANALYSIS AND FINDINGS

Land use Zonal Variance is a major concern especially for risky land-uses adjacent to other regular land-uses. The study area consisting of 3 oil depots which stores massive amount of petroleum and also manual handling within the study area increases the risk of hazard. On the other hand the power points located right next to the petroleum depots are on 225MW capacity which adds to the risk to trigger an explosion.

3.1 Hazard Index

Five components are selected for hazard index.

- Distance from depot
- Smoker by habit
- Electric connection status
- Cooking system
- Distance from power station.

Sub-components of status of electric connection are legal connection and illegal connection and the sub-components of cooking system are electric cooker, Stove, LPG and pyre. Using the Analytical Hierarchy Process the weight of each of the components and sub-components are determined. Table 1 shows the weight of each components and sub-components.

Table 1: Weights of Component and sub-component of hazard index

Component	**Sub-component**	**Weight**	
		Sub-component	**Component**
Distance from Depot	0-0.375	0.1	0.421
	0.376-0.75	0.2	
	0.751-1.125	0.3	
	1.125-1.5	0.4	
Distance from power station	0-0.5	0.1	0.244
	0.51-1	0.2	
	1.01-1.5	0.3	
	1.51-2	0.4	
Cooking System	Stove	0.095	0.080
	LPG	0.307	
	Electric Cooker	0.040	
	Pyre	0.557	
No. of Smoker	1	0.3	0.044
	2 or more	0.7	
Electrical Connection	Legal Connection	0.3	0.211
	Illegal Connection	0.7	

Source: Author, 2019

Finally the hazard index of a building is calculated by using the given formula.

$$\text{Hazard Index} = \sum_{n=1}^{20} \text{Weight of sub component} * \text{Weight of component}$$

Then the fire hazard index is classified into three categories, low (0.140-0.220), medium (0.220-0.300) and high (0.301-0.380). According to this classification, 25% buildings are at low level, 35% are at medium level and 40% are at highly hazardous.

3.2 Vulnerability Index

Six components are selected for vulnerability index.

- Building type,
- Surrounding land-use,
- Fire station distance,
- Distance of hospital,
- Building storied
- Fire Management System.

Sub-components of building type are "pucca", "semi-pucca" and "katcha", the sub-components of surrounding landuse are residential building, commercial area, industrial area and vacant land and the sub component of fire management system are fire exist, fire extinguisher, both and none. Using the Analytical Hierarchy Process the weight of each of the components and sub-components are determined. Table 2 shows the weight of each component and sub-component of vulnerablity index.

Table 2: Weights of Component and sub-component of vulnerability index

Component	Sub component	Weight	
		Sub-component	Component
Building Type	Pucca	0.2	0.351
	Semi-pucca	0.3	
	Katcha	0.5	
No. of Building Storied	1	0.1	0.067
	2-4	0.3	
	5 or more	0.6	
Distance From Fire Station	4-4.5	0.2	0.102
	4.51-5	0.3	
	5.01-5.5	0.5	
Surrounding Landuse	Residential Area	0.218	0.205
	Commercial Area	0.109	
	Industrial Area	0.051	
	Vacant	0.622	
Distance from hospital	2-2.5	0.4	0.046
	2.51-3	0.6	
Fire management System	Not Present	0.5	0.229
	Fire Exist	0.2	
	Fire Extinguisher	0.2	
	Both	0.1	

Source: Author, 2019

Finally the vulnerability index of a building is calculated by using the given formula.

$$\text{Vulnerability Index} = \sum_{n=1}^{20} \text{Weight of sub component} * \text{Weight of component}$$

Then the vulnerability index is classified into three categories, low (0.15-0.233), medium (0.234-0.317) and high (0.318-0.4). According to this classification, 15% buildings are at low level, 60% are at medium level and 25% are at highly vulnerable to fire risk.

3.3 Element at Risk Index

Four components are selected for risk element index.

- Population size
- Population distribution
- Health condition
- Monetary property value.

Sub-components of population distribution are children, elderly and women and the sub-components of health condition are fit, problem in movement and incapable to move. Using the Analytical Hierarchy Process the weight of each of the components and sub-components are determined. 25% buildings are at low level, 35% are at medium level and 40% are at high level. Table 3 shows the weight of each of the component and sub component of element at risk index.

Table 3: Weights of Component and sub-component of risk element index

Component	Sub component	Weight	
		Sub-component	Component
Total Population	0-6	0.1	0.490
	7-12	0.2	
	13-18	0.3	
	19-24	0.4	
Population Distribution	1-2	0.1	0.182
	3-4	0.2	
	5-6	0.3	
	6 or more	0.4	
Health Condition	Fit	0	0.253
	Problem in movement	0.3	
	Incapable to move	0.7	
Property Value	0-1	0.1	0.074
	1-2	0.2	
	2.1-5	0.3	
	5.1 or more	0.4	

Source: Author, 2019

Finally the element at index of a building is calculated by using the given formula.

$$\text{Element at risk index} = \sum_{n=1}^{20} \text{Weight of sub component} * \text{Weight of component}$$

Then the element at risk index is classified into three categories, low (0.140-0.220), medium (0.220-0.300) and high (0.301-0.380).

