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Journal of Integrated Disaster Risk Management

Original paper

# Earthquake and Fire Hazard Risk Perception: A Study on the Emerging Rangpur City of Bangladesh

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**Abstract** Rangpur city is one of the emerging cities in Bangladesh. In 2012, this city upgraded from municipality to city corporation. On the one hand, the city population started to increase; on the other hand, vulnerability to earthquake and fire hazards are increased due to rapid urbanization. Therefore, we investigate the risk perception of earthquake and fire hazards in Rangpur. The purpose of this study is fourfold: (i) to assess the risk perception of earthquake hazards and fire hazards at the household level; (ii) to investigate the influence of demographic and socio-economic factors on the risk perception of each hazard; (iii) to investigate the preparedness for earthquake and fire hazards; and (iv) to propose planning guidelines and policy interventions for the disaster resilience of the Rangpur city focusing on earthquake and fire hazards. We conducted a questionnaire survey with 558 participants and 9 semi-structured interviews in fifteen electoral wards in Rangpur city. Afterward, we analyzed the data in SPSS and ArcMap platforms. The study results show that socio-demographic indicators such as gender, household ownership type, and residential floor are likely to influence citizens' risk perception. We also find that the spatial distribution of risk perception of both hazards is diversified at the electoral ward level. At the same time, we observe that the level of preparedness for both hazards is not satisfactory. Based on the study findings, we recommend a few planning guidelines and policy interventions for disaster resilience in Rangpur city.

**Keywords:** Risk perception, earthquake hazard, fire hazard, disaster resilience, Bangladesh

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## 1. INTRODUCTION

Risk perception is connected with people's willingness to take precautionary actions, and knowing the citizens' perception could guide the government and related organizations to formulate risk reduction policies (Fernandez, Tun, Okazaki, Zaw, & Kyaw 2018). Apart from that, people take actions according to their priorities and objectives (Norton, Atun, & Dandoulaki 2015). The success of disaster risk management policies and interventions depends on the level of disaster risk perception and knowledge of the matter at the household level.

There is a paradox that increased risk perception is not always connected to protective measures because numerous contextual factors could influence risk perception, such as the ability to recall past damages and trust in public and related authorities. (Wachinger, Renn, Begg, & Kuhlicke 2013). Still, people should understand the risk associated with different hazards to take preparedness measures against potential hazards. Moreover, assessing risk perception in a multi-hazard environment is essential in identifying vulnerable individuals' reality with respect to a particular hazard because distinct hazard characteristics influence risk perception (Sullivan-Wiley & Gianotti 2017).

Psychometric theory and cultural theory are considered the primary theories that can explain risk perception (Shrestha, Sliuzas, & Kuffer 2018). Appleby-Arnold, Brockdor, Jakovljev, & Zdravković (2018, p.38) argued - *"both living in a disaster-prone area and previous experience of disasters have been found to affect disaster risk perception, but they do not directly translate into an increase of perceived future risks"*. However, socio-demographic characteristics, such as age, gender, ethnicity, socio-economic status, etc., influence risk perception of numerous hazards (Appleby-Arnold et al. 2018; Fernandez et al. 2018).

It is considered that high population growth could intensify the multi-hazard environment (Sullivan-Wiley & Gianotti, 2017); thus, the growing cities of Bangladesh are likely exposed to the multi-hazard environment (LGED 2014; RpCC 2019). Therefore, this study investigates the risk perception of earthquake and fire hazards at the household level.

Bangladesh is an Asian country, ranking fifth among the world's disaster-prone countries (Rahman, Ansary, & Islam 2015). Notably, in Asia, around half of the deaths and disaster-related damage occurred by earthquakes compared to all natural disasters in the last decades (Kung & Chen 2012), and Bangladesh is at high risk of a severe earthquake (Rahman et al. 2015). Like many other Bangladeshi cities, Rangpur city does not encounter regular flooding, but this city is vulnerable to earthquakes.

Rangpur city is one of the emerging cities in Bangladesh. In 2012, this city upgraded from municipality to city corporation. Consequently, the city population started to proliferate; in 2012, the total population was 584,448, and in 2017 it was 796,556 (RpCC 2019). At the same time, Bangladesh is divided into three seismic zones (zone 1, 2 & 3), and Rangpur city is located on the borderline of seismic zone-1 and zone-2 (Ali 1998; Paul & Bhuiyan 2010; Rahman 2020). Moreover, Rangpur city was the epicenter in some past major earthquakes (Ali 1998).

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Apart from earthquake risk, the cities in Bangladesh often face devastating fire accidents, causing many deaths each year (Burke & Hammadi 2012; Jones 2010; Safi 2019). Considering the above facts, we planned to carry out this study by selecting 15 electoral wards from the Rangpur City Corporation (RpCC) area (Figure 1). According to our knowledge, this study is the first one that uncovers the fire and earthquake risk perception in Rangpur city. The findings from this study could be helpful for government authorities in formulating planning guidelines and policies. At the same time, the study could be a baseline study for the cities with similar social, cultural, and physical characteristics.

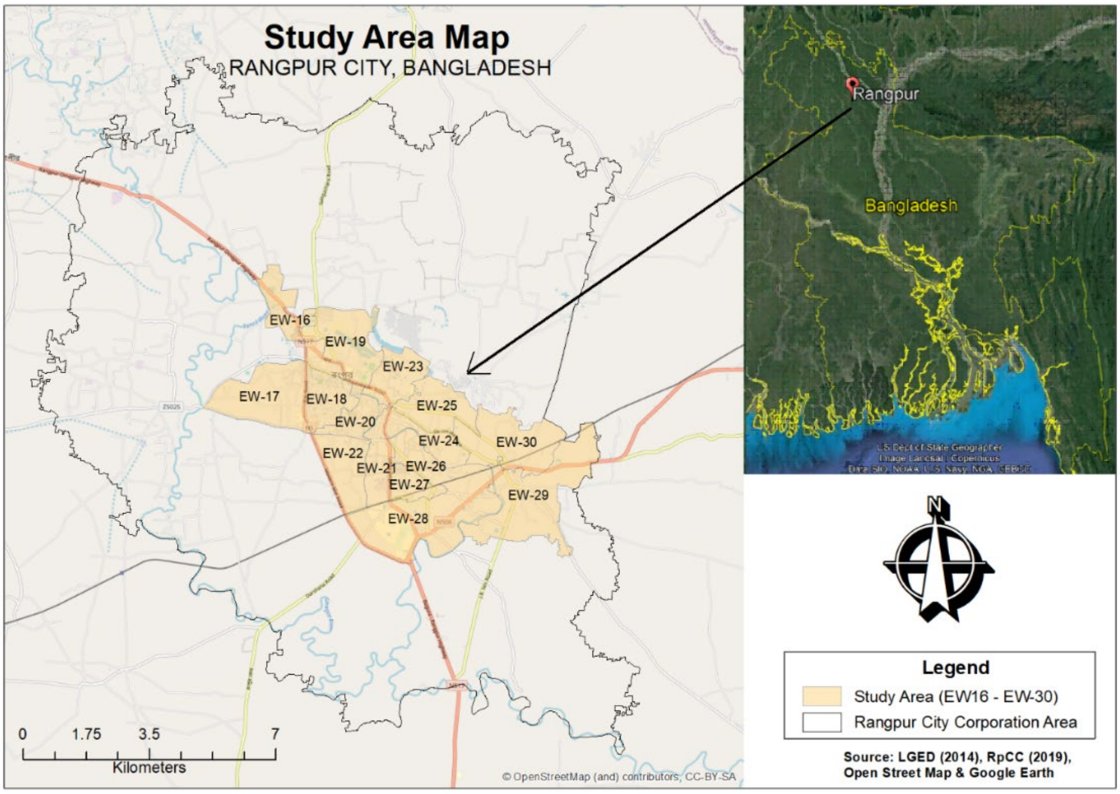


**Figure 1.** Study area map (Source: LGED, 2014; RpCC, 2019; Open Street Map, 2000 & Google Earth, 2020)

The objectives of this study are (i) to assess the risk perception of earthquake hazard and fire hazards at the household level; (ii) to investigate the influence of demographic and socio-economic factors on the risk perception of each hazard; (iii) to investigate the preparedness for earthquake and fire hazards; and (iv) to propose planning guidelines and policy interventions for the disaster resilience in the Rangpur city focusing on earthquake and fire hazards.

# 2. DATA AND METHODS

## 2.1 Sources of data

A mixed-method approach (qualitative and quantitative) was adopted to carry out this research. The quantitative aspect of this research includes collecting and statistical analysis of risk perception data and analysis of risk perception dynamics at the electoral ward level. The qualitative approach includes the semi-structured interview with key persons; this helped us understand the results from quantitative analysis and formulate planning guidelines and recommendations.

Thus, we collected primary and secondary data from 15 electoral wards (EW16-EW30) in Rangpur city; primary data were collected from direct field surveys and semi-structured interviews. 558 participants have participated in the questionnaire survey, and 382 samples from the survey were considered for final analysis. We eliminated one hundred ninety-eight samples because the survey duration of those samples was less than eight minutes which seems less reliable for further analysis.

**Table 1.** List of interviewees and interview duration

| Key persons for the semi-structured interview | Interviewee Code |
|---|---|
| One of the professors of the Department of Disaster Management, Begum Rokeya University, Rangpur (BRUR) | I-1 |
| One of the professors of the Department of Geography and Environmental Science, BRUR | I-2 |
| One of the officials of Disaster Management E-learning Center, BRUR | I-3 |
| One of the officials of Fire Service and Civil Defence, Rangpur | I-4 |
| One of the officials Rangpur City Corporation (RpCC) | I-5 |
| One of the professors of the Faculty of Life and Earth Sciences, BRUR | I-6 |
| One of the social activists, Rangpur | I-7 |
| One of the ward commissioners, RpCC | I-8 |
| One of the ward commissioners, RpCC | I-9 |

Data from the questionnaire survey provided socio-demographic and risk perception information. At the same time, we conducted 9 semi-structured interviews with key people (Table 1). Apart from the primary data, secondary data (shapefiles) provided the administrative boundaries at different scales (national, district, city corporation, and electoral ward).

## 2.2 Risk Perception Index (RPI)

To assess the risk perception on earthquake and fire hazards, we adapted a few questions (Table 2 & Table 3) from the available literature on earthquake and fire hazard risk perception (Chan *et al.* 2018; Kung & Chen 2012; Paul & Bhuiyan 2010; Shrestha *et al.* 2018). Two different Risk Perception Indices (RPI) were used to calculate earthquake risk perception (Equation 1) and fire risk perception (Equation 2); both equations were adapted from (Rahman 2020).

**Table 2.** Indicators, interview questions, and assigned values of earthquake risk perception

| Question Number | Indicator | Interview Question | Scale | Assigned Perception Value | Type | |
|---|---|---|---|---|---|---|
| 1 | Witness of the previous incident | Did you witness or experience an earthquake? | No<br>Yes | 0<br>1 | Perception | Risk Perception |
| 2 | Future possibility | Do you agree that a severe earthquake may hit your living place? | Strongly disagree<br>Disagree<br>Neutral<br>Agree<br>Strongly Agree | 0<br>0.25<br>0.50<br>0.75<br>1 | | |
| 3 | Effect on personal life and family | Do you agree that the earthquake will affect you and your family? | Strongly disagree<br>Disagree<br>Neutral<br>Agree<br>Strongly Agree | 0<br>0.25<br>0.50<br>0.75<br>1 | | |
| 4 | Perceived risk of property damage | Do you agree that the earthquake may result in damage to your property? | Strongly disagree<br>Disagree<br>Neutral<br>Agree<br>Strongly Agree | 0<br>0.25<br>0.50<br>0.75<br>1 | | |
| 5 | Perceived risk of death | Do you agree that the earthquake may result in death and injury? | Strongly disagree<br>Disagree<br>Neutral<br>Agree<br>Strongly Agree | 0<br>0.25<br>0.50<br>0.75<br>1 | | |
| 6 | Fearfulness | How fearful are you about a possible earthquake? | Not fearful<br>Little fearful<br>Moderate fearful<br>Highly fearful | 0<br>0.33<br>0.66<br>1 | | |
| 7 | Prior arrangement of first aid and emergency kits | Do you have any first aid kits or any emergency kits to face earthquake occurrence? | No<br>Yes | 0<br>1 | Preparedness | |
| 8 | Presence of emergency exit | Do you have any emergency exits for such type of situation? | No<br>Yes | 0<br>1 | | |

**Table 3.** Indicators, interview questions, and assigned values of fire risk perception

| Question Number | Indicator | Interview Question | Scale | Assigned Perception Value | Type | |
|---|---|---|---|---|---|---|
| 1 | Witness of the previous incident | Did you witness or experience any fire accidents? | Yes<br>No | 1<br>0 | Perception | Risk Perception |
| 2 | Anticipation of fire risk | What is the level of risk of fire at your house? | No Risk<br>Low Risk<br>Medium Risk<br>High Risk<br>Very High Risk | 0<br>0.25<br>0.50<br>0.75<br>1 | | |
| 3 | Anticipation of fire risk from cooker/stove | Do you think the fire can occur from the cooker/stove at your home? | Yes<br>Maybe<br>No | 1<br>0.50<br>0 | | |
| 4 | Level of sincerity | Do you go somewhere else or do other jobs while cooking? | Frequently<br>Often<br>Occasionally<br>Very Rare<br>Never | 0<br>0.25<br>0.50<br>0.75<br>1 | | |
| 5 | Anticipation of fire risk from short circuit | Do you think an electric short circuit can cause fire at your home? | Yes<br>Maybe<br>No | 1<br>0.50<br>0 | | |
| 6 | Alertness | Do you use multiplug at your home? | No<br>Yes | 1<br>0 | | |
| 7 | Safety information | Do you know where the electric main switch of your house is? | Yes<br>No | 1<br>0 | | |
| 8 | Level of alertness | How frequently do you check the condition/status of your stove/cooker? | Never<br>Once a year<br>Once a month<br>Once a Week<br>Everyday | 0<br>0.25<br>0.50<br>0.75<br>1 | Preparedness | |
| 9 | Level of alertness | How frequently do you check the electricity line of your house? | Never<br>Once a year<br>Once a month<br>Once a Week<br>Everyday | 0<br>0.25<br>0.50<br>0.75<br>1 | | |
| 10 | Availability of smoke detector | Do you have a smoke detector and/or fire alarm at your home? | Yes<br>No | 1<br>0 | | |
| 11 | Availability of fire extinguisher | Do you have a fire extinguisher (e.g., fireball, fire blanket, etc.) at your home? | Yes<br>No | 1<br>0 | | |
| 12 | Practical knowledge and skill | Have you ever participated in any fire drills? | Yes<br>No | 1<br>0 | | |

$$\text{Earthquake } RPI = \frac{P1+P2+\ldots\ldots+Pn}{n} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(Equation 1)}$$

Here,

$RPI$ = Risk perception index

$P_1, P_2, \ldots\ldots\ldots P_{in}$ = scores derived from the question/statement

$n$ = number of questions/statements

**Figure 2.** Equation 1: Earthquake Risk Perception Index (Rahman 2020).

$$\text{Fire } RPI = \frac{P1+P2+\ldots\ldots+Pn}{n} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(Equation 2)}$$

Here,

$RPI$ = Risk perception index

$P_1, P_2, \ldots\ldots\ldots P_{in}$ = scores derived from the question/statement

$n$ = number of questions/statements

**Figure 3.** Equation 2: Earthquake Risk Perception Index (Rahman 2020).

### 2.3 Data analysis

Statistical methods were employed to analyze the data. Descriptive analysis was carried out to understand the respondent's anticipation/opinion on different aspects of earthquake and fire hazards. Box and whisker plots were also used to investigate the influence of demographic and socio-economic factors on each hazard's risk perception. Correlation analysis and t-test were carried out to validate the relationship between socio-demographic factors and the hazard's risk perception.

## 3. RESULTS

### 3.1 Earthquake risk perception (ERP)

#### 3.1.1 Respondent's anticipation/opinion on different aspects of earthquake hazard

Respondent's anticipations/opinions on various aspects of earthquake hazard are shown in Table 4. The first question was related to the experience of previous earthquake events. 99% of respondents have experienced at least one earthquake. Among the respondents, only 3% strongly disagreed that a severe earthquake may hit their living place. On the other hand, 48% of the respondents agreed or strongly agreed about the possibility of the occurrence. Similarly, more than 50% of respondents agreed or strongly agreed that a possible earthquake could affect them and their family members; however, 7% of respondents disagreed or strongly disagreed in this regard.

**Table 4.** Respondent's anticipation/opinion on different aspects of earthquake hazard

| Questions | Opinion/anticipation | Respondents | |
|---|---|---|---|
| | | Number (*n*) | Percentage (%) |
| Did you witness or experience an earthquake? | Yes | 380 | 99 |
| | No | 2 | 1 |
| Do you agree that a severe earthquake may hit your living place? | Strongly disagree | 10 | 3 |
| | Disagree | 42 | 11 |
| | Neutral | 147 | 38 |
| | Agree | 128 | 34 |
| | Strongly Agree | 55 | 14 |
| Do you agree that an earthquake could affect you and your family? | Strongly disagree | 3 | 1 |
| | Disagree | 23 | 6 |
| | Neutral | 123 | 32 |
| | Agree | 126 | 33 |
| | Strongly Agree | 107 | 28 |
| Do you agree that an earthquake may result in damage to your property? | Strongly disagree | 2 | 1 |
| | Disagree | 12 | 3 |
| | Neutral | 115 | 30 |
| | Agree | 126 | 33 |
| | Strongly Agree | 127 | 33 |
| Do you agree that an earthquake may result in death and injury? | Strongly disagree | 1 | 0 |
| | Disagree | 20 | 5 |
| | Neutral | 101 | 26 |
| | Agree | 120 | 31 |
| | Strongly Agree | 140 | 37 |
| How fearful are you about a possible earthquake? | Not fearful | 58 | 15 |
| | Little fearful | 188 | 49 |
| | Moderate fearful | 75 | 20 |
| | Highly fearful | 61 | 16 |

Source: Fieldwork (January 2020)

### 3.1.2 Analysis of earthquake risk perception by socio-demographic factors

This section analyses how risk perception of earthquake hazards changes with different socio-demographic factors. Figure 4 and 'Appendix' show the changing nature of earthquake risk perception with the variation of socio-demographic factors.

**Earthquake risk perception by gender**

The risk perception of earthquake hazards slightly varies with gender. Female respondents have a higher risk perception than male respondents (Figure 4A). The women's median risk

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perception value is 0.70, while the median value is 0.66 for the men. The interquartile range is also higher for women. The t-test also shows that women have higher ERP than men ($p = 0.007$).

**Earthquake risk perception by age group**

The ERP value also changes within the different age groups. However, the changing pattern is not linear, and the '*p*' value for the ANOVA test is 0.952, which is not statistically significant. Respondents between 18-24 years old had the highest ERP value (mean value is 0.67, and the median value is 0.70), while the elderly (59 years+) has the lowest ERP (median, 0.65). However, the lowest ERP median value (0.67) was calculated in the second age group (Figure 4B).

**Earthquake risk perception by education level**

The education level did not show significant changes in the ERP ('*p*' value from ANOVA is 0.595). However, respondents with a bachelor's or higher degree showed higher risk perception based on the median ERP value (0.70) (Figure 4C).

**Earthquake risk perception by profession**

Statistically significant diverse ERPs were observed among the professional group (ANOVA shows that $p < 0.01$). The housewives and government service holders had the highest ERP (median values are 0.72 and 0.71, respectively). On the other hand, daily wage earners had the lowest ERP (median value is 0.56). However, farmers had the lowest ERP based on the mean value (0.59), while the mean ERP value for the daily wage earners was 0.60 (Figure 4D).

**Earthquake risk perception by monthly household income**

Figure 4E shows that the lower-income group had a lower ERP score, and the higher-income group had a higher ERP score ('*p*' value from ANOVA is 0.004). However, the fourth income group (30001-40000 in BDT) did not follow the risk perception trend of other income groups. This group has a lower ERP than the first two income groups.

**Earthquake risk perception by household type**

In general, the ERP by household type reveals that the better the household construction type, the higher the ERP (Figure 4F). The 'Jhupri'[3] houses had the highest ERP value based on both mean and median values. The reason behind this result could be the outlier and the low number of samples ($n$=11) of 'Jhupri.' After eliminating the outlier, 'Jhupri' shared the highest ERP with 'Pucca'[1] house (based on the mean value that is 0.68).

**Earthquake risk perception by a household storey**

Figure 4G shows that multi-storey households likely have slightly higher earthquake risk perception than single-storey households. The mean and median ERP values of single-storey households are 0.66 and 0.67, respectively. On the other hand, both the mean and median ERP value of multi-storey households are 0.68. However, the t-test did not find any significant relation with the ERP ($p = 0.294$).

[3] Jhupri (shacks); made of jute sticks, tree leaves, jute sacks etc. Pucca (permanent, life span over 25 years); will walls of bricks and roofs of concrete." (Source: https://en.banglapedia.org/index.php?title=Housing)

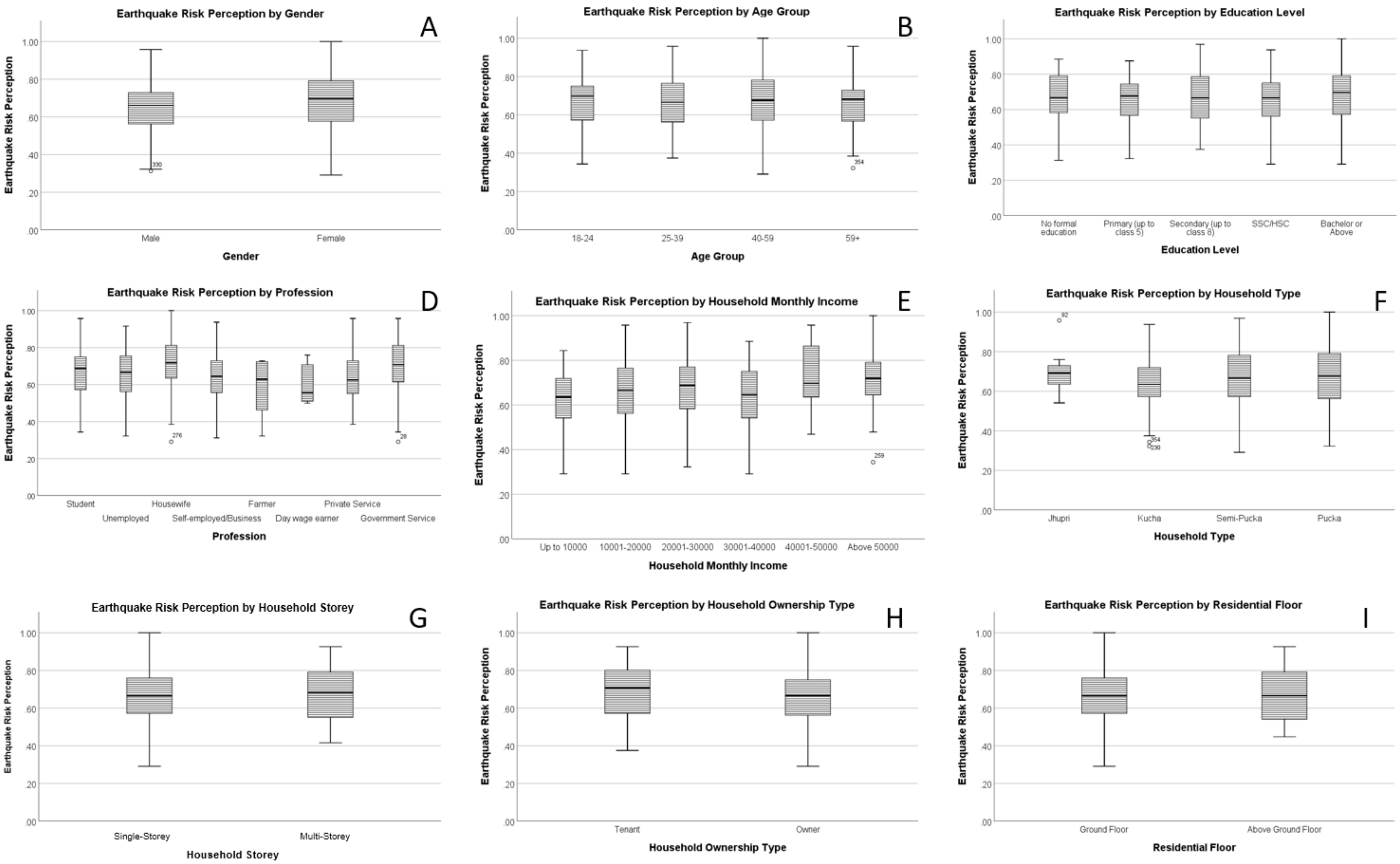


**Figure 4.** Earthquake risk perception and socio-demographic factors

**Earthquake risk perception by household ownership type**

It was observed that the tenants have higher ERP than the house owners. The median ERP value of tenants is 0.71, where the median ERP value of house owners is 0.67 (Figure 4H). Besides, the t-test also showed that the tenants have a higher risk perception of earthquake hazards than the house owners ($p = 0.027$).