3.4 Risk Index

To determine the risk index of the specified area risk function is mainly used in this study.

$\text{Risk} = \text{Hazard} * \text{Vulnerability} * \text{Elements at risk}$ (UNNOSA, 2019)

Table 4 shows the risk index and risk level of each of the 20 buildings.

Table 4: Risk Level of 20 selected building

Building No.	Building Coordinate	Hazard Index	Vulnerability Index	Risk Element Index	Risk Index	Hazard Level
1	22°52'00.6"N 89°32'07.2"E	0.146	0.297	0.149	0.0065	Low
2	22°51'56.7"N 89°32'07.5"E	0.185	0.283	0.195	0.0102	Moderate
3	22°51'55.6"N 89°31'58.7"E	0.338	0.39	0.187	0.0247	High
4	22°51'53.2"N 89°32'01.0"E	0.234	0.288	0.111	0.0075	Low
5	22°51'47.4"N 89°31'54.8"E	0.242	0.393	0.176	0.0167	Moderate
6	22°51'44.7"N 89°31'56.7"E	0.318	0.185	0.296	0.0174	Moderate

7	22°51'58.3"N 89°31'58.2"E	0.179	0.229	0.213	0.0087	Low
8	22°51'52.8"N 89°31'57.4"E	0.277	0.288	0.149	0.0119	Moderate
Building No.	**Building Coordinate**	**Hazard Index**	**Vulnerability Index**	**Risk Element Index**	**Risk Index**	**Hazard Level**
9	22°51'51.6"N 89°32'06.2"E	0.197	0.31	0.307	0.0187	Moderate
10	22°51'57.0"N 89°32'07.9"E	0.168	0.286	0.119	0.0057	Low
11	22°51'57.4"N 89°32'05.0"E	0.252	0.229	0.195	0.0113	Moderate
12	22°51'51.3"N 89°32'10.3"E	0.297	0.253	0.119	0.0089	Low
13	22°51'47.6"N 89°32'12.6"E	0.263	0.266	0.244	0.0171	Moderate
14	22°51'45.8"N 89°32'09.7"E	0.318	0.253	0.205	0.0165	Moderate
15	22°51'48.2"N 89°32'13.1"E	0.361	0.32	0.303	0.0350	High
16	22°51'58.5"N 89°32'15.8"E	0.336	0.273	0.213	0.0195	Moderate
17	22°51'52.7"N 89°32'25.0"E	0.266	0.307	0.195	0.0159	Moderate
18	22°51'44.9"N 89°32'18.4"E	0.378	0.253	0.327	0.0313	High
19	22°51'47.7"N 89°32'11.4"E	0.309	0.276	0.182	0.0155	Moderate
20	22°51'47.8"N 89°32'07.8"E	0.309	0.319	0.28	0.0276	High

Source: Author, 2019

From the analysis of the collected data the final output showed that 25% of the buildings are at low risk, 55% of them are at medium and 20% of the buildings are at a extreme risky condition.
Table 5 shows the classification of risk index.

Tabel 5: Classification of Risk Index

Risk Score Range	Risk Level	Number of Buildings	Parcentage
0-0.01	Low	5	25
0.0101-0.02	Moderate	11	55
Above 0.02	Extremly Risky	4	20