**Earthquake risk perception by residential floor**

The residential floor had no significant impact on the ERP (based on the median value). T-test also failed to show significant relations ($p = 0.699$). However, ground floor residents' mean ERP value is lower than the respondents living above the ground floor (Figure 4I).

### 3.1.3 Earthquake risk perception dynamics at electoral ward level

Table 5 shows the earthquake risk perception dynamics at the electoral ward (EW) level. EW-20 has the highest earthquake risk perception, and the risk perception score is 0.77. On the other hand, EW-18 has the lowest risk perception of earthquake hazard; the risk perception score is 0.56.

**Table 5.** Earthquake risk perception at electoral ward level

| Electoral Ward Number | Earthquake Risk Perception Score | Rank (high to low risk perception) |
|---|---|---|
| EW-20 | 0.7711 | 1 |
| EW-23 | 0.7708 | 2 |
| EW-16 | 0.7320 | 3 |
| EW-27 | 0.7189 | 4 |
| EW-30 | 0.7064 | 5 |
| EW-17 | 0.6818 | 6 |
| EW-21 | 0.6747 | 7 |
| EW-28 | 0.6557 | 8 |
| EW-19 | 0.6524 | 9 |
| EW-25 | 0.6434 | 10 |
| EW-26 | 0.6242 | 11 |
| EW-22 | 0.6105 | 12 |
| EW-29 | 0.5980 | 13 |
| EW-24 | 0.5930 | 14 |
| EW-18 | 0.5606 | 15 |

### 3.1.4 Preparedness on earthquake hazard at the household and electoral ward level

Figure 5 shows overall preparedness for earthquake hazards in RpCC. 47% of respondents have an emergency first-aid kit at home (Figure 5A). At the same time, 59% of households have an emergency exit. No household has an emergency kit in the most vulnerable area, EW-18. Moreover, households of EW-18 have the least percentage of emergency exits (Figure 5B). On the other hand, 89% of households of EW-20 have an emergency first-aid kit, and 84% of households of EW-16 have an emergency exit. It is worth mentioning again that 99% of the respondents have experienced an earthquake.

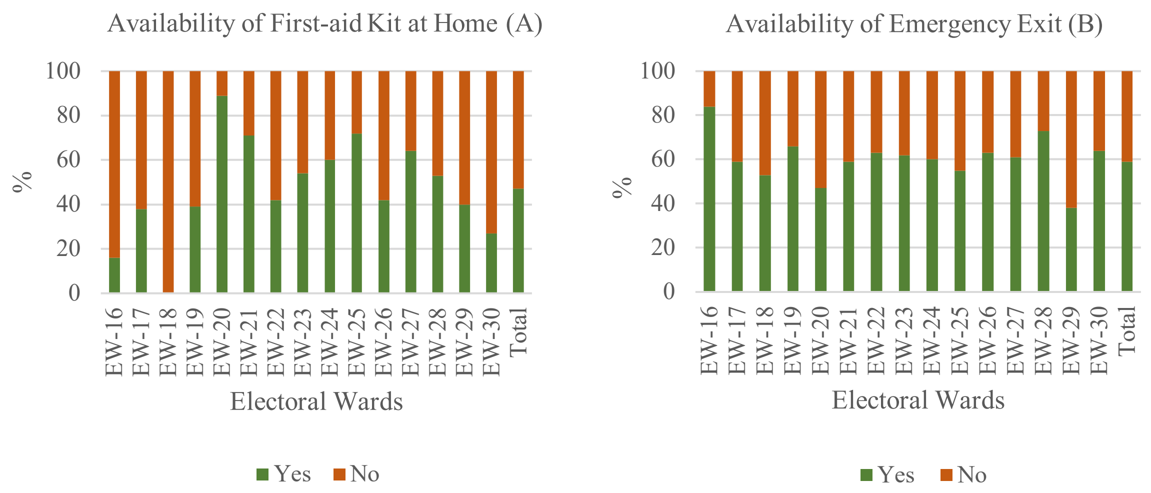


**Figure 5.** Availability of first-aid kit at home (A) and availability of emergency exit at home (B).

### 3.2 Fire risk perception (FRP)

### 3.2.1 Respondent's anticipation/opinion on different aspects of earthquake hazard

Respondent's anticipations/opinions on different aspects of fire hazard are shown in Table 6. Among 382 respondents, 81% of respondents witnessed/experienced the fire hazard. 70% of respondents anticipated that fire risk is less likely to affect their households. On the other hand, only 6% of respondents think there is a high and very high risk of fire affecting their household.

More than half of the surveyed population (53%) assume that fire can occur from the household's cooker or stove, while 15% responded as 'no', and 31% replied as 'maybe'. Among the respondents, 16% never leave the kitchen until the cooking is finished and the cooker is switched off. However, a large number of respondents (43%) replied that they frequently or often leave the kitchen during cooking activities to attend to another task.

A relatively large number of respondents (60%) agreed that a short-circuit or electric disturbance might result in a fire at home. In comparison, 30% of the respondents said ‘maybe’ an electric short-circuit could be the cause of fire at home and, 10% denied the possibility.

However, 93% of respondents knew the location of the electric main switch, which could be switched off during such an event. Besides, 68% of households use multiplug to connect their electric appliances though electric short-circuit could occur.

**Table 6.** Respondent's anticipation/opinion on different aspects of fire hazard

| Question | Opinion/ anticipation | Respondents | |
|---|---|---|---|
| | | Number ($n$) | Percentage (%) |
| Did you witness or experienced any fire accidents? | Yes | 309 | 81 |
| | No | 73 | 19 |
| What is the level of risk of fire at your house? | No Risk | 104 | 27 |
| | Low Risk | 164 | 43 |
| | Medium Risk | 93 | 24 |
| | High Risk | 15 | 4 |
| | Very High Risk | 6 | 2 |
| Do you think the fire can occur from the cooker/stove at your home? | Yes | 204 | 53 |
| | Maybe | 120 | 31 |
| | No | 58 | 15 |
| Do you go somewhere else or do other jobs while cooking? | Frequently | 104 | 27 |
| | Often | 62 | 16 |
| | Occasionally | 98 | 26 |
| | Very Rare | 58 | 15 |
| | Never | 60 | 16 |
| Do you think an electric short circuit can cause fire at your home? | Yes | 230 | 60 |
| | Maybe | 116 | 30 |
| | No | 36 | 10 |
| Do you know where the electric main switch of your house is? | Yes | 357 | 93 |
| | No | 25 | 7 |
| Do you use multiplug at your home? | Yes | 260 | 68 |
| | No | 122 | 32 |

Source: Fieldwork (January 2020)

### 3.2.2 Analysis of fire risk perception by socio-demographic factors

In this section, we analyzed how fire risk perception changes with different socio-demographic factors. Figure 6 shows how fire risk perception changes with different socio-demographic factors.

**Fire risk perception by gender**

Figure 6A shows that fire risk perception also varies with gender, as does earthquake risk perception. However, here the observation is opposite to ERP. The median line shows that females have lower risk perception than males. Moreover, the male population's mean FRP value is slightly higher than the female population (0.42 for males and 0.39 for females). The results of the t-test also showed significance ($p = 0.006$).

**Fire risk perception by age group**

The FPR value by age group reveals that the higher the age, the higher the fire risk perception; however, the result is not statistically significant ('*p*' value from ANOVA is 0.061)). The respondents between 18-24 years old have the lowest risk perception of fire hazard, while the respondents with 59+ years of age have the highest risk perception. The younger group's median value is 0.38, and the older group had a 0.44 median value on FRP (Figure 6B).

**Fire risk perception by education level**

Figure 6C shows that the level of education positively influenced the FRP. Respondents with no formal education to secondary education were more likely to have slightly lower risk perception (median FRP 0.40). Respondents with SSC or HSC levels have slightly higher FRP than the previous group (0.42 median FRP value). Consequently, people with a bachelor's or above education had the highest FRP (median FRP value of 0.44). However, the ANOVA does not signify the linearity as the '*p*' value is 0.665.

**Fire risk perception by profession**

Like ERP, the relationship between fire risk perception and profession also has a statistically significant diverse pattern ('*p*' value from ANOVA is 0.003). Farmers, private service holders, and government service holders have the highest FRP (median value 0.46). Day wage earners were likely to have the lowest FRP (median value is 0.35). This time, housewives also have a low-risk perception of fire hazard (median FRP value is 0.38), which is the second-lowest score (Figure 6D).

**Fire risk perception by monthly household income**

Figure 6E shows that the higher income group is likely to have higher FRP. However, the lowest income group (income up to 10000 BDT) does not follow the trend. On the other hand, the highest income group (income more than 50000 BDT) has a higher FRP (median value is 0.46).

**Fire risk perception by household type**

Figure 6F uncovers that jhupri, kucha[4] and semi-pucca[4] houses likely have the same median FRP value (0.4). However, the mean value is different for these three types of houses. Mean FRP values are 0.37, 0.39, and 0.40 of Jhupri, Kucha, and Semi-Pucca, respectively. The Pucca houses have FRP (mean and median values) 0.43 and 0.44, respectively. It can be said that there is a similarity in the pattern of FRP with the household types, considering the mean value.

[4] "Kutcha (temporary); made of mud brick, bamboo, sun-grass, wood and occasionally corrugated iron sheets as roofs. Semi-pucca (semi-permanent); where walls are made partially of bricks, floors are cemented and roofs of corrugated iron sheets" (Source: https://en.banglapedia.org/index.php?title=Housing)

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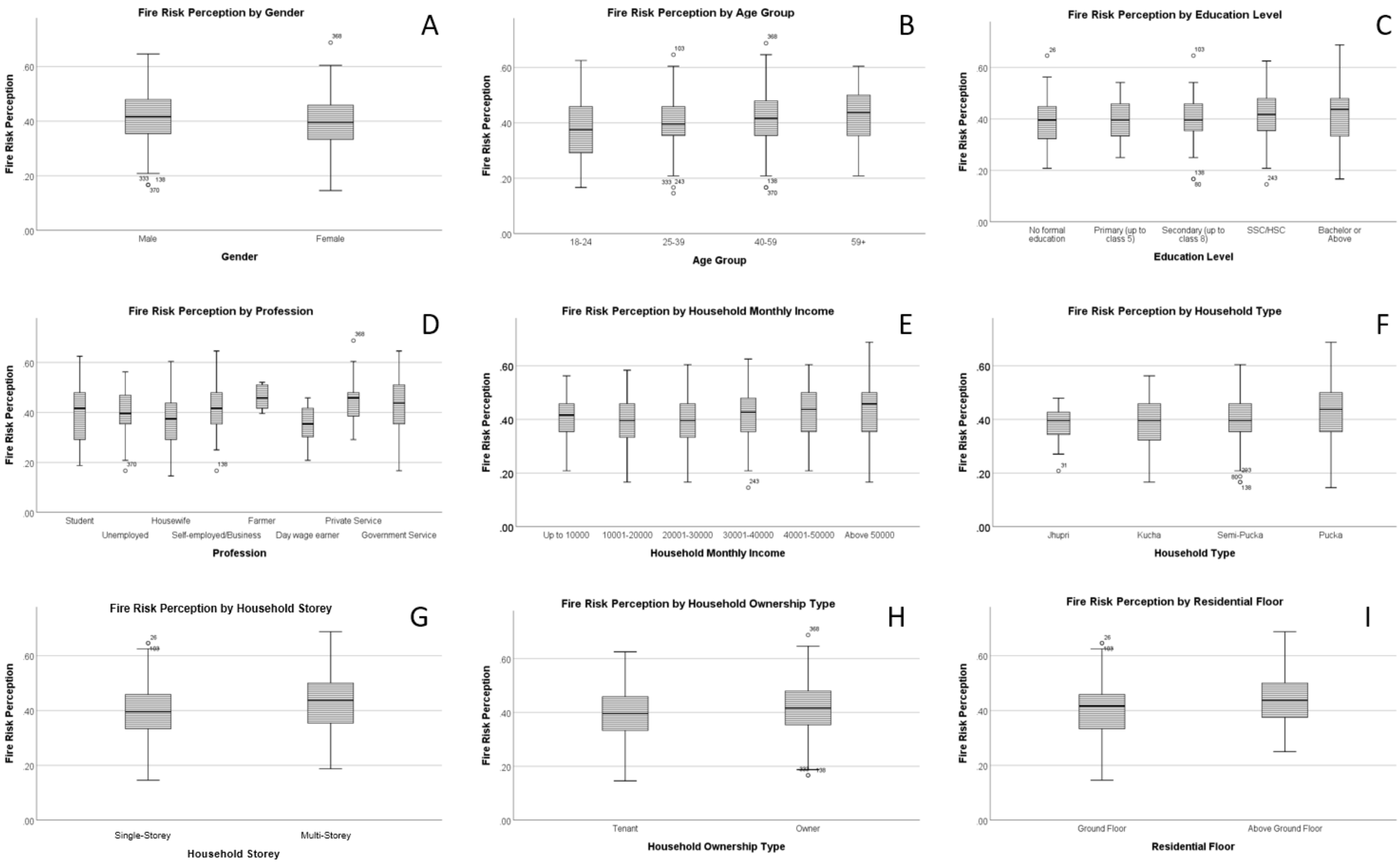


**Figure 6.** Earthquake risk perception and socio-demographic factors

**Fire risk perception by a household storey**

Figure 6G shows that single-storey household has lower risk perception on fire hazard than the multi-storey households. The mean and median FRP values of multi-storey households are 0.43 and 0.44, respectively. On the other hand, the mean and median FRP values of single-storey households are 0.40 and 0.44, respectively. The observed *p*-value from the t-test is 0.11.

**Fire risk perception by household ownership type**

The FRP by household ownership type shows that the house owners have slightly higher FRP than the tenants. The significance ($p = 0.04$) was observed by the t-test when an equal variance is assumed. Here, FRP values of owners and tenants are 0.40 and 0.42, respectively (Figure 6H).

**Fire risk perception by residential floor**

The residential floor showed a trend in FRP (Figure 6I). The ground floor residents have lower FRP (mean is 0.40 and the median is 0.42), where residents from above the ground floor have higher FRP (mean is 0.43 and median is 0.44). The results of the t-test also showed the significance ($p = 0.04$) when an equal variance is assumed.

### 3.2.3 Fire risk perception dynamics at electoral ward level

**Table 7.** Fire risk perception at electoral ward level

| Electoral Ward Number | Fire Risk Perception Score | Rank (high to low-risk perception) |
|---|---|---|
| EW-21 | 0.4424 | 1 |
| EW-16 | 0.4360 | 2 |
| EW-30 | 0.4300 | 3 |
| EW-25 | 0.4283 | 4 |
| EW-18 | 0.4247 | 5 |
| EW-22 | 0.4242 | 6 |
| EW-29 | 0.4215 | 7 |
| EW-26 | 0.4179 | 8 |
| EW-17 | 0.4028 | 9 |
| EW-19 | 0.3942 | 10 |
| EW-27 | 0.3896 | 11 |
| EW-20 | 0.3884 | 12 |
| EW-28 | 0.3663 | 13 |
| EW-23 | 0.3662 | 14 |
| EW-24 | 0.3540 | 15 |

Table 7 shows the fire risk perception dynamics at the electoral ward (EW) level. EW-21 has the highest fire risk perception; the risk perception score is 0.44. On the other hand, EW-24 has the lowest risk perception of a fire hazard; the risk perception score is 0.35.

### 3.2.4 Preparedness on fire hazard at the household and electoral ward level

Figure 7 shows preparedness for earthquake hazards in RpCC at the household level. A total of five questions were asked to understand the preparedness for that hazard. The first question was related to checking the condition of the stove/cooker. According to the survey results, 67% of respondents never check their cooker; they only check if it is broken or not functional (Figure 7A). Moreover, 79% of people have experienced fire hazards; still, they never check their cooker. However, 13% of respondents check the condition of the cooker once a year, and the other 12% check once a month.

On the other hand, 6% of respondents check the cooker once a week, and the other 2% check every day before cooking. Respondents from EW-20 have the highest tendency not to check their cooker. 95% of respondents said they never checked their stove or cooker in this electoral ward, while 5% of respondents check once a year. In contrast, 32% of respondents from EW-22 said they check the stove or cooker at least once a month as a precaution against fire incidents.

Among the respondents, 65% never check their electricity connections until any electric lines/switches are broken; however, around 80% have already experienced fire hazards (Figure 7B). This trend is highest in EW-23; 85% of respondents of this electoral ward never check their electricity connections. 30% of respondents check the electricity line at least once a year. Besides, 4% of respondents check it once a month and 1% once a week. No respondents were found who check the electricity connections every day.

Figure 7C reveals that 80% of the respondents do not have a fire extinguisher at home; the other 20% do have this. From EW-18, 59% of respondents had a fire extinguisher. Besides, fire alarms were only used by the respondents of EW-18 and EW-22 (Figure 7D). 18% of respondents from EW-18 and 11% from EW-22 has a fire alarm at their house. However, considering all the respondents, only 1% had a fire alarm at their house.

The last question related to the preparedness on fire hazards was on fire drill participation. 16% of respondents said they have this experience, while 84% do not (Figure 7E). EW-25 is far more ahead in this regard; 59% of respondents participated in a fire drill. On the other hand, the worst-case was seen in EW-24. No respondents from this electoral ward have ever participated in any fire drills.

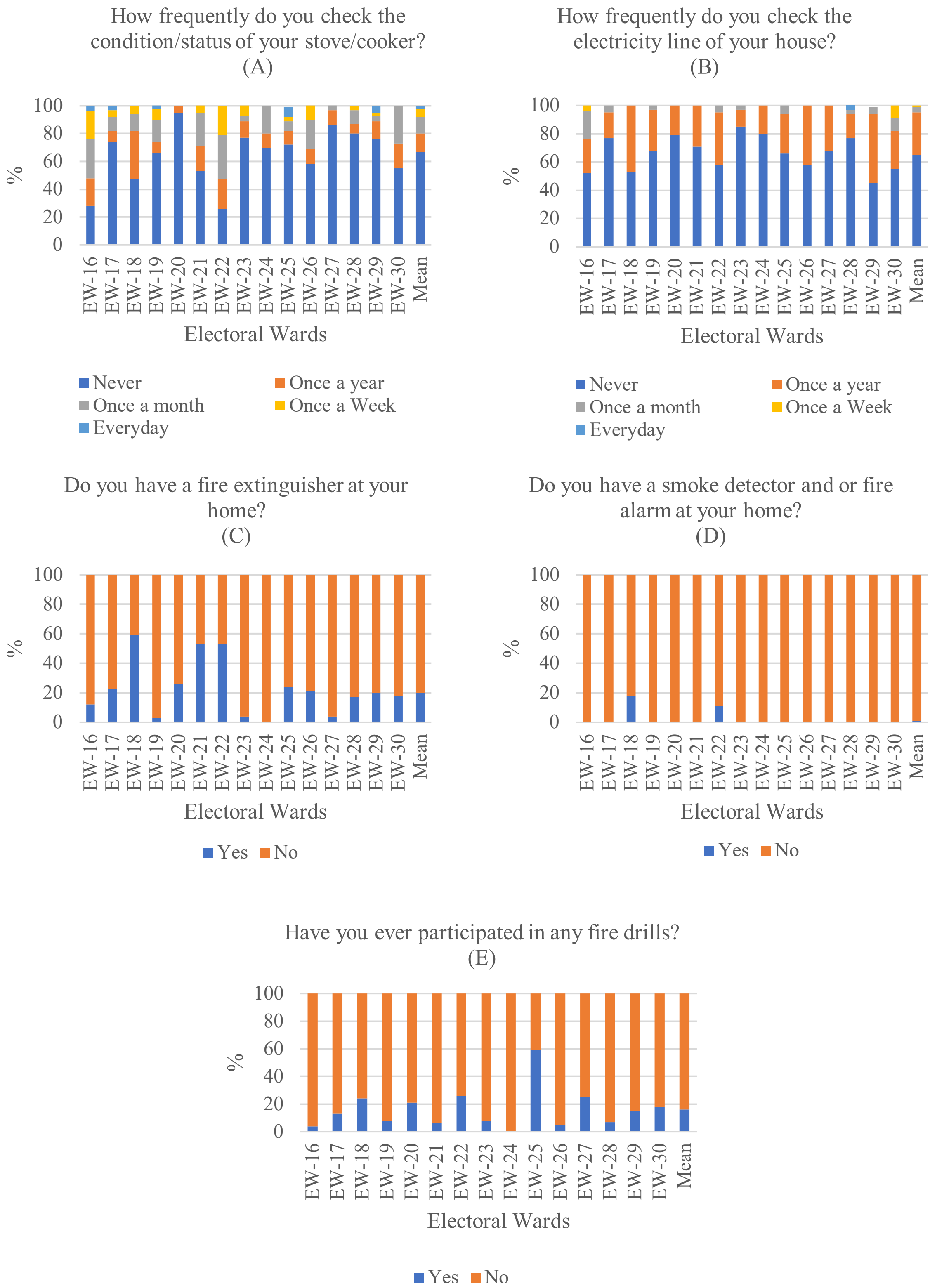


**Figure 7.** Preparedness on fire hazard (A-E)

# 4. DISCUSSIONS

## 4.1 Risk perception analysis

In this study, risk perception analysis is focused on earthquake hazards and fire hazards. We looked at three different aspects of the said hazards. Firstly, how risk perception changes with socio-demographic factors; secondly, how the citizen's perception of hazards is spatially distributed; and finally, how the preparedness level of citizens is spatially distributed.

This study's risk perception analysis suggests that women likely have a slightly higher anticipated risk of earthquake hazard than men. Paul & Bhuiyan (2010) also overserved a similar result for the case of Dhaka City. On the other hand, men likely have a slightly higher anticipated risk of a fire hazard than women. In general, women are more vulnerable than men in any hazard (Rahman et al., 2015) because most Bangladeshi women are unemployed and stay at home most of the time. At the same time, they always try to protect the younger family members, risking their own life during any hazardous events. However, Chan et al. (2018) did not find any statistically significant association between gender and fire risk perception. The field observation reveals that as a family head, men are most likely concerned about financial loss due to any hazards, while women are concerned about the severity of a hazard. Fire hazards could bring more financial loss to men than earthquake hazards, which is why men perceived higher risk in the fire hazard than women.

Risk perception by age group also reveals counterintuitive results. Young people (18-24 years old) have a higher anticipated risk of earthquake hazard than the older age group (59+), while the reverse result was observed for fire risk perception. Experience from the field suggests that the older people have stronger religious beliefs, and they think that an earthquake is 'God's will', and they have nothing to do in this event. As a result, older people anticipated a low risk of earthquake hazards.

Fire risk perception is positively correlated with education level. However, respondents with bachelor's degrees and above were more likely to have a higher perception of earthquake hazard risks. Risk perception by profession also suggests that government employees have higher anticipation than others, which could be due to their higher level of education.

We carried out a correlation analysis to understand the association between socio-demographic variables and risk perception. Four variables were binary variables among the eight socio-demographic factors. Thus, we considered four binary variables for the correlative analysis of risk perception (Table 8). We found from the correlation study that ERP has a very weak positive correlation ($r = 0.139$) with gender. Thus, it seems that the higher the ratio of the female member, the higher the risk perception could be on earthquake hazard. Besides, household ownership type has a very weak negative correlation ($r = -0.113$) with ERP. That means the tenants could likely have slightly higher ERP than the house owners because they are informed about their house's condition and are less likely to fear an earthquake. At the same time, fire risk perception has a statistically significant correlation with all four binary variables. FRP and gender have a weak negative correlation ($r = -0.140$); this correlation means that men have higher FRP than women. Correlation between FRP and the household storey reveals that FRP increases with the residential height/floors. Besides, ownership also has a slightly positive correlation (0.102) with FRP; the house owners have higher FRP because they are afraid of fire hazards because of immediate financial loss. Finally, the residential floor also has a positive correlation ($r = 0.105$) with FRP; the higher the residential floor number, the higher FRP of the residents.

**Table 8.** Pearson correlation matrix of earthquake risk perception and socio-demographic factors

| | Gender | Household Storey | Household Ownership Type | Residential Floor | Earthquake Risk Perception |
|---|---|---|---|---|---|
| Gender | 1 | | | | |
| Household Storey | 0.007 | 1 | | | |
| Household Ownership Type | -0.004 | -.345** | 1 | | |
| Residential Floor | 0.013 | .663** | -.329** | 1 | |
| Earthquake Risk Perception | 0.139** | 0.054 | -0.113* | 0.020 | 1 |
| Fire Risk Perception | -0.140** | 0.129* | 0.102* | 0.105* | 1 |

**. Correlation is significant at the 0.01 level (2-tailed); *. Correlation is significant at the 0.05 level (2-tailed).

The spatial pattern of risk perception is distinct for both hazards due to the variation of socio-demographic factors. The abundance of highly educated people and government employees enhances the risk perception at certain electoral wards; on the other hand, the abundance of low-income groups, elderly people, and 'jhupri' houses causes a low-risk perception in some electoral wards. At the same time, there might be other factors related to this result, such as residential density and population density, which could be addressed in any future research.

### 4.2 Preparedness

We already know that RpCC is in earthquake zone 1 and 2 in Bangladesh. Nearly one million people are living in this city. Thousands of new buildings are in the construction phase. As one of the oldest former municipalities of Bangladesh, the core area of RpCC has hundreds of old buildings as well. Considering those, respondent 'I-1' (Table 1) from the local university warned that:

> "In every hundred years, we face a severe earthquake. The last one was at Assam in 1897. As Rangpur is in earthquake zone 1 and 2, we are in danger. If it occurs, most of the buildings of the city will collapse. So, building codes need to be maintained properly."

Nobody can stop the incidence of an earthquake, but sufficient preparedness measures can reduce the vulnerability to this hazard (Paul & Bhuiyan 2010). Indeed, the overall preparedness on earthquake hazards in RpCC seems insufficient. The earthquake risk perception results show that 53% of the household do not have any emergency kits. That means they need external help for any medical or evacuation supports. Having the first-aid kits at home is also one of the preparedness measures (Paul & Bhuiyan 2010). Let us look at the spatial distribution of the availability of the emergency kit. We can see that EW-18 is most vulnerable (100% of surveyed households do not have an emergency or first-aid kit) and EW-20 is most prepared (89% of surveyed households have an emergency or first-aid kit).

The preparedness results also show that 41% of the surveyed households do not have an emergency exit to evacuate during a fire emergency. In general, a resident's evacuation behaviour during or after an earthquake event changes with the nearby road layout and the knowledge about a place (Shrestha et al., 2018). So, residents from these households will try to escape from the only door to the nearby roads, which could create a chaotic situation at that moment. From the field experience, we were informed that many house owners lock the main entrance during the night. They do not even give the keys to the tenants. So, if an earthquake event occurs at night, the consequence could be more devastating.

Institutional initiatives on earthquake preparedness are not visible so far here in RpCC. However, one of the officials of RpCC (respondent I-5; Table-1) confirmed that they have a contingency plan to deal with a possible severe earthquake. According to the official:

> "We have a contingency plan considering 7-8 scale earthquake. We have used the HAZUS earthquake model to calculate the possible damages. Besides, we have modeled nighttime and daytime scenarios. We have calculated how many people might die and how many people might be injured. Moreover, we have calculated how many buildings could partially or completely collapse. This contingency plan has everything, including healthcare service, evacuation, relief management, security….. everything."

On the other hand, according to field evidence, the preparedness for fire hazards is also not satisfactory. 80% of households do not have a fire extinguisher, and 84% of respondents did not ever participate in a fire drill. Moreover, 99% of the households do not have a smoke detector. Notably, a smoke detector can protect the life of the residents by alerting the residence, and a fire extinguisher can reduce the damage of a residential fire hazard (Stumpf, Knuth, Kietzmann, & Schmidt 2017).

In RpCC, Fire Service and Civil Defence (FSCD), Rangpur plays a significant role in preparing and mitigating fire hazards. Their enthusiasm, hard work, and professionalism seem very high from the field experience and observations. The FSCD has identified several causes of fire hazards in RpCC. One of the officials from FSCD (respondent I-4; Table 1) said:

> "We identified a total of 17/18 reasons behind fire hazard. Among them, the biggest reason is electrical disturbances. In addition, the blast of gas cylinders is another reason. Besides, the use of anti-mosquito coils, throwing of cigarette filters, and the use of poly bags play a great role in the occurrence of fire hazard."

Despite the hard work of the FSCD members, several issues make their efforts more challenging. Considering this, we asked the previous spokesman about the difficulties of FSCD during an event, and he (respondent I-4; Table 1) replied:

> "Firstly, the narrowness of the roads. The fire service team cannot reach the location of the events properly. Traffic jam due to auto-rickshaw also creates a barrier to reach the location. There is a lack of water sources; most sources are filled up for residential or commercial purposes. Especially, the 'Shyamashundari Canal' is almost destroyed. These could play a vital role. We need to set fire hydrants like developed countries; it will be beneficial in the long term to fight the fire. Besides, too many curious people create an extra barrier during a fire accident. It is challenging to control curious people."

He (respondent I-4; Table 1) also emphasized that:

> "More than 250 high-rise buildings (above six floors) are planned for construction and have approval from the city corporation, but we do not have sufficient and suitable equipment supports for those buildings. We need different vehicles (for example, TTI's) to fight at a high-rise building. We are expecting to get those soon from the government."

The above remarks depict that the electrical disturbances, the blast of a gas cylinder, flammable anti-mosquito coils, and cigarette filters are the major causes of fire hazards in the RpCC area. Narrow roads and traffic jams are the main barriers to reach the place of a fire accident. Besides, FSCD faces difficulty obtaining water sources during the fire-fighting because water sources are used for other purposes, and there is an absence of fire hydrants in RpCC. Furthermore, FSCD needs proper equipment to protect more than 250 high-rise buildings in any possible fire events. Besides, FSCD should arrange more fire drills across the city.

### 4.3 Planning guidelines and policy interventions

According to the RpCC master plan, the city corporation should establish City Disaster Management Committee (CDMC) and other supporting standing committees (LGED 2014). These committees should have been formulating provisions for pre-disaster risk mitigation and post-disaster recovery program. Nevertheless, this committee has not been formed yet. After establishing the committee, we suggest that this study's results could be considered for planning and policy interventions to reduce the risk of different hazards based on the local context's need.

Based on the evidence from this study, we suggest that RpCC needs specific planning guidelines and policy interventions to reduce the risk of earthquake and fire hazards. Widening the roads and ensuring accessibility of water availability are critical priority areas of the building bylaws for earthquake and fire safety measures. Though RpCC Master Plan has plans and provisions for wide road and building safety (LGED 2014), neither plans nor provisions are fully functional.

The spatial variation of fire risk perception and preparedness in the electoral wards can assist the authority in initiating area-based awareness programs. The highest priority for awareness campaigns should be given to the EWs with very low-risk perception and preparedness. Apart from that, an emergency exit in every household should be obligatory; it will help the residents to evacuate the residential building quickly in the occurrence of both hazards. Moreover, using a smoke detector and fire extinguisher should be mandatory for every household of RpCC.

We also suggest that preparedness for both hazards needs cooperation and collaboration among citizens and different authorities. The local university could provide academic supports to the respective authorities. Moreover, as a parent organization of the city, the RpCC needs to increase awareness programs significantly.

## 5. KEY FINDINGS, PLANNING GUIDELINES, AND CONCLUSION

Key findings are as follows, based on the results and discussions of the study:

- ❑ Earthquake risk perception (ERP) has significant relations (very weak) with gender and household ownership.
- ❑ Fire risk perception (FRP) has significant relations (very weak) with gender, household storey, and residential floor.
- ❑ Moreover, ERP is higher in women, and FRP is higher in men. Awareness programs could be initiated considering the above facts. At the same time, EW-18 needs much attention to preparedness measures.
- ❑ EW-16 could be a model electoral ward considering both types of risk perception and preparedness.

We also suggest a few planning guidelines and policy interventions for disaster resilience in Rangpur city. They are:

- ❑ Widen roads.
- ❑ Ensure water availability /fire hydrants.
- ❑ Reenforce the building bylaws.
- ❑ Enhance the capacity of the Fire Service and Civil Defence (FSCD) (as 250 high-rise buildings are under construction).
- ❑ Inhibit the construction of high-rise buildings until the FSCD achieves the ability.
- ❑ Ensure mandatory emergency exit, smoke detectors, and fire alarms in every house.

Finally, this study uncovered many aspects of risk perception and preparedness at the household and electoral ward levels. The study results reveal that gender, social status, and economic status influence citizens' risk perception. At the same time, risk perception changes at the electoral ward level as well. The government and concerned authorities should consider these planning and policy formulation issues, emphasizing the city's disaster resilience. However, there were a few limitations to this study. Maintaining an equal ratio for single-storey and multi-storey buildings was not possible during the questionnaire survey due to the accessibility issue. Residents from the upper floors were not reachable due to the lock at the main entrance. Moreover, they do not feel safe opening the gate and answering the questionnaire. Another limitation of this study is that the questions (for risk perception analysis) were formulated based on previous literature. However, there was a little number of literature (Islam & Adri 2008; Ministry of Disaster Management and Relief 2015; Paul & Bhuiyan 2010; Rahman et al. 2015) available in the context of Bangladesh. For future research, we suggest that multiple regression analysis could be carried out to examine the relationships between risk perceptions and socio-demographic attributes for predicting associated risk factors. Moreover, the relationship between the perception of earthquake and fire hazards has not been done in this study. This relationship could be analyzed in future studies composing the correlation analyses in future possibilities, effect on personal life and family, perceived risk of property damage, perceived risk of death, and fearfulness of the earthquake and fire perceptions.

## REFERENCES

Ali, M. H. (1998). *Earthquake Database and Seismic Zonning of Bangladesh. INCEDE Report* (Vol. 11). Bangkok. Retrieved from http://cidbimena.desastres.hn/pdf/eng/doc12294/doc12294-contenido.pdf

Appleby-Arnold, S., Brockdor, N., Jakovljev, I., & Zdravković, S. (2018). Applying cultural values to encourage disaster preparedness: Lessons from a low-hazard country, 31, 37–44. https://doi.org/10.1016/j.ijdrr.2018.04.015

Burke, J., & Hammadi, S. (2012, November 25). Bangladesh textile factory fire leaves more than 100 dead | World news | *The Guardian*. Retrieved September 15, 2019, from https://www.theguardian.com/world/2012/nov/25/bangladesh-textile-factory-fire

Chan, E. Y. Y., Lam, H. C. Y., Chung, P. P. W., Huang, Z., Yung, T. K. C., Ling, K. W. K., … Chiu, C. P. (2018). Risk Perception and Knowledge in Fire Risk Reduction in a Dong Minority Rural Village in China: A Health-EDRM Education Intervention Study. *International Journal of Disaster Risk Science, 9*, 306–318. https://doi.org/10.1007/s13753-018-0181-x

Fernandez, G., Tun, A. M., Okazaki, K., Zaw, S. H., & Kyaw, K. (2018). Factors influencing fire, earthquake, and cyclone risk perception in Yangon, Myanmar. *International Journal of Disaster Risk Reduction*, *28*, 140–149. https://doi.org/10.1016/j.ijdrr.2018.02.028

Islam, M. M., & Adri, N. (2008). Fire Hazard Management of Dhaka City: Addressing Issues Relating to Institutional Capacity and Public Perception. *Jahangirnagar Planning Review*, *6*(6), 57–68.

Jones, A. (2010, January 4). Dhaka fire 2010 kills at least 77, injures 100 | World news | *The Guardian*. Retrieved September 15, 2019, from https://www.theguardian.com/world/2010/jun/04/dhaka-fire-deaths

Kung, Y.-W., & Chen, S.-H. (2012). Perception of Earthquake Risk in Taiwan: Effects of Gender and Past Earthquake Experience. *Risk Analysis*, *32*(9), 1535–1546. https://doi.org/10.1111/j.1539-6924.2011.01760.x

LGED. (2014). *Rangpur City Master Plan: 2014-2033*. Retrieved from https://www.rpcc.gov.bd/city-plan/Rangpur_city_corporation_Master_Plan_Final_Report.pdf

Ministry of Disaster Management and Relief. (2015). *Atlas: Seismic Risk Assessment in Bangladesh for Bogra, Dinajpur, Mymensingh, Rajshahi, Rangpur and Tangail City Corporation / Paurashava Areas, Bangladesh*. (S. M. Haque, Ed.), *ATLAS, Ministry of Disaster Management and Relief*. Retrieved from https://www.undp.org/content/dam/bangladesh/docs/Publications/Pub2016/Seismic%20Risk%20Assessment%20in%20Bangladesh.pdf

Norton, J., Atun, F., & Dandoulaki, M. (2015). Exploring Issues Limiting the Use of Knowledge in Disaster Risk Reduction. *Tema. Journal of Land Use, Mobility and Environment*, (Special Issue ECCA), 135–154. https://doi.org/10.6092/1970-9870/3032

Paul, B. K., & Bhuiyan, R. H. (2010). Urban earthquake hazard: perceived seismic risk and preparedness in Dhaka City, Bangladesh. *Disasters*, *34*(2), 337–359. https://doi.org/10.1111/j.1467-7717.2009.01132.x

Rahman, N., Ansary, M. A., & Islam, I. (2015). GIS based mapping of vulnerability to earthquake and fire hazard in Dhaka city, Bangladesh. *International Journal of Disaster Risk Reduction*, *13*, 291–300. https://doi.org/10.1016/j.ijdrr.2015.07.003

Rahman, M. Z. (2020). Relationship Between Multiple Deprivation and Disaster Risk Perception in Rangpur City, Bangladesh. (Master's thesis, Faculty of Geo-Information Science and Earth Observation, University of Twente, Enschede, Netherlands). Retrieved from http://essay.utwente.nl/85174/

RpCC. (2019). Introduction to Rangpur City Corporation. Retrieved September 15, 2019, from https://rpcc.portal.gov.bd/site/page/0046cdb2-b2a0-499e-b4cf-1c1c0e89a49d

Safi, M. (2019, February 21). Dhaka fire that killed 80 raises questions over chemical stores | World news | *The Guardian*. Retrieved September 15, 2019, from https://www.theguardian.com/world/2019/feb/21/dhaka-fire-more-than-50-die-in-apartments-used-as-chemical-store

Shrestha, S. R., Sliuzas, R., & Kuffer, M. (2018). Open spaces and risk perception in post-earthquake Kathmandu city. *Applied Geography*, *93*, 81–91. https://doi.org/10.1016/j.apgeog.2018.02.016

Stumpf, K., Knuth, D., Kietzmann, D., & Schmidt, S. (2017). Adoption of fire prevention measures – Predictors in a representative German sample. *Safety Science*, *94*, 94–102. https://doi.org/10.1016/j.ssci.2016.12.023

Sullivan-Wiley, K. A. S., & Gianotti, A. G. S. (2017). Risk Perception in a Multi-Hazard Environment. *World Development*, *97*, 138–152. https://doi.org/10.1016/j.worlddev.2017.04.002

Wachinger, G., Renn, O., Begg, C., & Kuhlicke, C. (2013). The risk perception paradox-implications for governance and communication of natural hazards. *Risk Analysis*, *33*(6), 1049–1065. https://doi.org/10.1111/j.1539-6924.2012.01942.x

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# Survey on Post-Disaster Timelines Following a Large-Scale Disaster Expected to Occur in the Near Future for Pre-Disaster Recovery Planning

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**Abstract** The limitation of resources for post-disaster recovery after a large-scale disaster is a global problem. It is difficult to restart all activities simultaneously, so it is critical to determine when diverse social and economic activities should resume, called a post-disaster timeline (PDT). We surveyed PDTs in Aichi Prefecture, which is the most industrialized prefecture in Japan and, therefore, economically important. The results revealed differences in PDTs according to sex, occupation, and reference group (the main group the respondent had in mind when answering questions, such as Japan, Aichi Prefecture, and the disaster-affected area). We estimated PDTs for Aichi Prefecture as a whole and determined what kind of activities are socially acceptable even in the earlier stages of recovery. In pre-disaster recovery planning, it is critical to build consensus by considering the differences in PDTs among different groups of people. Furthermore, when a disaster occurs, PDTs in the disaster-affected prefecture as a whole and the existence of people with different PDTs should be taken into account.

**Keywords:** post-disaster timelines, pre-disaster recovery planning, social norms, economic recovery, consensus building,

## 1. INTRODUCTION

Pre-disaster recovery planning is important for achieving better recovery and reconstruction outcomes, and currently, many areas in Japan are engaged in such efforts. This planning

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involves beginning to plan for recovery during the pre-disaster phase (Otsuyama and Maki 2018). The Japanese government has published guidelines on this practice (Ministry of Land, Infrastructure, Transport and Tourism 2018). However, such guidance focuses mainly on medium- to long-range city planning, not on short- to medium-range activities for recovery. We need to develop another guideline on pre-disaster recovery planning focusing on short- to medium-range activities for recovery.

Citizen participation is also important for recovery and reconstruction efforts(1). After a disaster occurs, collecting public opinions and building consensus often takes a long time which ultimately causes an unbeneficial delay in implementing recovery activities. However, because the recovery process greatly impacts the lives of local residents, it is critical to prepare a means by which their opinions, especially those on short- to medium-range recovery efforts, can be collected and taken into consideration. The guideline on pre-disaster recovery planning focused on short- to medium-range activities for recovery needs to refer to effective ways of citizen participation to create the plan.

Against this backdrop, we have begun to prepare a short- to medium-range pre-disaster recovery plan in our study area(2), Aichi Prefecture, Japan. Aichi Prefecture is at risk of a magnitude 8–9 earthquake along the Nankai megathrust, the fault running under the Nankai Trough off the southeastern coast of Japan (Aichi Prefectural Government 2014). There is a 70%–80% possibility of a Nankai megathrust earthquake in the next 30 years (Ministry of Education, Culture, Sports, Science and Technology 2020), and the study area is at high risk of severe damage from such an event (Aichi Prefectural Government 2014). Aichi Prefecture is an economically important area in Japan because it is home to one of the largest car manufacturing companies in the world and its suppliers(3). Therefore, it is necessary to plan a recovery strategy to realize a quick economic recovery in this area(4). The results of a survey conducted in 2020 of 2,000 people affected by the 2011 Great East Japan Earthquake revealed that only 17.7% of the respondents felt that “the local economy has recovered from the earthquake” (NHK 2020). This result also indicates the importance of a quick and effective economic recovery strategy. It is important to discuss economic recovery in short- to medium-range pre-disaster recovery planning.

In contrast, search and rescue activities, humanitarian logistics, shelter operations, restoration of lifelines, and providing temporary housing are all deemed necessary after a large-scale earthquake. If we know when local people accept activities aimed at economic recovery without public backlash, discussions on pre-disaster recovery planning become easier to promote. This paper uses the term post-disaster timeline (PDT) to describe the timing for when to restart diverse social and economic activities following a disaster.

There is a good example of the importance of PDTs. The Niigata-Chuetsu-Oki earthquake occurred on July 16, 2007, off the western coast of Niigata Prefecture. Water service was suspended after the earthquake in Kashiwazaki city. It took nearly three weeks to restore all the water supply systems (Japan Water Works Association 2008). Still, the city's water supply

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for an economically important factory was restored just one week after the earthquake, on July 23 (Ministry of Economy, Trade and Industry 2018). Because the factory was producing an essential component for the automobile industry and many related companies supported the factory's reopening, the city prioritized restoring water service to the factory. However, elsewhere in the city, the water restoration rate on July 23 was only around 50% (Ministry of Health, Labour and Welfare 2007). This means that many people were without water at that time. In this city, the mayor’s decision to prioritize an economically important factory in the earlier stages of recovery was accepted by local residents, but in other cities, there may be a risk of public backlash. Therefore, it is important to know when such actions will become acceptable in the affected area.