Source: Author,2019

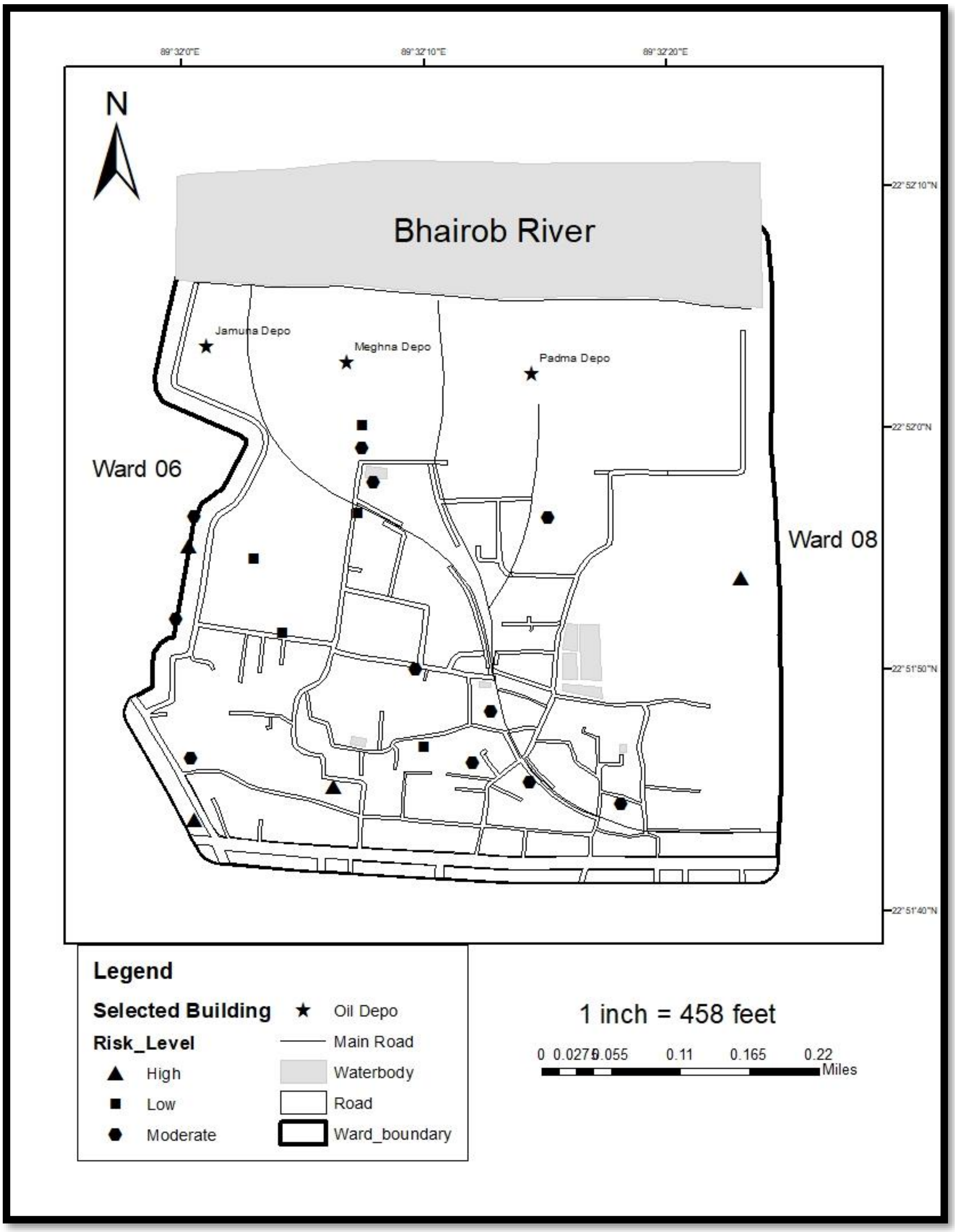

Figure 2: Fire Risk Level of 20 selected Building
(Source: Author, 2019)

4. CONCLUSIONS

The study was focused on determining the risk of the general land-uses next to the risky land-uses in Ward no. 7 of Khulna City. Basically the objective was to display the ignorance towards maintaining the land-use zonal variance. The building located in the study area are under huge risk of fire hazard due to 3 oil depots and 2 power stations in the area. The oil depots creates a huge risk of masive fire explotion wherease the power stations add to the risk.

The factors considered for the fire hazard and risk determination were calculated by AHP method providing specific score and then weightage to the factors. Then finally using the risk function the risk for 20 selected buidings were calculated. Then using the GPS coordinates of the buildings they were pointed out in a map generated with ArcGIS 10.5 to show the current status. The result shows that

- Classifying the building according to the hazard index, 25% buildings are at low level of hazard, 35% are at medium level and 40% are at highly hazardous. The main reason behind this is the ignorance land use zonal variance and lack of concerns about fire hazards.
- Vulnerability index leads to categorizing the buildings into 3 levels of vulnerability, 15% buildings are at low level, 60% are at medium level and 25% are at highly vulnerable to fire risk arising due to lack of governance towards policy formulation and its proper application. Absence of urban planning prior to the development of the area worsens the condition.
- For element at risk 25% buildings are at low level, 35% are at medium level and 40% are at high level. Due to the high population density and most of the people living there are well-off the monetary value of the property at risk are quite high.
- The final output showed that 25% of the buildings are at low risk, 55% of them are at medium and 20% of the buildings are at an extreme risky condition.

As the area is a well established and already developed as a mixed landuse, it is not possible overtime to change or relocate the landuses. Therefore to reduce the risk of fire hazard the precautions and preparedness are the only measures. For precaution the depots and power stations should assure strict rules to avoid triggering a fire hazard and should also have that preparedness to address a fire hazard at a primary stage. The local people needs to be enlightened about the risk and their current vulnerable situation and trained them about their roles and reactions during an accidental fire breakdown.

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