When we discuss PDTs, it is important to consider the practical and strategic aspects involved and the priorities of various stakeholders concerning diverse social and economic activities. We must also determine how much of each resource—time, money, energy, supplies, and personnel—can be allocated to each activity during the recovery phase. However, it is equally important to consider social psychological perspectives. For example, as of the writing of this paper, the COVID-19 pandemic is ongoing, and there is a general sentiment that more resources should devote to preventing the spread of infection rather than using resources for other issues. In Japan, a government-subsidized domestic travel campaign was widely criticized. Common people, scholars and even business owners argued that the government should channelize the financial resources for public health efforts to curtail the spread of COVID-19 (AERA 2020; The Asahi Shimbun 2020a, 2020b). Given that society has not experienced a pandemic like the COVID-19 in a century, it is impossible to collect enough data to perform a cost-benefit analysis to determine the most practical policies to implement. Such criticism is not so much a comment on evidence-based practical strategy but rather on social norms concerning what should be prioritized. In this kind of situation, people are more likely to rely on what others think—social norms—rather than their own thoughts or ideas. People try harder to read public sentiment in such unprecedented times when assessing what kind of recovery activities should be prioritized unless they have their own strong preference. Put another way, assumed social norms influence what actions people take. Therefore, it is important to know PDTs in the study area from a social psychological perspective for pre-disaster recovery planning. We designed our survey from this viewpoint, asking respondents to think about what social norms would be like following a disaster, rather than giving their own subjective views on what actions should be taken and what is in order(5). (We present the questionnaire survey items in the Methods section.)

Previous studies have investigated individual psychological changes following a disaster. Kimura (2007) proposed a recovery-and-reconstruction calendar and revealed the psychological changes in individuals affected by a disaster through questionnaire surveys. Miyamoto and Atsumi (2011) conducted interviews with disaster-affected individuals and asked them to describe a curve, which they call a revitalization curve, showing their psychological state since the disaster occurred. Other studies have tried to generalize individual psychological changes after a disaster. Bryant (2006) focused on a timeline of mental health

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care after a disaster, and Tanaka *et al*. (1999) considered the changes in the mental state of disaster-affected individuals based on their actions following the disaster. Solnit (2010) focused on social norms in studying the community spirit that arises following a disaster. According to the authors' knowledge, there is no comprehensive study on post-disaster social norms of an imminent earthquake. Therefore, this study aims to identify PDTs in a specific area from the social psychological perspective by conducting a survey and evaluating whether the survey method is appropriate for finding a methodology of pre-disaster recovery planning focusing on short- to medium-range activities for recovery.

## 2. METHODS

The questionnaire survey was conducted online with 750 residents of Aichi Prefecture using the Internet. Although a survey of private firms is important when considering economic recovery, we first focused on residents in the area to investigate social norms and the possibility of public backlash in response to government actions aimed at disaster recovery.

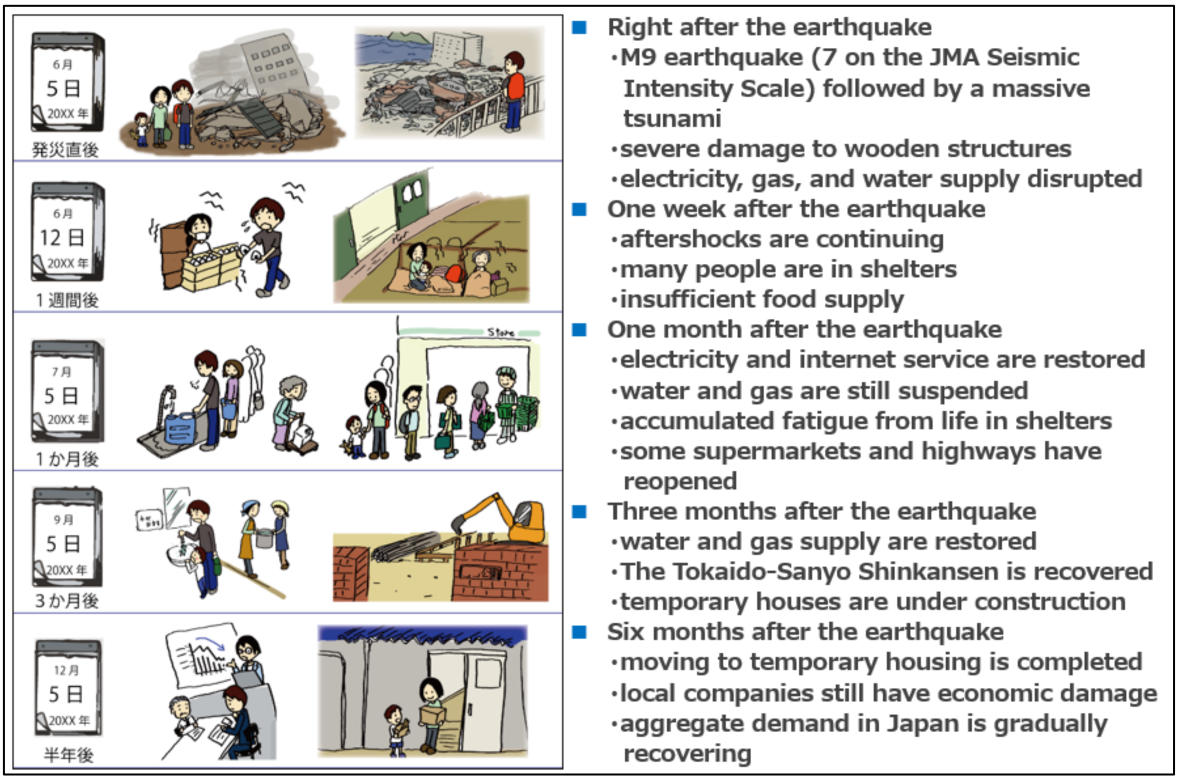


**Figure 1.** Outline of the hypothetical scenario of the disaster

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In the questionnaire, we provided a hypothetical scenario of a disaster. We then asked whether various activities would be socially acceptable at each of the listed time points following the disaster. The disaster scenario was written based on the Nankai megathrust earthquake that is anticipated by the Japanese government (Central Disaster Management Council 2013; Cabinet Office 2019). It included an illustration to help respondents more quickly understand the outline of the scenario. Figure 1 shows the outline of the scenario.

The question is "Suppose you are now facing the large-scale earthquake disaster described in the following hypothetical scenario. When do you think it would be acceptable to start the activities listed below? For each activity, check only one time point (of the six choices). After that time point, the activity will be considered socially acceptable. Please answer based on your perception of public sentiment rather than your own personal opinion" (Hereinafter, we refer this as 'main question'). The six choices were - "right after the earthquake," "1 week after the earthquake," "1 month after the earthquake," "3 months after the earthquake," "6 months after the earthquake," and "more than six months after the earthquake."

We included 32 activities based on the following research below. We performed a literature survey of past large-scale earthquake disasters in Japan, including a comprehensive review of the 1995 Great Hanshin Earthquake (National Land Agency 1999), an analysis of the media news and the public's response (Yamanaka 2005), an economic recovery report from the 2016 Kumamoto earthquakes (Ito and Kashima 2018), an analysis of television commercials after the 2011 Great East Japan Earthquake (Kamei 2011), and so on. We also obtained information from several individuals who had experienced an earthquake disaster and local government officials and private firms in Aichi Prefecture. We extracted those activities that seemed to be important from these information sources. Because we wanted to know when to prioritize activities related to economic recovery, we prepared equal numbers of economic and non-economic activities (Table 1). We included activities that were not directly related to disaster recovery because they also give us information about social norms after a disaster.

We aimed to sample the same numbers of respondents in three different areas of Aichi Prefecture, as shown in Table 2, in order to determine whether there are any differences in thinking about PDTs according to location and occupation. The three areas were those recognized by the Aichi Prefectural Government (2020). The names of the areas are Owari, Nishi-Mikawa, and Higashi-Mikawa. Owari locates in the west part of Aichi Prefecture and is the most populated area. Nishi-Mikawa locates in the middle part of the prefecture and is the most industrialized area. Higashi-Mikawa locates in the east part of the prefecture and is a comparatively rural area. All three areas are supposed to be hit and severely damaged by a Nankai megathrust earthquake and tsunami (Aichi Prefectural Government 2014). Occupation categories are public employees, including government officials, company employees, full-time workers, and executives, including part-time workers, self-employed individuals, non-working spouses, the unemployed, and students.

**Table 1.** Post-disaster activities included in the survey

| Economic activities | Non-economic activities |
|---|---|
| Commercials are broadcast on television. | A celebrity uploads photos of their elaborate birthday party on social media. |
| Local economic federations submit a letter of request for support with economic recovery activities to the government. | A TV station in Tokyo broadcasts a program on the likelihood for Tokyo to be struck by an earthquake in the near future. |
| A tourism campaign for affected areas is launched. | Disaster-related trash collection service ends. |
| A waterworks bureau prioritizes the restoration of water service to an economically important area. | Local governments close small shelters, and the residents there are asked to move to a larger shelter. |
| A major firm in the area requests earlier repair works of the approaching roads to the company's site. | Individuals sheltering in school classrooms are asked to move to the gym by the local government in order to resume the classes. |
| The prime minister calls for the quick restart of automobile exports. | Local governments hold an election for members of the prefectural assembly. |
| Volunteer groups begin to help not only affected households but also affected firms. | Local governments hold workshops to develop the city’s reconstruction plan. |
| Pachinko parlors reopen. | Broadcasting of comedy shows on television resumes. |
| Local governments end the free distribution of food and daily necessities at shelters. | The prime minister makes a state visit to a foreign country. |
| Local governments reduce the number of officers for shelters and local residents and reassign them to assist with economic recovery efforts. | The provision of food and bathing facilities by the Self-Defense Forces ends. |
| A major firm in the area engages in business with a company in another area rather than a local company to resume normal operations more quickly. | Local governments issue an alert for typhoons and heavy rains in their local newsletter. |
| A major firm decides to leave the affected area to resume normal operations more quickly. | Interviews of disaster-affected individuals are conducted to learn lessons of from the disaster. |
| A manufacturing company asks all its employees to return to work. | A charity music festival is held to lift the spirits of disaster-affected individuals. |
| Automotive dealerships launch a sales promotion campaign. | Governments reduce the number of people working to find missing persons. |
| A company makes large-scale personnel changes (such as transfers or layoffs). | A professional baseball game is held in the affected area. |
| Construction of the Linear Chuo Shinkansen maglev line resumes. | Local governments finalize the city’s reconstruction plan. |

**Table 2.** Sampling plan

| | Owari area | Nishi-Mikawa area | Higashi-Mikawa area | Total |
|---|---|---|---|---|
| Public employee | 50 | 50 | 50 | 150 |
| Company employee | 100 | 100 | 100 | 300 |
| Others | 100 | 100 | 100 | 300 |
| Total | 250 | 250 | 250 | 750 |

After the main question, we asked, "In the main question, we asked you to answer based on your perception of public sentiment. As the meaning of 'public,' which one did you mainly imagine?" We set five choices for this question: Japan, the disaster-affected area, Aichi Prefecture, one's local community, and others. We considered that the idea of a 'reference group' had been emphasized in previous social psychological theories (Shibutani 1955). A reference group is one that people think of when they perceive or assess social norms. (Shibutani (1955) discusses there are three types of usage of this term: (1) groups which serve as comparison points; (2) groups to which men aspire; and (3) groups whose perspectives are assumed by the actor. In this paper, we use this term as the meaning of (3).) Reference groups are considered critical in shaping social norms and the impacts of social norms on individuals. Reference groups can range in size from families to classes in schools, local communities, cities, states, nations, and even the entire world. The purpose of the question above is to reveal the reference groups of the respondents.

We also asked respondents to inform their sex, age, household members (including whether there are young children less than six years old or elderly relatives 65 years of age or older), household income, and experience staying in a shelter for more than one night.

## 3. RESULTS

### 3.1 Sampling results

The survey was conducted from August 21 to 24, 2020, and samples were obtained according to the plan shown in Table 2. The age and sex distributions of the samples are shown in Tables 3 and 4.

**Table 3.** Distribution of age

| | |
|---|---|
| Under 20 | 2 |
| 20s | 73 |
| 30s | 145 |
| 40s | 205 |
| 50s | 188 |
| 60s | 109 |
| 70s | 27 |
| 80s and older | 1 |
| Total | 750 |

**Table 4.** Distribution of sex

| | |
|---|---|
| Male | 497 |
| Female | 251 |
| Others | 2 |
| Total | 750 |

### 3.2 Differences between groups based on respondent attributes

First, we looked for differences in responses to the main question between groups. We created the groups based on differences in respondent attributes and used the chi-squared test to compare them. The tested groups were as follows(6).

- Location– between Owari and Nishi-Mikawa, between Owari and Higashi-Mikawa, and between Nishi-Mikawa and Higashi-Mikawa
- Occupation– between public employees and company employees, between public employees and others, and between company employees and others
- Age– between those in their 50s and younger and those in their 60s and older
- Sex– between males and females
- Household groups – between households with young children or/and elderly relatives and those without
- Household income– between those earning less than 5 million yen and those earning 5–10 million yen, between those earning less than 5 million yen and those earning more than 10 million yen, and between those earning 5–10 million yen and those earning more than 10 million yen
- Reference group– between Japan and the disaster-affected area, between Japan and Aichi Prefecture or one’s local community, between the disaster-affected area and Aichi Prefecture or one’s local community

We also wanted to investigate differences according to the experience of staying in a shelter for more than one night. Still, we were unable to obtain a sufficient number of samples for the chi-squared test.

The results of the chi-squared tests are shown in Table 5. We conducted tests for all 32 activities listed in Table 1, and thus the maximum number of statistical differences is 32. We checked that cells with expected values of less than five did not account for more than 20% of the data (Cochran's rule).

**Table 5.** Number of statistical differences between the groups

| Groups | | p<0.1 | p<0.05 | p<0.01 |
|---|---|---|---|---|
| Location | Owari and Nishi-Mikawa | 6 | 3 | 1 |
| | Owari and Higashi-Mikawa | 7 | 5 | 1 |
| | Nishi-Mikawa and Higashi-Mikawa | 6 | 4 | 0 |
| Occupation | Public employees and company employees | 1 | 1 | 0 |
| | Public employees and others | 22 | 16 | 7 |
| | Company employees and others | 15 | 12 | 7 |
| Age (<59, >60) | | 8 | 2 | 1 |
| Sex (male, female) | | 24 | 21 | 12 |
| With young children or/and elderly relatives and without | | 2 | 2 | 0 |
| Household income | <5 million yen and 5–10million yen | 2 | 2 | 0 |
| | <5 million yen and >10 million yen | 3 | 1 | 0 |
| | 5–10 million yen and >10 million yen | 4 | 4 | 0 |
| Reference group | Japan and the disaster-affected area | 32 | 32 | 31 |
| | Japan and Aichi Prefecture or one's local community | 31 | 31 | 25 |
| | The disaster-affected area and Aichi Prefecture or one's local community | 2 | 1 | 0 |

We found relatively many statistical differences between occupations, sexes, and reference groups. In contrast, the statistical differences between the locations, ages, household members, and household incomes were relatively small. We checked the relationships between occupations, sexes, and reference groups. We found some correlation between sexes and occupations and between occupations and reference groups. Still, these correlations were not large enough to explain all the differences between responses to the main question(7). Now we know that PDTs differ mainly according to occupation, sex, and reference group.

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### 3.3 Characteristics of the difference between groups

In this section, we analyze the characteristics of between-group differences, namely, volume and tendencies. Especially, we want to know which group tends to accept the post-disaster activities in Table 1 earlier. The method is exemplified in Table 6. We calculated the accumulated percentage of respondents who answered “acceptable” at each time point for each activity and each group and then calculated differences between two groups at each time point. We counted the number of time points in which differences of 10% or more were found. In Table 6, there are ‘2’ differences greater than 10%(‘right after’ and ‘1 week’). We summed this number for all 32 activities.

Because the differences of 10% or more between two groups are all positive (not negative) in Table 6, we see that those whose reference group is Japan accept the activity ‘earlier’ than those whose reference group is the disaster-affected area. In other words, the ‘Japan’ group includes more respondents who answered “acceptable” compared with the other group at the same time point.

**Table 6.** Example of a difference between groups

Activity: Commercials are broadcast on television.

| | Right after | 1 week | 1 month | 3 months | 6 months | More than 6 months |
|---|---|---|---|---|---|---|
| Japan (A) | 34.3% | 50.2% | 69.5% | 83.6% | 92.0% | 100.0% |
| The disaster-affected area (B) | 24.0% | 35.9% | 61.1% | 80.5% | 95.2% | 100.0% |
| Difference (A-B) | 10.3% | 14.3% | 8.4% | 3.0% | -3.2% | 0.0% |

↑ ↑

≥10%

Table 7 shows the results of the analysis. We analyzed the groups that had relatively large effects on the differences in PDTs found in the previous section.

We found that differences depending on the reference group were larger than those depending on other groups regarding the absolute value of the differences. We also found that public employees, company employees, males, and those whose reference group is Japan tend to believe that activities are acceptable earlier than other groups because the differences were all positive. Interestingly, there was no negative difference of 10% or more. The nonexistence of negative differences means that the difference in PDTs does not differ according to activity; indeed, for nearly every activity, the tendencies of differences were the same (Figure 2).

**Table 7.** Analysis of differences in PDTs between two groups
(number of time points in which differences of 10% or more were found)

| | | 10%–15% | 15%–20% | >20% | Which group accepts earlier? |
|---|---|---|---|---|---|
| Occupation | Public employees and company employees | 1 | 0 | 0 | Public employees |
| | Public employees and others | 46 | 3 | 3 | Public employees |
| | Company employees and others | 28 | 4 | 0 | Company employees |
| Sex (male, female) | | 27 | 2 | 0 | Males |
| Reference group | Japan and disaster-affected area | 35 | 24 | 22 | Japan |
| | Japan and Aichi Prefecture or one's local community | 49 | 37 | 10 | Japan |
| | Disaster-affected area and Aichi Prefecture or one's local community | 0 | 0 | 0 | |

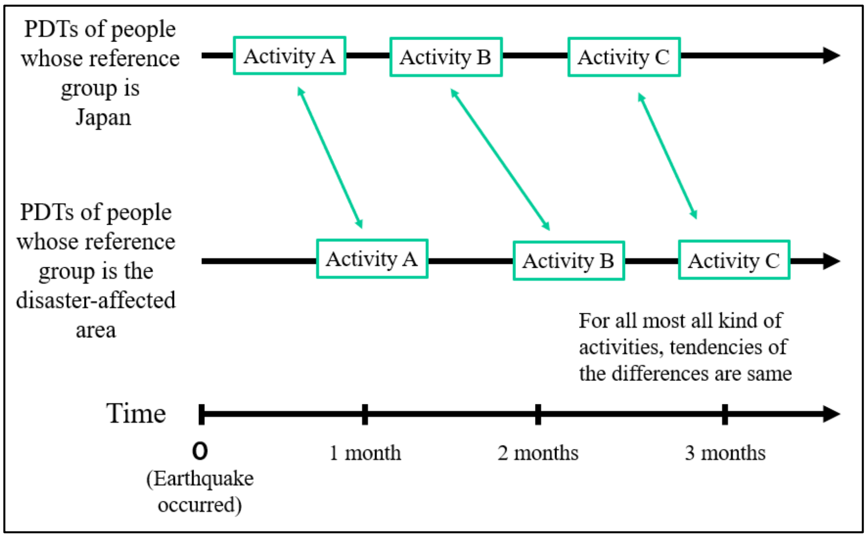


**Figure 2.** Simplified illustration of differences in PDTs between groups

### 3.4 Estimation of PDTs in Aichi Prefecture as a whole

The distributions of samples we obtained were not the same as the actual distributions of the population of Aichi Prefecture. Therefore, in this section, we adjust the distributions we obtained according to the actual distributions based on census data collected and reported by the Japanese government. In particular, we adjusted for occupation and sex, which were found

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to have relatively large impacts on the differences in PDTs, and then calculated the PDTs of Aichi Prefecture as a whole[8]. The results are shown in Table 8.

**Table 8.** Estimated PDTs of Aichi Prefecture as a whole

| | | Right after | 1 week | 1 month | 3 months | 6 months | More than 6 months | Group |
|---|---|---|---|---|---|---|---|---|
| E | A waterworks bureau prioritizes the restoration of water service to an economically important area | 31.7% | 50.4% | 75.4% | 87.9% | 96.1% | 100.0% | 1 |
| | Local governments issue an alert for typhoons and heavy rains in their local newsletter | 32.1% | 43.9% | 71.7% | 86.6% | 96.8% | 100.0% | 2 |
| E | Commercials are broadcast on television | 24.9% | 37.2% | 62.3% | 81.7% | 93.6% | 100.0% | 3 |
| E | A major firm in the area requests earlier repair works of the approaching roads to the company's site | 22.5% | 36.3% | 62.0% | 79.4% | 93.4% | 100.0% | 3 |
| E | Volunteer groups begin to help not only affected households but also affected firms | 20.9% | 37.6% | 62.3% | 79.4% | 95.1% | 100.0% | 3 |
| E | Local economic federations submit a letter of request for support with economic recovery activities to the government | 20.5% | 32.2% | 58.8% | 81.4% | 97.1% | 100.0% | 3 |
| | Local governments close small shelters, and the residents there are asked to move to a larger shelter | 15.4% | 26.7% | 50.3% | 74.3% | 92.8% | 100.0% | 4 |
| | Broadcasting of comedy shows on television resumes | 14.0% | 27.9% | 51.4% | 73.5% | 93.3% | 100.0% | 4 |
| | Individuals sheltering in school classrooms are asked to move to the gym by the local government in order to resume the classes | 11.3% | 22.4% | 52.2% | 79.6% | 95.6% | 100.0% | 5 |
| | A charity music festival is held to lift the spirits of disaster-affected individuals | 13.1% | 24.0% | 51.2% | 72.1% | 94.5% | 100.0% | 6 |
| E | Local governments reduce the number of officers for shelters and local residents and reassign them to assist with economic recovery efforts | 15.6% | 24.5% | 46.7% | 69.0% | 91.8% | 100.0% | 7 |
| E | The prime minister calls for the quick restart of automobile exports | 13.8% | 21.7% | 46.0% | 71.6% | 90.7% | 100.0% | 7 |
| | A TV station in Tokyo broadcasts a program on the likelihood for Tokyo to be struck by an earthquake in the near future | 13.5% | 20.3% | 40.6% | 58.3% | 83.4% | 100.0% | 7 |
| | The provision of food and bathing facilities by the Self-Defense Forces ends | 12.9% | 16.4% | 32.2% | 59.8% | 86.1% | 100.0% | 7 |
| | Local governments finalize the city's reconstruction plan | 12.7% | 21.1% | 41.3% | 65.8% | 93.5% | 100.0% | 7 |
| E | A major firm in the area engages in business with a company in another area rather than a local company to resume normal operations more quickly | 12.5% | 19.1% | 40.9% | 62.8% | 82.4% | 100.0% | 7 |
| | A celebrity uploads photos of their elaborate birthday party on social media | 12.1% | 17.3% | 34.1% | 54.0% | 75.7% | 100.0% | 7 |
| E | A manufacturing company asks all its employees to return to work | 11.2% | 22.0% | 44.2% | 67.8% | 90.2% | 100.0% | 7 |
| E | A major firm decides to leave the affected area to resume normal operations more quickly | 11.1% | 17.3% | 33.4% | 52.0% | 77.9% | 100.0% | 7 |
| | The prime minister makes a state visit to a foreign country | 10.6% | 17.5% | 40.2% | 59.2% | 82.0% | 100.0% | 7 |
| | Interviews of disaster-affected individuals are conducted to learn lessons of from the disaster | 10.5% | 19.5% | 41.7% | 61.8% | 90.6% | 100.0% | 7 |
| | Local governments hold workshops to develop the city's reconstruction plan | 9.5% | 15.8% | 34.7% | 62.9% | 91.4% | 100.0% | 7 |
| | A professional baseball game is held in the affected area | 8.8% | 13.9% | 35.0% | 55.3% | 83.0% | 100.0% | 7 |
| E | A company makes large-scale personnel changes (such as transfers or layoffs) | 7.2% | 13.0% | 29.8% | 52.4% | 80.3% | 100.0% | 7 |
| E | Construction of the Linear Chuo Shinkansen maglev line resumes | 9.4% | 16.1% | 31.1% | 47.6% | 79.9% | 100.0% | 8 |
| E | A tourism campaign for affected areas is launched | 8.2% | 14.2% | 28.2% | 48.6% | 80.2% | 100.0% | 8 |
| E | Automotive dealerships launch a sales promotion campaign | 7.1% | 11.6% | 29.4% | 47.7% | 79.6% | 100.0% | 8 |
| E | Local governments end the free distribution of food and daily necessities at shelters | 7.0% | 13.4% | 27.9% | 48.8% | 80.6% | 100.0% | 8 |
| | Governments reduce the number of people working to find missing persons | 6.0% | 10.3% | 24.0% | 41.8% | 76.7% | 100.0% | 8 |
| E | Pachinko parlors reopen | 10.2% | 16.5% | 32.3% | 49.6% | 72.6% | 100.0% | 9 |
| | Disaster-related trash collection service ends | 9.8% | 14.4% | 25.8% | 38.7% | 64.5% | 100.0% | 9 |
| | Local governments hold an election for members of the prefectural assembly | 6.5% | 10.2% | 22.4% | 42.3% | 74.7% | 100.0% | 9 |

Values are the percentage of respondents who answered "acceptable" to the main question for each time point. "E" indicates economic activities shown in Table 1. Cells with values less than 25% are colored red, 25%–50% are orange, 50%–75% are yellow, and greater than 75% are blue. "Group" means groups that are defined by combinations of 25th percentile value, 50th percentile value, and 75th percentile value[9]. Group 1 indicates activities that are socially acceptable at the earliest stage of the disaster recovery, and group 9 indicates those that are socially acceptable at the final stage of the disaster recovery.

The results indicate that socially acceptable time points differ according to the activity. It is important to note that economic activities are not concentrated at the bottom of Table 7 (group 8 or 9) but are distributed widely from the earlier stages (group 1, 2, or 3) to the later stages of the recovery phase. The above trend indicates that some economic activities are socially acceptable at the earlier stages, including “A waterworks bureau prioritizes the restoration of water service to an economically important area (group 1)” and “A major firm in the area requests earlier repair works of the approaching roads to the company's site (group 3).” Accordingly, we consider that infrastructure recovery should be prioritized, taking into account the economic recovery of this area. If we want to avoid public backlash from attempting early efforts aimed at economic recovery, the order of conducting the economic activities can be determined by referencing Table 8.

## 4. DISCUSSION

The survey results revealed the characteristics of PDTs in the study area. PDTs differ according to sex, occupation, and reference group rather than location, age, household members, and household income. The PDTs of public employees, company employees, males, and those whose reference group is Japan are generally earlier than those of other people. We also estimated the PDTs of Aichi Prefecture as a whole and found that some kinds of economic activities are socially acceptable in the earlier stages of the disaster recovery (e.g., “A waterworks bureau prioritizes the restoration of water service to an economically important area.”, “Commercials are broadcast on television.”, “A major firm in the area requests earlier repair works of the approaching roads to the company's site.”, “Volunteer groups begin to help not only affected households but also affected firms.” and “ Local economic federations submit a letter of request for support with economic recovery activities to the government.”). Although the actual reasons for accepting these activities in the earlier stage are unknown from the survey data, we conjecture that people in Aichi Prefecture generally recognize contributions of manufacturing to their daily lives and accept to distribute recovery resources to economic recovery.

It is important to note that PDTs are not a single timeline but rather multiple timelines. Accordingly, the PDTs of Aichi Prefecture consist of an aggregation of each person’s PDT, which differ according to the individual or group. Hence, we refer to multiple PDTs.

The findings of this study can be applied in two ways.

The first use is for consensus-building on a better recovery process in the area. If only the PDTs of Aichi Prefecture as a whole were followed, small and medium-sized firms would likely have difficulty maintaining adequate cash flow because such companies lack the money to survive beyond one month after a disaster. Although the Small and Medium Enterprise Agency (2012) recommends that firms have reserves for one month as part of their business continuity plan (BCP), many cannot easily secure that amount. Furthermore, we know that a large company in the area set 1 month as its target for restarting production (i.e., recovery time objective) in its BCP. In contrast, in the PDTs of Aichi Prefecture, for example, "The prime minister calls for the quick restart of automobile exports" was acceptable to 46% of the population at one month after the earthquake. However, if the government were to follow the other 54% and postpone support for the economic recovery, many small and medium-sized firms would have difficulty surviving. The large company mentioned above may not be able to achieve its recovery time objective. We consider that the people of Aichi Prefecture need to discuss this kind of problem. If we host a workshop where residents with different PDTs can gather, the discussion may lead to a pre-disaster recovery plan acceptable to many people. Suppose such a discussion is held only within the government (public employees) or at private firms (company employees). In that case, a consensus may be reached quickly because there are few differences in PDTs, but the majority of the public may not accept it. According to the reference group, we know that there are differences in PDTs. Therefore, people in the central government whose responsibility is to consider policies for Japan and those in local governments whose responsibility is to consider policies for their area need to collaborate on pre-disaster recovery planning. These points above should be included in guidelines on pre-disaster recovery planning focused on short- to medium-range activities for recovery. In addition, in the field of science and technology studies, there is an idea of "mini-publics" (Ryan and Smith 2014), which involves randomly sampling people to create groups for holding deep discussions of a given topic. We can utilize the knowledge on the differences in PDTs produced in the present study to make better "mini-publics" in which diverse opinions on the recovery process can be exchanged.

Additionally, the authors have already begun to hold a series of workshops on the recovery process in this area and plan to use the findings from the present survey going forward. As one example, when we organized the first trial workshop, we took care to have an appropriate ratio of male and female participants because generally, there are differences in PDTs between the sexes.

Another way to utilize the findings of this survey is to promote consideration of the existence of people who have different and diverse PDTs. It is very difficult to reach a perfect consensus because it is nearly impossible for all stakeholders to participate in the process, and the actual disaster may differ substantially from the one that was predicted. Some people may have no choice but to participate in activities even when they are not socially acceptable to others. In such cases, those engaged in recovery activities may choose better words when they need to communicate with the public if they know the PDTs of Aichi Prefecture as a whole and keep in mind that there are differences in PDTs between people. Choosing thoughtful words reduce any potential backlash.

Finally, to assess the validity of the findings and evaluate whether the survey method is appropriate, we compared the survey results with similar large-scale disasters, namely, the 1995 Great Hanshin Earthquake and the 2011 Great East Japan Earthquake. In response to the activity "Local governments hold an election for members of the prefectural assembly," 42.3% of respondents answered that it was acceptable at three months and 74.7% at six months. Following the Great East Japan Earthquake, the prefectural assembly election in Miyagi Prefecture was postponed (Ministry of Internal Affairs and Communications 2011) until nearly eight months after the earthquake (Miyagi Prefectural Government 2012). We could find no record of public objections to holding the election at the rescheduled time, so we can assume that most people accepted this activity, which is in line with the present study results. As another example, Hyogo Prefecture finalized its reconstruction plan just two months after the Great Hanshin Earthquake, leading to a strong public backlash (National Land Agency 1999). In our survey, 41.3% of respondents answered that finalizing reconstruction plans were acceptable at one month and 65.8% at 3 months, so we can assume that such an activity is not acceptable to most people at two months.

Considering the two abovementioned comparisons, our survey results can be regarded as reliable for revealing the PDTs in the study area. The reliability of the survey results indicates the appropriateness of our survey method. Although the survey was conducted based on a single disaster scenario, it is not a problem for revealing characteristics of PDTs in a target area. Blackouts, water and gas supply disruption, and evacuation to temporary housing will occur in most large-scale disasters. If we consider, for example, "3 months" in the present scenario as "the time when the water and gas supply are restored" and "6 months" as "the time when people will move to temporary housing," then the generalizability of the survey results increases. Accordingly, we consider that our method for surveying PDTs was appropriate.

## 5. CONCLUSIONS

This study surveyed PDTs in the most industrialized prefecture in Japan and identified many related characteristics in the area. We also evaluated our survey method was appropriate for revealing PDTs in a target area. Surveying PDTs and designing a consensus process by considering the differences in PDTs among different groups of people are important for pre-disaster recovery planning focused on short- to medium-range activities for recovery.

We will focus on differences in PDTs between prefectures in future research by conducting a survey in another area. Considering the importance of the reference groups, we will investigate the thought processes that lead to the selection of reference groups. We will also continue our workshops for pre-disaster recovery planning in the study area with reference to the present results. Doing so will help us more fully understand the differences in PDTs and find new ways of building consensus.

## ACKNOWLEDGEMENT

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## FOOTNOTES

(1) For example, in the 1995 Great Hanshin Earthquake in Japan, the city's reconstruction plan was finalized two months after the earthquake. There was a strong public backlash due to the lack of citizen participation in the process (National Land Agency 1999).

(2) Takahashi *et al*. (2016) proposed the same kind of idea and tried to develop a pre-disaster recovery plan of road networks in Kagawa Prefecture, Japan by using a mathematical modeling approach.

(3) Industrial firms in Aichi Prefecture contribute about 48.7 trillion yen to the Japanese economy, which is the largest of all 47 prefectures. (Ministry of Economy, Trade and Industry 2020)

(4) In this area, certain roads have been designated as critical to disaster response, so it is a priority to reopen these roads within 7 days after an earthquake (Chubu-region Main Roads Council 2020). However, there are no agreements regarding priorities for other roads and infrastructure.

(5) We do not intend to insist that the recovery process should be determined by social norms alone. Such reliance on social norms would lead to many problems. We discuss this point in the Discussion section.

(6) When making groups based on sex, we excluded samples who answered "others." When making groups based on the reference group, we combined the responses "Aichi Prefecture" and "one's local community" as a single category for the statistical analysis to ensure a sufficient number of samples. The two answers have similar meanings because the survey was conducted of residents of Aichi Prefecture and their local community would be within the prefecture. Additionally, we excluded samples who answered "others" to the reference group question.

(7) First, the samples in this survey have a different proportion of sexes in each occupation. We checked the statistical difference between sexes in the occupation category "others." (We were unable to perform the same analysis for public employees and company employees due to an insufficient number of samples.) The numbers of statistical differences between male and female respondents by the chi-squared test were 9 ($p<0.1$), 4 ($p<0.05$), and 1 ($p<0.01$). Compared with Table 5, the numbers of statistical differences between the sexes were smaller but some still exist.

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Second, we checked relationships between reference group and sex and between reference group and occupation. We conducted the chi-squared test. There was no statistical relationship between the reference groups and the sexes (p=0.678; we excluded "others" from both categories) but there was a statistical relationship between the reference groups and the occupations (p=0.023; we excluded "others" from the reference group category). However, as in Table 9, there was not a strong relationship between the reference groups and the occupations.

**Table 9.** Cross tabulation of reference group and occupation

| | Japan | The disaster-affected area | Aichi Prefecture | One's local community | Others | Total |
|---|---|---|---|---|---|---|
| Public employee | 36 (17%) | 59 (18%) | 30 (25%) | 23 (29%) | 2 (40%) | 150 (20%) |
| Company employee | 99 (46%) | 130 (39%) | 37 (31%) | 32 (40%) | 2 (40%) | 300 (40%) |
| Others | 78 (37%) | 145 (43%) | 51 (43%) | 25 (31%) | 1 (20%) | 300 (40%) |
| Total | 213 | 334 | 118 | 80 | 5 | 750 |

The percentages are the proportions of occupations in each reference group.

(8) The adjustment method is shown in Figure 3.

Census data（2015）

| | Public employee | Company employee | Others | Total |
|---|---|---|---|---|
| Male | 60925 | 1476309 | 2203610 | 3740844 |
| Female | 26604 | 576367 | 3139313 | 3742284 |
| Total | 87529 | 2052676 | 5342923 | 7483128 |

Proportions

| | Public employee | Company employee | Others | Total |
|---|---|---|---|---|
| Male | 0.008142 | 0.197285 | 0.294477 | 0.499904 |
| Female | 0.003555 | 0.077022 | 0.419519 | 0.500096 |
| Total | 0.011697 | 0.274307 | 0.713996 | 1 |

The samples

| | Public employee | Company employee | Others | Total |
|---|---|---|---|---|
| Male | 125 | 235 | 137 | 497 |
| Female | 25 | 64 | 162 | 251 |
| Total | 150 | 299 | 299 | 748 |

Proportions

| | Public employee | Company employee | Others | Total |
|---|---|---|---|---|
| Male | 0.167112 | 0.314171 | 0.183155 | 0.664439 |
| Female | 0.033422 | 0.085561 | 0.216578 | 0.335561 |
| Total | 0.200535 | 0.399733 | 0.399733 | 1 |

↓

Weights for the adjustment

| | Public employee | Company employee | Others | Total |
|---|---|---|---|---|
| Male | 0.04872 | 0.627954 | 1.607802 | 0.75237 |
| Female | 0.106372 | 0.900197 | 1.937037 | 1.490327 |
| Total | 0.058328 | 0.686227 | 1.786184 | 1 |

**Figure 3.** Calculation of a weights table for the adjustment

The upper left table presents census data from Aichi Prefecture and the upper right table presents their proportions. We divided the values from the census proportion table by the values from the sample proportion table in order to create the weights table. We multiplied the weights by each sample to obtain the PDTs for Aichi Prefecture as a whole.

(9) The definitions of each group in Table 8 are presented in Table 10.

**Table 10.** Relationships between the groups and percentile values

| Group no. | 25th percentile value | 50th percentile value | 75th percentile value |
|---|---|---|---|
| 1 | right after the earthquake | 1 week after the earthquake | 1 month after the earthquake |
| 2 | right after the earthquake | 1 month after the earthquake | 3 months after the earthquake |
| 3 | 1 week after the earthquake | 1 month after the earthquake | 6 months after the earthquake |
| 4 | 1 week after the earthquake | 1 month after the earthquake | 6 months after the earthquake |
| 5 | 1 month after the earthquake | 1 month after the earthquake | 3 months after the earthquake |
| 6 | 1 month after the earthquake | 1 month after the earthquake | 6 months after the earthquake |
| 7 | 1 month after the earthquake | 3 months after the earthquake | 6 months after the earthquake |
| 8 | 1 month after the earthquake | 6 months after the earthquake | 6 months after the earthquake |
| 9 | 1 month after the earthquake | 6 months after the earthquake | more than 6 months after the earthquake |

## REFERENCES

AERA (2020) Policies for COVID-19 are in a maze; conflicts between epidemic prevention and economic recovery are getting more severe. July 27: 22. (in Japanese)

Aichi Prefectural Government (2014) A report on damage estimations of earthquakes in Aichi prefecture. (in Japanese) https://www.pref.aichi.jp/bousai/2014higaiyosoku/whitebooknew2.pdf

Aichi Prefectural Government (2020) Cities, towns and villages in prefecture. (in Japanese) https://www.pref.aichi.jp/site/userguide/link-citytown.html

Bryant, R. A (2006) Recovery after the tsunami: Timeline for rehabilitation. *The Journal of Clinical Psychiatry, 67* (Suppl 2): 50-55.

Cabinet Office (2019) A report on quantitative damage estimations of Nankai megathrust earthquakes in each prefecture (damages on facilities). (in Japanese) http://www.bousai.go.jp/jishin/nankai/taisaku_wg/pdf/2_sanko.pdf

Central Disaster Management Council (2013) A second report on scenario-based damage estimations of Nankai megathrust earthquakes in each prefecture (damages on facilities). (in Japanese) http://www.bousai.go.jp/jishin/nankai/nankaitrough_info.html http://www.bousai.go.jp/jishin/nankai/taisaku_wg/pdf/20130318_shiryo2_1.pdf

Chubu-region main roads council (2020) Road recovery strategy in Chubu-region "Kushinoha strategy". (in Japanese) https://www.cbr.mlit.go.jp/road/kanri-bunkakai/pdf/202006_kushinoha.pdf

Ito, T. and Kashima, H. (eds.) (2018) *The 2016 Kumamoto Earthquake and The Regional Industries*. Nippon Hyoron Sha: Japan, pp.171 (in Japanese)

Japan water works association (2008) A report on damages of water facilities in 2007 Niigata -Chuetsu-Oki earthquake. (in Japanese) http://www.jwwa.or.jp/houkokusyo/houkokusyo_08.html

Kamei, A (2011) The serious earthquake in the eastern Japan and public service advertising: Roles of advertising at a stricken time and effects of public service advertising on suffered consumers. The bulletin of the Graduate School of Commerce, 73: 1-14. (in Japanese)

Kimura, R. (2007) Recovery and reconstruction calendar. *Journal of Disaster Research, 2* (6): 465-474.

Ministry of Economy, Trade and Industry (2018) Lessons from 2007 Niigata-Chuetsu-Oki earthquake and future disaster prevention plan; BCP as a basis of a continuous enterprises management. (in Japanese) https://www.chusho.meti.go.jp/koukai/kenkyukai/kyoujin/181226kyoujin.htm https://www.chusho.meti.go.jp/koukai/kenkyukai/kyoujin/2018/181226kyoujin06.pdf

Ministry of Economy, Trade and Industry (2020) Census of Manufacture 2019. (in Japanese) https://www.meti.go.jp/statistics/tyo/kougyo/result-2/r01/kakuho/chiiki/index.html

Ministry of Education, Culture, Sports, Science and Technology (2020) A list of results of long-term evaluations on possibilities of earthquakes. (in Japanese) https://www.jishin.go.jp/main/choukihyoka/ichiran.pdf

Ministry of Health, Labour and Welfare (2007) An 11th report on damage and countermeasures in 2007 Niigata-Chuetsu-Oki earthquake. (in Japanese) https://www.mhlw.go.jp/houdou/2007/07/h0723-1.html

Ministry of Internal Affairs and Communications (2011) Elections and 2011 Great East Japan Earthquake. (in Japanese) https://www.soumu.go.jp/senkyo/chihou17_01.html

Ministry of Land, Infrastructure, Transport and Tourism (2018) A guideline for pre-disaster recovery planning. (in Japanese) https://www.mlit.go.jp/toshi/toshi_tobou_fr_000036.html

Miyagi Prefectural Government (2012) An election of members of Miyagi prefectural assembly in November 13, 2011. (in Japanese) https://www.pref.miyagi.jp/site/miyagi-senkyo-kekka/h23kengi.html

Miyamoto, T. and Atsumi T. (2011) Visualization of disaster revitalization processes – collective construction of survivors' experiences in the 2004 Niigata Chuetsu Earthquake. *Progress in Asian Social Psychology Series*, 8: 307-323.

National Land Agency (1999) Lessons from Great Hanshin-Awaji earthquake. (in Japanese) http://www.bousai.go.jp/kyoiku/kyokun/hanshin_awaji/ http://www.bousai.go.jp/kyoiku/kyokun/hanshin_awaji/data/detail/pdf/3-3-3.pdf

NHK (2020) 9 years have passed since the earthquake but still not fully recovered. A recovery and reconstruction calendar of 2,000 damaged people. (in Japanese) https://www3.nhk.or.jp/news/html/20200304/k10012311741000.html (expired)

Otsuyama, K. and Maki, N. (2018) A comparative analysis and identification on legislative systems for pre-disaster recovery planning in Japan and U.S. *Journal of the City Planning Institute of Japan, 53* (2): 132-143. (mostly in Japanese) https://www.jstage.jst.go.jp/article/journalcpij/53/2/53_132/_article/-char/en

Ryan, M. and Smith, G. (2014) Defining Mini-Publics. In Grönlund, K., Bächtiger, A. and Setälä, M.(Eds.), *Deliberative mini-publics: Involving citizens in the democratic process*. ECPR Press: United Kingdom, 9-26.

Shibutani, T. (1955) Reference Groups as Perspectives. *American Journal of Sociology, 60* (6): 562-569.

Solnit, R. (2010) *A Paradise Built in Hell -The Extraordinary Communities That Arise in disaster-*. penguin: U.S., pp.368

Takahashi, K., Isouchi, C., Shiraki, W., Iwahara, H., Inomo, H. and Sato, E. (2016) Studying the strategic restoration schedule for Takamatsu area's road networks: The Nankai megathrust earthquakes' aftermath. *Journal of Japan Society of Civil Engineers*, Ser. F6 (Safety Problem), *72* (2): I_99-I_106. (mostly in Japanese) https://www.jstage.jst.go.jp/article/jscejsp/72/2/72_I_99/_article/-char/en

Tanaka, S., Hayashi, H. and Shigekawa, K. (1999) Behavior of Disaster Victims along the Course of Disaster Process. *Journal of Japan Society for Natural Disaster Science, 18* (1): 21-29. (in Japanese)

*The Asahi Shimbun* (2020a) A travel promotion campaign is beginning but some people in sightseeing areas say prevention of spreading COVID-19 should be prioritized. July 15(morning edition): 7 (in Japanese)

*The Asahi Shimbun* (2020b) What do you think about the travel promotion campaign against COVID-19. October 14(morning edition): 12 (in Japanese)

The Small and Medium Enterprise Agency (2012) A guideline of BCP for small and medium enterprise. (in Japanese) https://www.chusho.meti.go.jp/bcp/contents/level_a/bcpgl_05a_4.html

Yamanaka, S. (2005) *Media in earthquake disasters.* Sekaishisosha: Japan, pp.238 (in Japanese)

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Original paper

# Tsunami Impact Assessment and Vulnerability Index Development using Computable General Equilibrium (CGE) Model and Geographic Information System (GIS) – A Study on Mie Prefecture, Japan

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**Abstract** Japan is highly prone to multiple natural hazards, such as typhoons, earthquakes, and tsunamis in general. However, the compound disaster that entailed earthquake, tsunami, and a nuclear crisis, along with disruption of the global supply chain triggered by the Great East Japan Earthquake in 2011, highlighted the need for a holistic risk assessment of impacts amplified by multiple disasters. According to the Cabinet Office of Japan, the occurrence probability of a Nankai Trough Earthquake and Tsunami is 70% within the next 30 years. It suggests the need for comprehensive impact assessment to enhance the disaster risk reduction strategies of the region. This study conducts a tsunami impact assessment using quantitative analysis to identify vulnerable industries in Mie Prefecture, Japan, famous for tourism, value-added sectors of aquaculture, food processing, and petroleum refining tanks situated in at-risk areas. To create a tsunami shock scenario, we apply a computable general equilibrium (CGE) model using an input-output table of the Mie Prefecture (2015 version) and geographic information system (GIS). The street-level business entity data enable us to incorporate with the disaster scenario to provide evidence-based damage estimates of capital and labor loss due to a tsunami. We present the simulation results of output change, price change, external trade, and welfare analysis and propose creating a vulnerability index (VI) for disaster impact. These quantified and visualized indicators would provide informative implications for *ex-ante* policymaking and risk financing to cope with fragile sectors effectively.

JEL: C68, Q54, N75

**Keywords:** Tsunami disaster, CGE, GIS, IO table, Mie, Japan

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# 1. INTRODUCTION

Natural disasters, such as typhoons, heavy rains, floods, and earthquakes, affect our daily lives; however, the tsunami is a disaster that stakeholders tend to overlook its impacts due to its low occurrence rate. The Asian tsunami struck in 2004 and conveyed important messages to coastal countries about the importance of tsunami awareness and preparedness. Despite the reconstruction work that included tsunami information dissemination of hazard maps and other structural countermeasures, the massive losses due to the Great East Japan Earthquake and Tsunami of 2011 again revealed the inadequacies and potential for more effective measures (Løvholt, Setiadi, Birkmann, *et al*., 2014). This event also highlighted the importance of significant price changes and disruption of the global supply chain (Cavallo *et al*., 2014). Therefore, estimation of disaster impact is desirable for making *ex-ante* disaster risk management plans and countermeasures.

This study uses the Mie Prefecture as a case study to estimate the potential economic impact of the Nankai Trough earthquake with a 70% probability of occurrence in the next 30 years. Mie is a prefecture with an estimated population of 1.77 million and an area of 5,774 km$^2$, located mid-west of the mainland (Honshu) Japan. Its coastline facing the Sea of Japan is 1,140 km long and is the seventh longest coastline in Japan. Mie Prefecture is blessed with abundant marine resources and is known for its lobster and pearl farming, which is one of the main reasons for its flourishing as a tourist destination. On the other hand, Mie Prefecture's primary industry is manufacturing, a higher value-added industry, and it generates more employment when compared to the national average (METI 2014). The northern part of Mie belongs to the Chukyo Industrial Zone, one of three major industrial zones in Japan.

Due to its geographical features, the Mie Prefecture frequently experiences natural disasters, including typhoons and tsunamis. Typhoon Talas in 2011 caused extensive damage, including building collapse and 82 casualties. A major earthquake hit the prefecture in 1944, and several more occurred in the last few decades. Studies have predicted a tsunami at the height of 26 m in the coming decades (Shima City and Toba City; Cabinet Office of Japan 2012a). Studies have predicted that the risk of liquefaction is particularly high in the coastal areas of Ise Bay (DPCD 2014).

The prefectural capital city of Tsu is the administrative and cultural center of the Mie Prefecture, where many companies with cutting-edge technologies, medical centers, and hospitals are based. Tsu has prospered as a trading port since ancient times, and today, it is a seaside city with an urban area along the coast. The city is home to one of Japan's largest shipbuilding and heavy industry plants as well as electronic component factories. In addition to the city center, which has the second-largest number of offices (approximately 14% of the total amount in the prefecture (DSPD 2016)) in the Mie Prefecture, these functions of Tsu as the center of the oceanic economy are essential to the prefecture's socioeconomic activities. Therefore, the occurrence of natural disasters in Tsu would have a severe impact on the entire prefecture.

## 1.1 Review on disaster impact assessment

For economic disaster impact analysis, there are several types of conventional economic models, such as Input-Output (IO), Social Accounting Matrix (SAM), and Computable General Equilibrium (CGE) (Okuyama 2008).

An IO table can provide an overview of the economic structure and sectoral interdependence in the disaster scenario setting stage. Moreover, it can also help distinguish between economic losses triggered by labor and capital production factors (Okuyama and Chang 2004). The logic of IO analysis has been widely recognized to provide a timely estimate of the interconnected impact for recovery plans and finances to evaluate disaster countermeasures in the pre-event period (Okuyama and Santos 2014). Nevertheless, the limitation of IO analysis is its feature of linear analysis, identical and fixed products, and efficient employment of all local resources. The county-level SAM could be used to estimate economic damage due to lifeline failures (Cole 1998).

To further reveal the change in production and price resulting from a disaster shock, the computable general equilibrium (CGE) model is widely used. For example, it has been used to assess economic losses from natural disasters in studies conducted by Boisvert (1992), Brookshire and McKee (1992), Rose and Guha (2004), and Rose and Liao (2005). Moreover, in the realistic sense, price change, factor losses in capital, and labor endowment triggered by disaster shock may require non-linear interpretation, such as the CGE model, to simultaneously capture the fluctuation. For disaster impact assessment, the usefulness of the CGE model serves to identify vulnerable sectors for potential disasters. Such a model could provide a theoretical basis to explain the linkages of an economy with indirect impacts due to production loss (Huang and Hosoe 2016, 2017).

The application of the Global Trade Analysis Project (GTAP) model (multiregional, multisectoral CGE modeling) is considered an effective tool to investigate the disaster impact on price change, external trade, and welfare change on a global scale (Huang and Masuda 2020; Huang, Tanaka, and Yoshioka forthcoming). The quantified economic impact could visualize sectoral vulnerability and advise about disaster reduction plans in an *ex-ante* manner.

Under the support of a quantitative approach like the CGE model, the spatial analysis could strengthen the analytical capability with plausible geographic parameters in the model scope (Kajitani and Tatano 2019). While the CGE model is mainly limited to a single region scope, the support of a geographic information system (GIS) can efficiently improve the accuracy of estimated impacts (Chen *et al*., 2011). Moreover, building and population data can provide essential information for factor change assumptions to allocate public facilities (Lwin and Murayama 2009). For example, for studies in Japan, Tanaka and Huang (2021) analyzed the tsunami risk of Hakodate City in the Hokkaido area using a dynamic CGE model based on a hazard map and census used to assess tsunami disaster impact. Their simulation results showed that fisheries and other ocean-related industries would be highly vulnerable and may not recover simply with the fiscal support of Hakodate.

In addition to the abovementioned econometrics, the vulnerability index (VI) has been discussed through many perspectives, such as the climate vulnerability index through GIS hazard mapping (Yusuf and Francisco 2009; Peduzzi, Dao, Herold *et al*. 2009; Moench, Khan, MacClune *et al*. 2017), livelihood vulnerability index to identify administrative level with socioeconomic and biophysical datasets (Shah, Dulal, Johnson *et al*. 2013; Mainali and Pricope 2019), and flood vulnerability to estimate the sub-catchment effect (Balica and Wright 2010; Balica, Wright, and Van der Meulen 2012; Karmaoui and Balica 2019). These multidisciplinary approaches to measuring the VI imply quantitative implications for disaster risk management. For instance, the VI of economic impact, propagation length, and sector size demonstrates the usefulness of enabling policymakers to determine key sector prioritization post-disaster (Yu, Tan, Aviso, *et al*. 2014).

### 1.2 Aims and analytical flow

This study provides a systematic methodology framework to estimate disaster risk and its economic impact using an industry and welfare analysis. Through CGE modeling based on an IO table of the Mie Prefecture and GIS analysis, we expect to capture the spatial features of the industry with concrete policy implications for disaster risk reduction. Additionally, the sectoral economic impact and VI will be demonstrated as comprehensive indicators to interpret the level of vulnerability.

The study proceeds as follows - Section 2 explains data-used, sectoral classification from IO table, the model structure and scenario setting of CGE, and tsunami damage estimation by GIS; section 3 presents the simulation results and design of the VI; the concluding remarks in section 4 provide policy recommendations and prospects.

## 2. METHOD

### 2.1 Data

In order to merge geographical information of industries and IO table datasets, we applied various data. Table 1 summarizes the information used in the study.

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**Table 1.** Summary of data used

| Name of data | Source | Spatial scale | Year | Note. |
|---|---|---|---|---|
| Tsunami hazard map | MLIT (2016) | 10 m | 2016 | |
| Office (capital) geographical data | NSS Corporation Ltd. (2020) | Longitude, Latitude | 2020 | 155 sectors |
| Labor endowment | Statistics Bureau of Japan (2018) | Street division | 2016 | 99 sectors |
| Building types | MIC (2019) | City, town | 2019 | Table A.1 |
| Damage definition | CDMC(2003), Hokkaido Disaster Risk Reduction Information (2006) | Japan | 2003, 2006 | Applied in Tanaka and Huang (2021) |
| Input-output table | DSPD (2020) | Prefecture | 2015 | 42 sectors |

## 2.2 Sectoral classification

**Table 2.** Economic structure of Mie Prefecture (%)

| Abbreviation | Sector | Output share | Capital dependency |
|---|---|---|---|
| AGR | Agriculture | 0.8 | 78.6 |
| FIS | Fishery | 0.3 | 57.6 |
| POA | Coal and petroleum | 8.1 | 91.0 |
| FOD | Food processing | 3.8 | 53.6 |
| WPP | Wood, paper, and printing | 1.7 | 39.0 |
| CHM | Chemical products | 9.7 | 49.2 |
| POT | Pottery | 1.1 | 47.5 |
| STL | Steel | 5.7 | 39.9 |
| MCH | Machinery | 5.1 | 39.2 |
| EEQ | Electronic equipment | 13.1 | 61.1 |
| TEQ | Transport equipment | 10.9 | 42.8 |
| MAN | Manufacturing | 1.0 | 26.8 |
| CON | Construction | 2.7 | 15.6 |
| ELY | Electricity and water | 3.0 | 65.4 |
| PUB | Public administration | 1.9 | 41.7 |
| COM | Commerce | 6.9 | 36.5 |
| FIN | Finance | 5.2 | 83.3 |
| TRS | Transportation | 2.9 | 31.8 |
| EDU | Education | 3.1 | 27.0 |
| MED | Medical service | 3.3 | 16.6 |
| REC | Recreation, restaurant, and hotel | 2.4 | 39.8 |
| SRV | Service | 7.3 | 48.4 |

Source: Extracted by the authors based on Mie Prefecture 2015 IO table

We categorized 22 new sectors aggregated from 42 sectors organized in the 2015 Mie Prefecture IO table. Table 2 demonstrates the new sectoral classifications with the display of output share and capital dependency sourced from the IO table. The output share shows that the output share of 1st industry of agriculture (AGR) and fishery (FIS) was only 1.1%. In contrast, electronic equipment (EEQ), transport equipment (TEQ), chemical products (CHM), and coal and petroleum (POA) are the most important sectors of the 2nd industry in the Mie Prefecture, accounting for 41.8% of the total output. For the 3rd industry, service (SRV), commerce (COM), and finance (FIN) sectors account for 19.3% of the total output.

### 2.3 Computable general equilibrium (CGE) model

#### 2.3.1 Model structure

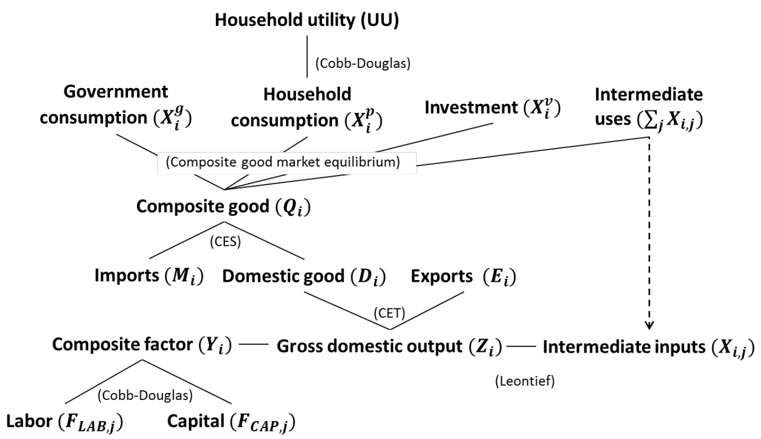


**Figure 1.** CGE model structure

Source: Amended by authors based on Hosoe *et al*. (2010) and Tanaka and Huang (2020).

To analyze the impact of tsunami disaster, we applied a CGE model to capture the economic impact triggered by an assumed tsunami shock. Based on the model structure developed by Hosoe, Gasawa, and Hashimoto (2010), we accommodated Mie's IO table with the disaster analysis methods initiated by Huang and Hosoe (2016). Figure 1 shows the model structure.

The production assumed a substitution between capital and labor factors in value-added production with Cobb–Douglas production functions. While the labor and capital input contributed to the sectoral output with the Leontief-type function as the production function for gross output made up of value-added and intermediate inputs. On the other hand, household and government, investment, and intermediate uses with elasticities are under Armington's composite goods (Armington 1969) assumption, which was calibrated from the GTAP database version 10. We conducted a sensitivity test to ensure the robustness of the simulation results, as shown in tables A3 and A4. The gross output was transformed into domestic goods and exports, with constant elasticity of transformation (CET) functions as follows:

- Gross domestic output transformation function: $Z_i = \theta_i\left(\xi e_i {E_i}^{\phi_i} + \xi d_i {D_i}^{\phi_i}\right)^{1/\phi_i}$

  where $Z_i$ : sectoral output; $\xi$ : share parameter; $E_i$ : export good; $D_i$ : domestic good;

  $e_i, d_i$ : share coefficient for transformation; $\phi_i$=transformation elasticity parameter.

- Export supply function: $E_i = \left[\frac{{\theta_i}^{\phi_i}\xi e_i(1+\tau_i^z)p_i^z}{p_i^e}\right]^{1/(1-\phi_i)} Z_i$
- Domestic good demand function: $D_i = \left[\frac{{\theta_i}^{\phi_i}\xi d_i(1+\tau_i^z)p_i^z}{p_i^d}\right]^{1/(1-\phi_i)} Z_i$

  where ${\theta_i}^{\phi_i}$: scale parameter in Armington function; $p_i^d, p_i^z, p_i^e$: the price of goods.

Composite goods were produced with domestic goods, and imports with constant elasticity of substitution (CES) functions as follows:

- Gross domestic output substitution function: $Q_i = \gamma_i(\delta m_i {M_i}^{\eta_i} + \delta d_i {D_i}^{\eta_i})^{1/\eta_i}$

  where $Q_i$ : sectoral output; $\delta$: share parameter; $M_i$ : import good; $D_i$ : domestic good;

  mi, di : share coefficient for substitution; $\eta$i=substitution elasticity parameter;

- Import demand function: $M_i = \left[\frac{{\gamma_i}^{\eta_i}\delta m_i p_i^q}{(1+\tau_i^m)p_i^m}\right]^{1/(1-\eta_i)} Q_i$
- Domestic good demand function: $D_i = \left[\frac{{\gamma_i}^{\eta_i}\delta d_i p_i^q}{p_i^d}\right]^{1/(1-\eta_i)} Q_i$

  where ${\gamma_i}^{\eta_i}$: scale parameter in Armington function; $p_i^d, p_i^q, p_i^e$: the price of goods.

We use a Cobb-Douglas-type utility function to analyze social welfare, measured by the Hicksian equivalent variations (EVs) based on a household's change in consumption. Welfare refers to the expenditure function that contributes to the utility of EVs before $UU^0$ and after $UU^1$ in response to a disaster shock with output and price changes. Finally, we assume the household to be in Cobb–Douglas utility function, which depends on the consumption goods composite.

- Household demand for goods: $X_i^p = \frac{\alpha_i}{p^q}\left(\sum_{h,j} p_{h,j}^f FF_{h,j} - S^p - T^d\right)$

  where $p^q$ : price of Armington's goods, $p^f$ : factor price, $S^p$ : private savings, *and* $T^d$ is tax.

- The welfare function was determined by $ep(p^q,\ UU) = \min_{XP}\{p^q \cdot |UU(X^p) = UU\}$

$$EV = ep(p^q,\ UU^1) - ep(p^q,\ UU^0)$$

where *ep(·)* :expenditure function, $X^p$: consumption vector, *and* $p^q$ :price vector.

*UU*: utility level (given); *UU(·)*: utility function

The impact of disasters on capital and labor losses may lead to decreased production and a price change, resulting in a new equilibrium in household welfare as a social benefit or cost. If the price of import goods is lower than domestic goods, consumption and production may alter accordingly.

### 2.4 GIS analysis

#### 2.4.1 Office (capital) points and labor endowments in the tsunami hazard map

The direct impact of tsunami hazard is determined by the estimated inundation area and height of the tsunami. We calibrated tsunami height data with the report prepared by Cabinet Office (2012a, 2012b) modeling a Nankai Trough M9.1 Earthquake. The seven most serious tsunami fault models for the Mie Prefecture were selected, and the simulation results were overlapped to extract the highest tsunami height, which was applied to the tsunami hazard map. The height of the tsunami was categorized with seven quantiles (≤0.3m; 0.3-2m; 2-5m; 5-10m; 10-20m; 20-50m; and ≥50m).

We used the Mie Prefecture telephone dictionary to develop detailed simulations. In total, 710,059 office points supplied the names of offices by more than 1,200 industries. The number of industries was firstly categorized as 155 to ensure the analytical capacity of the study. Figure 2 shows the spatial distribution of tsunami flooding height and office location around Tsu in the Mie Prefecture.

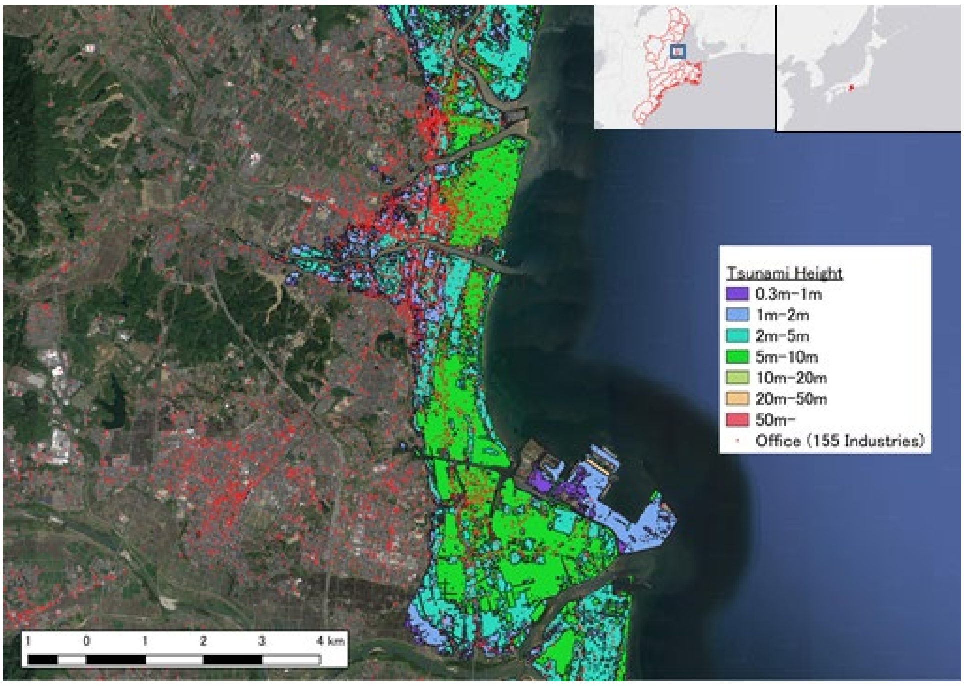


**Figure 2.** Tsunami-affected area and office (capital) points
Source: Estimated by the authors.

The office datasets have no information on labor; thus, it was assumed based on the Economic Census for Business Activity in 2016 with 99 industries and allocated to each office point based on the corresponding industrial classification. Merging 155 industries into 99 industries, we added the number of laborers in each industry at the street level to each point on the same street. Aggregating those 99 industries into sectoral classifications of Table 2, we consequently obtained geographical information of office points with the number of laborers from 22 industries and tsunami-height information.

### 2.4.2 Tsunami damage estimation

Damages caused by tsunamis generally differ based on the building material used and the structure. To accommodate this feature, we used city-level wooden/non-wooden ratio to estimate damage specifically, assuming that the homogenous ratio of wooden and non-wooden in each of the 29 sub-regions in the Mie Prefecture (Table A1). The damage definition for each building type followed the Central Disaster Management Council (CDMC) (2003) and Hokkaido Disaster Risk Reduction Information (2006), which distinguishes four damage categories: fully destroyed, half-destroyed, inundated over, and under floors with tsunami heights of 0.5 m or 1 m degree. However, the tsunami height published by the Mie Prefecture was categorized into seven quantiles, as mentioned above. Thus, the damage definition used in this study was not the same as that of the CDMC (2003) and Hokkaido Disaster Risk Reduction Information (2006). Table 3 lists the tsunami damage classifications.

**Table 3.** Tsunami damage definition

| Damage category | Flooded height (m) | |
|---|---|---|
| | **Wooden buildings** | **Non-wooden buildings** |
| 0 % | 0.0 m < H < 0.3 m | 0.0 m < H < 2.0 m |
| 25 % | 0.3 m ≦ H ≦ 1.0 m | 2.0 m ≦ H < 5.0 m |
| 50 % | 1.0 m ≦ H ≦ 2.0 m | 5.0 m ≦ H < 10.0 m |
| 100 % | 2.0 m ≦ H | 10.0 m ≦ H |

Table 4 summarizes the results of the damage estimates. The estimated tsunami risk was highly associated with the location and building type. The sectors of the fishery (FIS), food processing (FOD), electricity and water (ELY), and transport equipment (TEQ) revealed the most severe damage of 14.9 %–51.4%, while the total labor loss rate was 8.1%.

**Table 4.** Sectoral damage estimate

| Sector | Damaged wooden building | Damaged non-wooden building | Total building | Sector damage |
|---|---|---|---|---|
| AGR | 23 | 5 | 545 | 7.3% |
| FIS | 38 | 7 | 124 | 51.4% |
| POA | 5 | 1 | 73 | 12.2% |
| FOD | 135 | 26 | 1,171 | 14.9% |
| WPP | 99 | 18 | 1,536 | 11.6% |
| CHM | 29 | 5 | 663 | 8.9% |
| POT | 27 | 5 | 561 | 4.8% |
| STL | 90 | 20 | 1,169 | 13.9% |
| MCH | 66 | 14 | 992 | 10.9% |
| EEQ | 37 | 8 | 505 | 13.5% |
| TEQ | 46 | 10 | 541 | 14.7% |
| MAN | 30 | 6 | 431 | 12.2% |
| CON | 536 | 100 | 7,878 | 11.6% |
| ELY | 11 | 2 | 106 | 19.2% |
| PUB | 141 | 26 | 1,416 | 11.4% |
| EDU | 152 | 27 | 2,544 | 7.9% |
| COM | 1,651 | 305 | 19,562 | 14.1% |
| FIN | 427 | 77 | 5,104 | 11.7% |
| TRS | 175 | 31 | 2,340 | 12.5% |
| MED | 371 | 67 | 5,646 | 10.2% |
| REC | 1,300 | 234 | 15,358 | 13.9% |
| SRV | 634 | 112 | 8,841 | 11.2% |
| LAB | 49,559 | 9,120 | 726,863 | 8.1% |

## 3. SIMULATION RESULTS

### 3.1 Tsunami risk scenario

Based on the estimated damage shown in Table 4, we employed the CGE model with the aggregated 22-sector IO table. The capital and labor damage rates were calibrated into capital stock and labor endowment to reduce production factors. Meanwhile, to adequately demonstrate the sectoral losses resulting from tsunami damage and the actual situation of labor mobility, the capital was assumed to be immobile within a certain sector. In contrast, the labor factor was assumed to be mobile and could flow between sectors. Thus, the scenario setting could demonstrate the shock caused by a tsunami, its consequences for sectoral production, and the subsequent effect on prices and welfare.

After the tsunami shock in the scenario, the static simulation results of one period showed a change in economic indicators, including output, price, and external trade (Table 5). Thus, the impact was a one-year consequence, indicating the consequences of reducing production factors (capital and labor). The following subsection will interpret the results in detail and propose the design of the VI.

**Table 5.** Simulation results of tsunami shock (%)

| Sector | Output | Price | Export | Import |
|---|---|---|---|---|
| AGR | -7.3 | 0.7 | -4.4 | -13.5 |
| FIS | -39.8 | 20.8 | -51.3 | -4.6 |
| POA | -12.1 | 2.0 | -12.2 | -11.4 |
| FOD | -15.3 | 2.2 | -15.8 | -10.7 |
| WPP | -9.3 | 1.9 | -9.3 | -9.5 |
| CHM | -7.6 | 1.8 | -7.3 | -9.0 |
| POT | -4.2 | 1.5 | -3.0 | -10.3 |
| STL | -11.7 | 2.0 | -11.9 | -10.4 |
| MCH | -8.4 | 2.0 | -8.7 | -6.8 |
| EEQ | -12.1 | 2.4 | -13.7 | -7.3 |
| TEQ | -12.4 | 2.2 | -13.0 | -10.1 |
| MAN | -10.0 | 1.9 | -9.8 | -10.4 |
| CON | -6.3 | 1.6 | -5.6 | -6.9 |
| ELY | -15.8 | 5.0 | -22.6 | -3.6 |
| PUB | -9.8 | 1.6 | -9.2 | -10.6 |
| COM | -6.5 | 1.3 | -5.4 | -10.4 |
| FIN | -13.1 | 5.5 | -18.5 | -6.8 |
| TRS | -9.3 | 1.6 | -8.7 | -10.4 |
| EDU | -8.0 | 2.0 | -8.1 | -7.8 |
| MED | -9.3 | 0.9 | -7.5 | -11.0 |
| REC | -10.6 | 2.4 | -11.4 | -9.6 |
| SRV | -9.6 | 1.8 | -9.4 | -9.9 |
| EV | -496,756 million JPY | | | |

### 3.2 Output change

Due to the geographic features of the coastal area, the high exposure to tsunami risk of fisheries (FIS) was foreseeable. The output of the FIS decreased by 39.8%, followed by the sectors of electricity and water (ELY) (-15.8%), food processing (FOD) (-15.3%), finance (FIN) (13.1%), transport equipment (TEQ) (12.4%), electronic equipment (EEQ) (-12.1%), coa and petroleum (POA) (-12.1%), steel (STL) (-11.7%), while other manufacturing sectors showed a 4%–10% decrease. The impact was considerably high in the abovementioned industries in the Mie Prefecture.

### 3.3 Price change

The price indicator in the CGE model structure does not directly relate to the market price. Rather, it is a consequence of the new equilibrium of demand and supply. Nevertheless, the price indicator can help interpret the indirect impact of follow-up market transaction activities. Due to the massive output decrease in fisheries (FIS), the price increased substantially by 20.8%, implying the scarcity of production and reduced competitiveness in the export market (to other regions). Other notable changes are in electricity (ELY), finance (FIN) by 5%. The price change in different sectors showed a slight increase of 1%–2%, showing that the economic structure fluctuated accordingly.

### 3.4 External trades

The impact on sectoral exports showed a similar trend and decreased the rate with the output change, except that the fishery (FIS) showed a more significant decrease in exports by 51.3%. As for imports in other manufacturing sectors, agriculture (AGR), wood, paper, and printing (WPP), machinery (MCH), and pottery (POT) showed lower rates than their exports, implying that facility damage also reduced the demand for intermediate inputs.

### 3.5 Welfare analysis

Social welfare was measured using Hicksian Equilavent Variations (EV) based on the household consumption change according to the consumption composite ratio and income. Based on the simulation results, as all sectoral prices increased, the reduction of production generated resulted in a significant decrease in social welfare. Compared to the pre-disaster situation, the EV showed a decline of JPY496,756 million, equivalent to JPY668,049 for each household in the Mie Prefecture.[3]

### 3.6 Vulnerability index

In addition to the simulation results from the static CGE model analysis, we propose VI as an indicator that could help identify vulnerable sectors in the present situation. The purpose of the index is to provide an instant and visualized indicator to raise awareness for sectors where the vulnerability could be underestimated or overlooked within the indirect disaster impact, such as output or price change. When vital sectors in the second industry, such as electronic equipment (EEQ), transport equipment (TEQ), chemical products (CHM), and petroleum (POA), are more capable of implementing structural measures for disaster risk reduction, such as location and building reinforcement, small-medium enterprises (SMEs) may not be able to detect such risks. Their vulnerability remains hidden in the location of business units.

The design of the VI is set with the purpose of identifying the correlation between the disaster impact and the tsunami damage on the capital factor, highlighting sectors with less capital loss

[3] Based on the 2021 census, there are 743,592 households in the Mie Prefecture.

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but greater output loss. The formula can examine the ratio of disaster impact and capital damage to identify vulnerable sectors. The formula for VI was derived as follows:

$$Vulnerability\ Index\ (VI) = \frac{Disaster\ impact}{Capital\ damage}$$

where disaster impact: change of output, price, and external trade

VI may also represent the relative importance of a sector in contrast to other sectors in the economy. Following Yusuf and Francisco (2009), we normalized the index $\widetilde{VI_i}$ to the value between 0 and 1.

$$\widetilde{VI_i} = \frac{VI_i - VI_i^{Min}}{VI_i^{Max} - VI_i^{Min}}$$

where *i* is the sectoral impact, $VI_i^{Max} - VI_i^{Min}$ is the interval of the index, and the interval could be reversed if $VI_i$ is negative.

A higher unit represents higher vulnerability and a significant change. The visualization of the index could provide comprehensive information on the sectoral structures and serve as a good reference for stakeholders. Figure 3 shows the VIs of output, price, exports, and imports.

The output VI of agriculture (AGR), food processing (FOD), coal and petroleum (POA) were the highest among all sectors, followed by finance (FIN), medical service (MED), electronic equipment (EEQ), pottery (POT), public administration (PUB), service (SRV), chemicals (CHM). The VI for sectors in the second industry sector was relatively low, referring to their *ex-ante* countermeasures of location and building type. The sectors with a high VI implied that their exposed area and vulnerability could have been underestimated, and the disclosure of their fragility could be a reminder of a compound disaster risk because FOD, AGR, and POA should be the key sectors for disaster aftermath and reconstruction.

Price VI could be informative, especially for the sectors in the second industry, to adjust their strategy and *ex-ante* preparation for price fluctuations. The high price VI for fisheries (FIS), finance (FIN), pottery (POT), electricity (ELY) are quite significant, implying the scarcity of capital factor due to the sectoral damage and output decrease. In contrast, price VI of coal and petroleum (POA), food processing (FOD), wood, paper, and printing (WPP), and steel (STL) remained relatively low, indicating their resilience while facing the disaster.

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As for the external trade VI, we mainly focus on the second industry. The export of food processing (FOD), electronic equipment (EEQ), fisheries (FIS), coal and petroleum (POA) are more affected by the decrease in output. On the other hand, the high import VI in agriculture (AGR) and pottery (POT) indicated the decrease of aggregate demand.

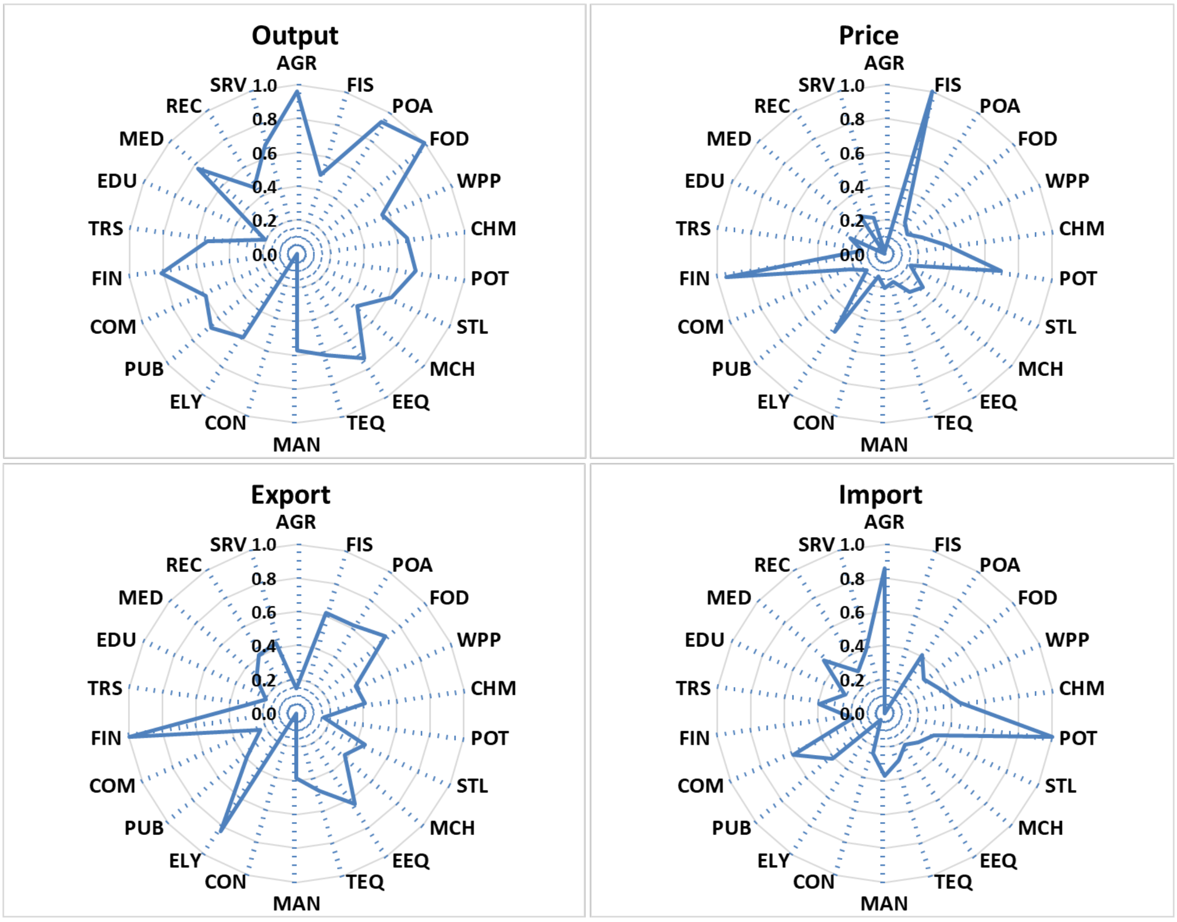


**Figure 3.** Vulnerability index of the impact

## 4. CONCLUSIONS AND POLICY IMPLICATION

This study provides a systematic and analytical methodology flow on disaster impact estimates of a possible Nankai Trough Earthquake and Tsunami in the Mie Prefecture of Japan by applying a CGE model and GIS.

The simulation results showed that the output of several sectors in the second industry could decrease significantly, such as electronic equipment (EEQ), transport equipment (TEQ), steel (STL), and commerce (COM), which could be reduced by 10%–15%. In comparison, their price fluctuates by 2%–3%. Additionally, fisheries (FIS) are drastically damaged in most indicators. The regional "vassal and harbor support mechanisms" should be developed to increase the capacity for disaster preparedness.

While the direct impact of a tsunami disaster could be interpreted in the form of capital and labor losses, we further proposed the creation of VI to further investigate the correlation between disaster impact and capital damage. Such indicators could help identify the indirect impact underestimated and overlooked, which could be informative for small and medium enterprises. VI can serve as an informative instrument for holistic risk identification. The highest output VI was revealed in food processing (FOD), agriculture (AGR), coal, and petroleum (POA), implying increased exposure in location and vulnerability to building type. Therefore, stakeholders should consider more *ex-ante* countermeasures, such as building reinforcement, relocation, or risk pooling through another insurance instrument to increase resilience.

This study has several limitations. Despite disaster impact and vulnerability assessment, the assumption of building categories of each capital may have been oversimplified at the city level. At the same time, the sector classification in the IO table, census, and GIS database was not specific or updated enough to enable more in-depth analysis. Meanwhile, interference between other regions in Japan was not considered, and an inter-regional analysis may be necessary. Nevertheless, this has been the most updated, accurate, and timely dataset that we could obtain.

As a future study, it would be more interesting to design a scenario of compound disasters for other cascading disasters, such as pandemics and energy crises, if the datasets permit. A dynamic analysis is desirable for follow-up research to estimate the recovery path and fund requirements for developing more financing instruments, enabling stakeholders to make cost-effective resource allocations for resilience investment.

We examine the impact of a tsunami on industries in Mie Prefecture by combining geographic information data and the CGE model. Our quantitative analysis provides insights for *ex-ante* disaster preparedness and risk mitigation investment by identifying vulnerable sectors in a region. The damage estimate enabled us to establish an evidence-based tsunami scenario with a comprehensive spatial analysis of the sectoral impact. The quantified and visualized disaster assessment would help researchers and stakeholders capture the economic impacts from the scope of sectoral vulnerability.

## REFERENCES

Armington, P. (1969) A Theory of demand for products distinguished by place of production. *IMF Economic Review 16*: 159–178.

Balica, S., and Wright, N. (2010) Reducing the complexity of the flood vulnerability index. *Environmental Hazards 9*(4): 321-339.

Balica, S., Wright, N., and van der Meulen, F. (2012). A flood vulnerability index for coastal cities and its use in assessing climate change impacts. *Natural Hazards* 64: 73-105.

Boisvert, S. (1992) *Indirect losses from a catastrophic earthquake and loca*l, regional, and national interest. In: Indirect Economic Consequences of a Catastrophic Earthquake, Washington, DC: National Earthquake Hazards Reduction Program, Federal Emergency Management Agency, 207–265.

Brookshire, D. and Mckee, M. (1992) Other indirect costs and losses from earthquakes: issues and estimation. In: Indirect Economic Consequences of a Catastrophic Earthquake, Washington, DC: National Earthquake Hazards Reduction Program, Federal Emergency Management Agency, 267–325.

Cabinet Office. (2012a) 南海トラフ巨大地震対策検討ワーキンググループ報道発表資料一式（平成２４年８月２９日発表）資料１－２都府県別市町村別最大津波高一覧表＜満潮位＞[Nankai Trough Earthquake Countermeasures Working Group Press Release (August 29, 2012), Document 1-2 Maximum Tsunami Height by City, Town and Village by Prefecture <High Tide Level>] (in Japanese).

Cabinet Office. (2012b) 南海トラフ巨大地震対策検討ワーキンググループ報道発表資料一式（平成２４年８月２９日発表）資料１－３市町村別平均津波高一覧表＜満潮位＞[The Nankai Trough Earthquake Countermeasures Working Group Press Release (released on August 29, 2012), Document 1-3: List of Average Tsunami Height by Municipality <High Tide Level> ] (in Japanese).

Cavallo, A., Cavallo, E., and Rigobon, R. (2014) Prices and supply disruptions during natural disasters. *Review of Income and Wealth 60*(52): 449-471.

Central Disaster Management Council (CDMC). (2003) 「東南海、南海地震等に関する専門調査会」（第１４回）東南海・南海地震防災対策推進地域の指定基準について [Special Investigation Committee on Tonankai and Nankai Earthquakes (14th), Designation criteria for Tonankai / Nankai earthquake disaster prevention measures promotion area] (in Japanese).

Chen, A., Peña-Mora, F. and Ouyang, Y. (2011) A collaborative GIS framework to support equipment distribution for civil engineering disaster response operations. *Automation in Construction 5*(20): 637-648.

Cole, S. (1998) Decision support for calamity preparedness: socioeconomic and interregional impacts, in: M. Shinozuka, A. Rose and R.T. Eguchi (Eds) Engineering and Socioeconomic Impacts of Earthquakes, NY: Multidisciplinary Center for Earthquake Engineering Research, 125-153.

Flanagan, B., Gregory, E., Hallisey, E., Heitgerd, J., and Lewis, B. (2020) A social Vulnerability index for disaster management. *Journal of Homeland Security and Emergency Management 8*(1).

Hokkaido Disaster Risk Reduction Information. (2006) 報告書データ（平成 18 年度　津波シミュレーション及び被害想定調査業務　太平洋沿岸西部）[Data of Report (Tsunami simulation and research of expected damage Western Pacific coast in 2006)] (in Japanese).

Hosoe, N., Gasawa, K., and Hashimoto, H. (2010) *Textbook of Computable general Equilibrium Modeling: Programming and Simulations*. Basingstoke: Palgrave Macmillan.

Huang, M., and Hosoe, N. (2016) Computable general equilibrium assessment of a compound disaster in northern Taiwan. *Review of Urban & Regional Development Studies 28*(2): 89–106.

Huang, M., and Hosoe, N. (2017) Fiscal and social costs of recovery programs for an earthquake disaster in northern Taiwan. *Journal of Asian Economics 53*: 1-17.

Huang, M., and Masuda, A. (2020) How do production networks affect the resilience of firms to economic and natural disasters: A methodological approach and assessment in Japan, Taiwan and Thailand. In: Anbumozhi V., Kimura F., Thangavelu S. (eds) *Supply Chain Resilience*. Springer.

Kajitani, Y., and Tatano, H. (2019) Advantages of the regional and sectoral disaggregation of a spatial computable general equilibrium model for the economic impact analysis of natural disasters. In Okuyama Y., Rose A. (eds) *Advances in Spatial and Economic Modeling of Disaster Impacts*, pp 327-358. Springer.

Karmaoui, A. and Balica, S. (2021) A new flood vulnerability index adapted for the pre-Saharan region, *International Journal of River Basin Management 19*(1): 93-107.

Løvholt, F., Setiadi, N., Birkmann, J., Harbitz, C., Bach, C., Fernando, N., Kaiser, G., and Nadim, F. (2014) Tsunami risk reduction - are we better prepared today than in 2004? *International Journal of Disaster Risk Reduction 10*: 127-142.

Lwin, K., and Murayama, Y. (2009) A GIS approach to estimation of building population for micro-spatial analysis. *Transactions in GIS* 13(4): 401-414.

Mainali, J. and Pricope, N. (2019) Mapping the need for adaptation: assessing drought vulnerability using the livelihood vulnerability index approach in a mid-hill region of Nepal, *Climate and Development 11*(7): 607-622.

Moench, M., Khan, F., MacClune, K.,Amman, C., Tran, P., Hawley, K. (2017) Transforming vulnerability: shelter, adaptation, and climate thresholds, *Climate and Development 9*(1): 22-35.

Mie Prefectural Government's Disaster Prevention and Countermeasures Department (DPCD). (2014) 地震被害想定調査結果（リスク関係）の概要について [The results of the earthquake damage estimation survey (hazard-related) Overview](in Japanese).

Mie Prefectural Government’s Statistics Division, Strategic Planning Department (DSPD). (2016) 平成２６年経済センサス [Results of the 2016 Economic Census] (in Japanese).

Mie Prefectural Government’s Statistics Division, Strategic Planning Department (DSPD). (2020) 平成２７年三重県産業連関表 [Input-Output table of Mie Prefecture in 2015] (in Japanese).

Mie Prefectural Government’s Disaster Prevention Measures Department (DPMD). (2015) 津波浸水予測図（平成２５年度地震被害想定調査）[The tsunami inundation expectation area map (Research of expected of damage by earthquake in 2015)] (in Japanese).

Ministry of Economy, Trade and Industry (METI). (2014) 三重県の地域経済分析 [Regional Economic Analysis of Mie Prefecture] (in Japanese).

Ministry of Internal Affairs and Communications (MIC). (2019) 令和元年度（平成３１年度） 固定資産の価格等の概要調書 [Outline report of price etc. of fixed assets] (in Japanese).

Ministry of Land, Infrastructure, Transport and Tourism (MLIT). (2016) Tsunami Inundation simulation data.

NSS Corporation Ltd. (2020) 全国事業所データベース [Database of nationwide offices] (in Japanese).

Okuyama, Y., and Chang, S. (2004) *Modeling Spatial and Economic Impacts of Disasters*, Springer.

Okuyama, Y. (2008) Critical review of methodologies on disaster impact estimation, Background paper for EDRR report.

Okuyama,Y. and Santos, J. (2014) Disaster impact and input-output analysis, *Economic Systems Research 26*(1): 1-12.

Peduzzi, P., Dao, H., Herold, C., and Mouton, F. (2009) Assessing global exposure and vulnerability towards natural hazards: The Disaster Risk Index. *Natural Hazards and Earth System Science 9*: 1149–1159.

Rose, A., and Guha, G. (2004) Computable general equilibrium modeling of electric utility lifeline losses from earthquakes. In: *Modeling Spatial and Economic Impacts of Disasters, Berlin*: Springer, 119-141.

Rose, A., and Liao, S. (2005) Modeling Regional Economic Resilience to Disasters: A Computable General Equilibrium Analysis of Water Service Disruptions. *Journal of Regional Science 45*(1): 75–112.

Statistics Bureau of Japan. (2018) 2016 Economic Census for Business Activity.

Tanaka, H., and Huang, M. (2021) Impact assessment and a fiscal recovery policy for tsunami risk: GIS and the general equilibrium approach in Hakodate city, Japan. Environment and Planning B: *Urban Analytics and City Science 48*(5):1144-1160. https://doi.org/10.1177/2399808320977865

Yu, K., Tan, R., Aviso, K., Promentilla, M. and Santos, J. (2014) A Vulnerability index for post-disaster key sector prioritization, *Economic Systems Research 26*(1): 81-97.

Yusuf, A., and Francisco, H. (2009) Climate change vulnerability mapping for Southeast Asia vulnerability, Economy and Environment Program for Southeast Asia (EEPSEA) https://www.preventionweb.net/files/7865_12324196651MappingReport1.pdf

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Original paper

# Social Innovation Hackathon for Driving Innovation in Disaster Risk Reduction (DRR)

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**Abstract** Time and again, disasters bring forth various challenges concerning risk communication, disaster-resilient infrastructure, last-mile delivery, disaster reporting, etc. These challenges often highlight the existing gap between research and academicians, and the policymakers and practitioners. Secondly, it brings forth the lack of adequate collaboration among experts and practitioners of different fields. Most of these challenges require innovative and low-cost solutions catering to local and contextualized problems, and calls for a multi- and transdisciplinary approach and collaboration.

With this vision, amidst the current pandemic of COVID-19, Resilience Innovation Knowledge Academy (RIKA) India, Indo-Japan Laboratory (Keio University, Japan) and four partnering universities have launched the Social Innovation Online Hackathon (SIOH) 2020. SIOH aims to provide a unique virtual platform to student innovators and mission-driven entrepreneurs from different fields like architecture, engineering, disaster management, etc., to collaborate and develop innovative solutions for tackling the pandemic and future disasters.

The paper aims to introduce SIOH and its four-step process as a tool of multi-disciplinary collaboration to promote innovation for Disaster Risk Reduction (DRR). Besides the critical outcomes of the SIOH, the paper seeks to flag some indirect positive impacts of such an exercise. Among others, these include, firstly, the introduction of the field of DRR to academicians and practitioners of other sectors, thereby paving the way for its mainstreaming in other sectors. Secondly, such an exercise involving young students envisages to invoke a spirit of inquiry and innovation, which is crucial for bringing social change. Thirdly, it

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highlights the critical role of proper sectoral mentorship in handholding the young innovators in their journey of building resilient societies.

**Keywords:** Innovation, disaster risk reduction, resilient, youth, entrepreneurs

## 1. INTRODUCTION

### Brief background and problem/gap

While disasters bring considerable destruction, they also provide an opportunity to learn from the process and recover stronger. Finding innovative approaches to risk reduction and management are among such opportunities. The recent development and implementation of effective evidence-based approaches call for the application of innovation in science and technology, as well as in the social domain. Despite the recognized importance of scientific and evidence-based policy-making in DRR, the policy-making keeps operating in silos without integrating the practices and knowledge of the DRR (Albris *et al.*, 2020). The Sendai Framework for Disaster Risk Reduction (SFDRR) advocates for an increase in investment to support innovation. One of the foremost gaps identified in the implementation of priorities of SFDRR pertains to the limitation of the knowledge management system, which integrates knowledge on DRR and engages the domain's experts in policy-making (Rahman and Fang, 2019). Hackathons are one of the most effective platforms for devising intuitive solutions in a limited time frame. In this aspect, the paper explores the case study of the Social Innovation Online Hackathon (SIOH) as a means and process of channelizing the creativity and energy of young students, towards innovative and entrepreneurial prospects. The SIOH uses digital technology to bring together students from different regions and academic skills and ushers in the use of technology to create solutions to various development challenges. The lack of supportive policies and initiatives limits the use of innovation, and science, and technology in DRR (Izumi *et al.*, 2019b). An increased co-production of knowledge, resources with practitioners and researchers, helps develop innovations, and SIOH is one of the platforms to bring together the stakeholders in DRR. This also helps in enhanced communication between the stakeholders and in bridging the gap between national and local initiatives and resources (ibid). The social sciences play an important role in new thinking on risk, vulnerability, poverty, and the human roles in DRR (ibid). The inter-disciplinary concepts foster innovation in resilience and facilitate feeding local information into DRR policy-making.

### Methods

The paper uses a case study approach to better understand the social innovation hackathon in DRR and sustainable development. The Indo-Japan Laboratory (IJL), Keio University

(Japan), and Resilience Innovation Knowledge Academy (RIKA) India in collaboration with the four coveted Indian universities, namely, Indian Institute of Technology (IIT) Roorkee, IIT Hyderabad, National Institute of Technology (NIT) Durgapur, and Visvesvaraya National Institute of Technology (VNIT) Nagpur jointly organized the Social Innovation Online Hackathon (SIOH) 2020. The close monitoring and evaluation of the SIOH helped in developing the current case study. The team undertook four rounds of assessments over two and a half months using different monitoring and evaluation tools to study the experience of involved innovators, mentors, the SIOH process, and its impacts. These tools included scoring rubrics, descriptive assessment, and online questionnaire-based assessment using Google forms. The developed questionnaire included both closed and open-ended questions targeting different phases of the SIOH. The assessments using the scoring rubrics were temporal and helped in comparing the understanding, learning, impacts, and overall experience of the innovators at the onset and completion of the SIOH. The paper captures the process of the SIOH, and some of these key changes, for highlighting the challenges faced and learning for future improvements in conducting and nurturing social innovation in DRR and sustainable development.

## 2. INNOVATION AND INCUBATION

Incubation is the process in which a nascent idea is nurtured and developed as an entrepreneurial start-up. Incubators are like launchpads for ideas to get progressed as implementable projects (Bajwa et al., 2021). The concept of the incubator originated in the early 1950s in the United States. The term incubator is derived from the root term, which means nurturing; incubators develop small companies in a protected environment (Rodrigues and Franco, 2019). Incubators provide support to budding entrepreneurs in the early start and development of their ideas. They help grow the idea through mentorship and association with industry networks and provide support in forming new partners, creating business models, integrating marketing techniques, and financial support. They provide financial support through seed funding, easing the access to market funds through loans or venture capitalists.

As per (Tidd *et al.*, 2005), there are four types of innovations; i) product innovation; ii) process innovation, which involves alternative ways of creating products; iii) position innovation, which involves ways of introducing products in the market, and; iv) paradigm innovation, which targets shifting of perception. The global policy frameworks highlight the increasing role of science and technology, the private sector, and research to achieve their targets. Priority 3 of the Sendai Framework refers to the importance of private investment, private cooperation, and business resilience. The Sustainable Development Goals (SDGs) talk about the need for investment in innovation, partnership, and sustainability. The Private Sector Alliance for Disaster Resilient Societies (ARISE) Initiative of UNDRR endeavors to increase the private sector's participation in DRR. In India, the Prime Minister's 10-point agenda

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highlights the importance of research, universities, and the role of the private sector's cooperation with the government in DRR.

In this aspect, social innovation is a process whereby the resultant solution or idea aims to address social problems. We can understand the domain of social problems from the envisaged goals and targets of the global frameworks of SDGs and SFDRR. Through their 17 goals, SDGs highlight the key issues of poverty, health, education, infrastructure, environment, etc., which can be taken up as challenges for innovation. Public-private partnership is one of the main platforms for visualizing and achieving social innovation. Social innovation may or may not lead to social entrepreneurship. When social innovation becomes the key focus of the incubation, those incubators may help drive the idea towards entrepreneurial ventures through training. As per (Murray *et al.*, 2010), there are six stages of social innovation, namely: i) Prompts- which highlight problems and inspirations with a need for a solution; ii) Proposals- which include idea generation process; iii) Prototypes-which focus on idea testing; iv) Sustaining- for integration of idea daily life along with steady revenue source; v) Scaling- for expanding the idea to different sectors through both increases in demand and supply, and; vi) Systemic change- which leads to a macroscopic change in the overall business, economy, or in the identified sector.

**Key challenges**

The main challenges in the sector of incubation for social innovation are the limited option of growth and the reliability of funding sources (Murray *et al.*, 2010). Since the business perspective may be limited in social innovation, it attracts fewer private investors. Further, the grant donors are more biased towards programs and projects than investing in incubators for social innovation (ibid).

## 3. INNOVATION HACKATHON

The term hackathon is derived from two words: hacking and marathon (Komssi *et al.*, 2015). This refers to an intense and continuous period of programming to crowdsource solutions for technological and social problems. Hackathons allow small groups to work on a specific challenge to derive solutions. Hackathons are popular in the technology world and require innovative thinking to develop a working model or prototype within a defined duration. Further, hackathons are social events that provide opportunities to meet new people and ideate with people from different disciplines and backgrounds. A hackathon begins with idea generation and team building as the first step. The group members are organized based on their skill set, and interest in the specific idea. Thereafter, within a specific time duration, the groups develop a working model to demonstrate solutions to the specific problem. Post-hackathon, the plausible solutions are often carried forward through sponsorships. Hackathons enable a

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bottom-up and collaborative approach to develop innovative ideas (ibid). Organizations conduct hackathons for their internal staff and teams to promote innovation and ideation. Such hackathons are called internal hackathons. The external hackathons involve a wide range of stakeholders from the local community, industry, academia, or government. External hackathons often lead to the generation of new start-ups.

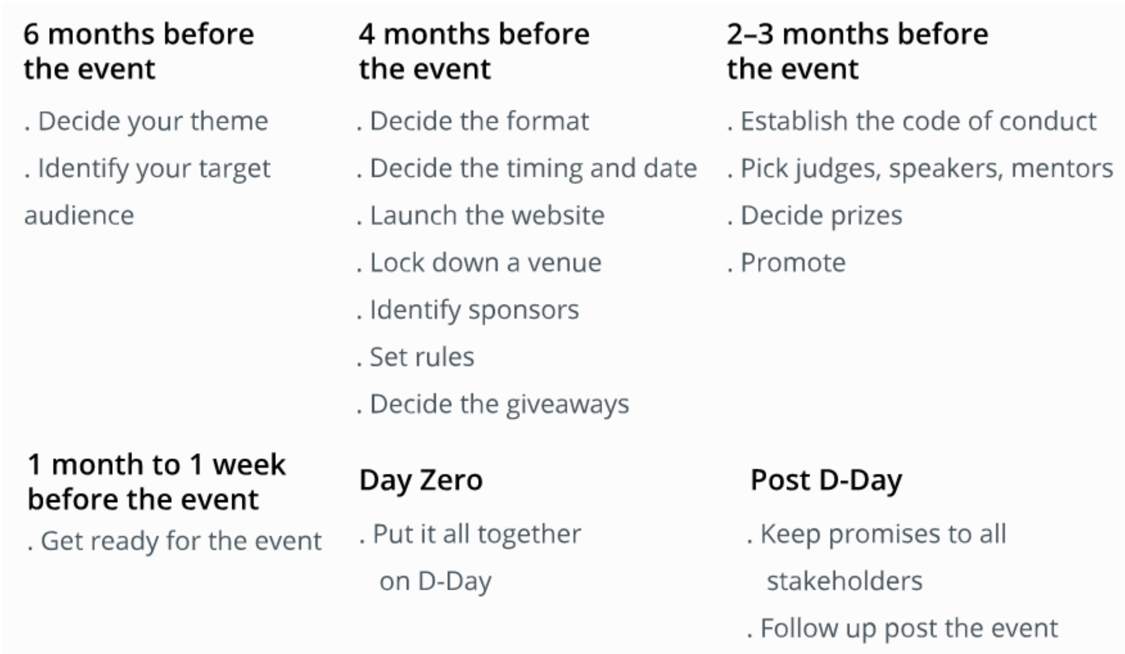


**Figure 1:** Basic format of the hackathon

Source: (HackerEarth, *n.d.*)

Social innovation hackathon goes beyond technological solutions and looks for ideas in new processes or new products that positively impact society. Social innovation hackathon builds solutions in the field of development. While commercial innovation aims at increasing profit margins, social innovation seeks to reduce disparity and strives to generate social capital through intervention (McKercher, 2017). The COVID-19 crises have witnessed increased social innovation events to counter the pandemic (Gegenhuber, 2020). The social innovation hackathon conducted in Germany (ibid) helped mobilize civil society towards innovative solutions and get funding from the government for the winning ideas. Social innovation hackathons help in community engagement and specifically provide a platform for youth to engage in problem-solving. Hackathons conducted with young innovators help to focus on local issues and enhance engagement with the local community. For environmental and climate change issues, the youth are already leading the change through their voices in the field of policy-making (ABC News, 2019). Hackathons conducted in universities offer opportunities for networking with industry partners, thus broadening the scope of employment options for the youth.

Despite the various objectives innovation hackathons fulfill, such as facilitating collaborations to ignite new ideas, they do not always lead to lasting innovations and market successes (Sastry and Penn, 2015). One of the key reasons for this is that innovation is inherently an iterative process of problem identification and solving, and often, the hackathons with the "winner-take-all" approach discourage the innovators from cherishing and learning from this iterative journey of innovation (ibid). Moreover, the closed ecosystem made available to the innovators during a hackathon tend to limit them from engaging with, understanding, and meaningfully undertaking ground/market studies (ibid). The concept of open innovations can address this limitation. Open innovation in the corporate world allows innovators' engagement with external stakeholders for enhancing the understanding and quality of the outcomes (Flores *et al.*, 2018)

## 4. INNOVATIONS AND INCUBATION IN DRR

### Factors triggering innovation in DRR

The world is witnessing substantial increase in the magnitude and frequency of disasters. The ever-increasing population, greater exposure & vulnerability meeting the climate-induced hazards result in intense and frequent disasters (Thomas and Lopez, 2015). Further, the nature of the hazards is evolving and giving rise to new, emerging and complex risks. The changing nature, intensity, and frequency of these disasters have caused a fundamental change and innovation in the existing approaches, products, and services to manage disasters and disaster risks. Additionally, underlying complex factors like rapid and unplanned urbanization, poverty, and environmental degradation, require more than conventional solutions and DRR measures (Izumi *et al.*, 2019a). Besides the changing landscape of climate and disaster risks, there is a significant development in science and technology over the years. The policy landscape in disaster risk management has also evolved significantly right from the Yokohama Strategy and Plan of Action for a Safer World, International Decade for Natural Disaster Reduction (IDNDR), to the adoption of the Sendai Framework for Disaster Risk Reduction (2015-30). The emerging landscapes have triggered the evolution of research and innovation in the field (Shaw, 2020).

The year 2015 witnessed global leaders resolve to strive to build a safer and sustainable world resilient to climate and disaster risks. This led to the adoption of various global frameworks and agreements, including the Sendai Framework, the 2030 Agenda for Sustainable Development, the Paris Climate Agreement, and the New Urban Agenda. The synchronous adoption of these frameworks and agendas provides and calls for multi-stakeholder and multi-sectoral collaborations along with the promotion of science and technology (Murray *et al.*, 2017). The practical implementation of these frameworks and agendas depends on the presence of a facilitating ecosystem that supports increased use of science, technology, innovation, knowledge-sharing, and capacity development (UN, 2017).

The Sendai Framework emphasizes investing in innovation for a better understanding of disaster risks and driving solutions towards disaster risk management (UN, 2015). This call for innovation in disaster risk management is not new. Earlier, the Hyogo Framework for Action 2005-15 had emphasized the "use of knowledge, innovation, and education for building the culture of safety and resilience at all levels" (UN, 2007).

Apart from these, a critical factor resulting in the effective implementation of innovations in different aspects of DRR is advancing scientific research and technologies in various related fields. For example, while the idea of earthquake early warning systems was conceptualized in 1868 by J.D.Cooper, the same could be implemented and tested much later after advancements in digital seismic instrumentations and digital communication technologies (Dabral *et al.*, 2021).

**Current status**

Like any other field, the innovations in DRR are not limited to products but are inclusive of process, approach, frameworks, and concepts, among others (Izumi *et al.*, 2019b). Innovation in DRR can be hazard-specific, or thematic, or concerning different phases of disaster management. As a multi- and inter-disciplinary field, DRR provides a great opportunity for innovation in its diverse dimensions, which are inclusive of natural, ecological, socio-cultural, economic, psycho-social aspects. Besides, there are various existing innovations targeting different phases of disaster management, such as prevention & mitigation, preparedness & capacity building, response & relief, and reconstruction, rehabilitation & recovery. Many innovations in DRR such as early warning systems, construction practices, and disaster-resilient practices are found to be very effective (ibid). Further, community-based DRR and risk management top the most effective innovations for DRR (Izumi *et al.* 2019b).

(Izumi *et al.* 2019a) recorded 30 innovative DRR products and approaches found effective for mitigating disaster risks. These include 14 products and 16 approaches. Some of these products are technological products such as GIS and remote sensing, drones, Doppler radar, earthquake early warning, etc. These have been useful in undertaking evidence-based interpretation, decision making, and raising timely alerts and warning for different hazards. Some products aimed at strengthening the infrastructural resilience include disaster-resilient materials, school cum cyclone shelter, concrete, and steel.

In contrast, other products include studies and survey exercises such as seismic micro-zonation and electricity resistant surveys. The key innovative approaches identified in (ibid) cater to different aspects of DRR such as hazard mapping, assessments, and terminologies enhancing the understanding of risk and supporting risk communication. Approaches such as Community-Based Disaster Risk Reduction (CBDRR), traditional practices, and evacuation behaviors and indigenous DDR technologies underscore the importance of community as a key stakeholder of DRR. Other innovative approaches such as Hyogo Framework for Action, the National Platform for Disaster Risk Reduction, and transnational initiatives on resilient cities have effectively laid down guiding and collaborative institutional mechanisms for DRR.

These innovative products and services were assessed on 6 critical parameters, including cost-effectiveness, impact on reducing deaths & number of affected persons, reduction in economic loss, level of application/penetration, environmentally friendly, and role in bringing behavioral change. A survey of academicians, NGOs, government, and private actors helped in understanding the effectiveness of these innovative products and services (Izumi *et al.*, 2019a). The survey found that both products and approaches are effective innovations that enhance the existing DRR efforts towards addressing newer challenges (ibid).

### Existing gaps

The newer challenges today in global society have highlighted the limitation of existing science and innovation systems and underscored the need for stronger support and promotion of science and innovation interface (OECD, 2004). For this, policies, funds, resources and stakeholders strengthening the science and innovation interface are required. The multi-sectoral and all-of-society approaches imbibed in the processes of DRR need to be reflected while undertaking the research and innovations of DRR. Besides these, the transboundary nature of climate and disaster risks such as the ongoing COVID-19 pandemic, cyclones, floods, and ecosystem degradation require a better understanding of the prevailing risks across borders, supported by cross-border knowledge sharing and collaboration, and innovation. However, platforms providing opportunities to diverse, multi- & inter-disciplinary, and cross-border innovators to come together to brainstorm and collaborate for DRR are not yet really popular.

The common perception of innovation being synonymous with technology is flawed. Innovation is inherently a human-centered process that includes inquiring, analysis, testing, and learning from unsuccessful attempts. While these can yield technological solutions but that may not always be the case (Callegaron 2017). (Izumi *et al.* 2019a) states that innovations may not always be high-technology products but can also be soft-measures like approaches and frameworks.

## 5. CASE STUDY OF SOCIAL INNOVATION ONLINE HACKATHON (SIOH) 2020

Amidst the uncertainties and disruption brought by the COVID-19 pandemic to the normal socio-economic functioning of the global society, the SIOH 2020 facilitated continuity of collaborative ideation and creation by young innovators. Because of the physical restrictions posed by the pandemic, the SIOH envisaged providing a virtual platform to innovators, academicians and field practitioners, and experts from diverse fields for co-creating solutions for social good and wellbeing (IJL and RIKA India, 2020). The key objectives of the SIOH include finding unique & innovative solutions for tackling impediments for sustainable development and DRR, co-creating local solutions for increasing societal resilience, promoting innovation and entrepreneurship among youth and young professionals, and encouraging the use of science and technology for social innovation.

## Themes and stakeholders of SIOH

The themes of SIOH targeted at six of the SDGs and envisaged to address some of the related socio-economic and ecological challenges which got aggravated during the COVID-19 pandemic. The six themes pertained to zero hunger (SDG 2), health and well-being (SDG 3), gender (SDG 5), clean water and sanitation (SDG 6), safe cities and communities (SDG 11), climate action (SDG 13). The forty-six students from the five participating universities were divided into six thematic groups for the SIOH based on the initial ideas proposed by them. The composition of the groups further ensured academic diversity through participants belonging to thirteen different academic disciplines such as disaster management, computer science, architecture, urban studies, and policy studies. Each group had students belonging to two countries, different universities and academic levels, such as graduation, post-graduation, and doctoral.

## SIOH 2020: Process

SIOH, which lasted for close to two and a half months, comprised of four stages to provide a systematic and guided experience to the young innovators on their journey of co-creating products and services for social good. These four stages are:

i. Ideation stage: This was the inception of the SIOH, and the stage allowed participating groups to virtually connect, brainstorm, discuss, and streamline their ideas.
ii. Maturation stage: The stage focused on consolidating and strengthening the group ideas by exploring and attempting to address the perceived implementation challenges.
iii. Tangible prototype development stage: This included putting the respective group ideas to test using different tools like online and field surveys of potential end-users, beneficiaries, and other stakeholders. The surveys helped the groups in identifying the gaps in the innovation and improving it. The stage also included the development of UI-UX-based interface designs by some groups to showcase their piloting strategies.
iv. Marketing strategy stage: During this stage, groups developed and refined their business model and strategies. The groups assessed their ideas for market feasibility and potential to generate revenue, while being commercially sustainable over time.

## Mentoring and monitoring

Throughout the entire process of SIOH, the six groups were closely guided, supported, and monitored by six professors and twenty-one thematic and cross-cutting mentors who were academicians, DRR practitioners, subject experts, and members of private sectors. Two to three thematic mentors assigned to each of the six groups provided theme-specific guidance and handholding across different stages of SIOH. These included mentoring on aspects of both hard and soft skills such as originality & practicality of the ideas, relevance of ideas to themes, scalability-adaptability-sustainability of the innovation, and strategies for effective brainstorming, problem-solving, presentation & communication skills, and time management.

The cross-cutting mentors were common for all groups. They provided overarching guidance to the groups on aspects of present gaps and challenges in innovation, practical applicability of innovations, understanding markets and end-users. Overall, thirty-five mentoring sessions of over fifty-two plus hours were conducted across different stages of the SIOH.

SIOH included four monitoring sessions spread across different stages of the SIOH to evaluate and assess the progress of each of the groups. Under these sessions, each group presented their ideas and progress made to a team of mentors and professors who evaluated the groups and provided feedback for improvement.

## SIOH 2020: Impact

The SIOH resulted in the consolidation of thirty-eight initial ideas to six final ideas. Three groups pitched their ideas to a larger audience comprising government authorities, private sector actors, potential investors, etc. Overall, the six innovations proposed by the groups have successfully identified the ground challenges in respective themes. The innovations broadly addressed a host of issues including supporting the livelihood of informally-operating street vendors during the current pandemic, providing safe queue management systems at COVID-19 testing and other health facilities, and facilitating water-efficient urban farming methods. They also focused on connecting local communities, with a view to help overcome the challenges of social isolation and other issues posed by an urban lifestyle, enabling plastic waste segregation at source in urban communities, et cetera.

Apart from these tangible innovations (products, services, platforms), SIOH made some intangible impacts on the participating groups, recorded through the four rounds of assessments (table 1). Assessments 1 and assessment 2 targeted the groups to understand their functioning, performance and temporal changes therein during the ideation (July 14, 2020) and maturation stages (August 18, 2020) through peer-based and self-assessment, respectively. The assessments used the tools like scoring rubrics and descriptive assessments. These assessments allowed the innovators to reflect on their as well as other groups' performance. Assessment 3 and assessment 4 were targeted at evaluating the process and impact of the SIOH, respectively. These assessments capture the individual learning, growth of the innovators, their experience, and feedback for improving the SIOH.

Assessment 1 and 2 evaluated the groups and individuals on parameters like comprehension, accuracy of information used, logical thinking, presentation material, attitude, and time management. The comparative results of peer assessment of group 1 are represented in figure 2. Responses A, B, C, N respectively refer to the most suitable, next suitable, less suitable, and non-applicable options under each of the six parameters. Figure 2 illustrates the positive change (in percentage) in the members of group 1 for almost all parameters. There is a remarkable improvement on the parameter of attitude (an increase from 2% to 15% for the most suitable option A). Similarly, time management of the group also improved significantly.

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**Table 1:** Four rounds of assessments under SIOH

| Assessment | Aim of assessment | Respondents | Tools used |
|---|---|---|---|
| Assessment1 | To evaluate groups' functioning and performance through peer-assessment during ideation & maturation phase | Student innovators (all groups) | Scoring rubrics, descriptive assessment |
| Assessment 2 | To evaluate groups' functioning and performance through self-assessment during ideation & maturation phase | Student innovators<br>(respective group members) | Scoring rubrics, descriptive assessment |
| Assessment 3 | To evaluate the process of innovation | Student innovators | Questionnaire (both closed and open-ended questions) |
| Assessment 4 | To evaluate the overall impact of the SIOH | Student innovators | Questionnaire (both closed and open-ended questions) |

Source: Authors

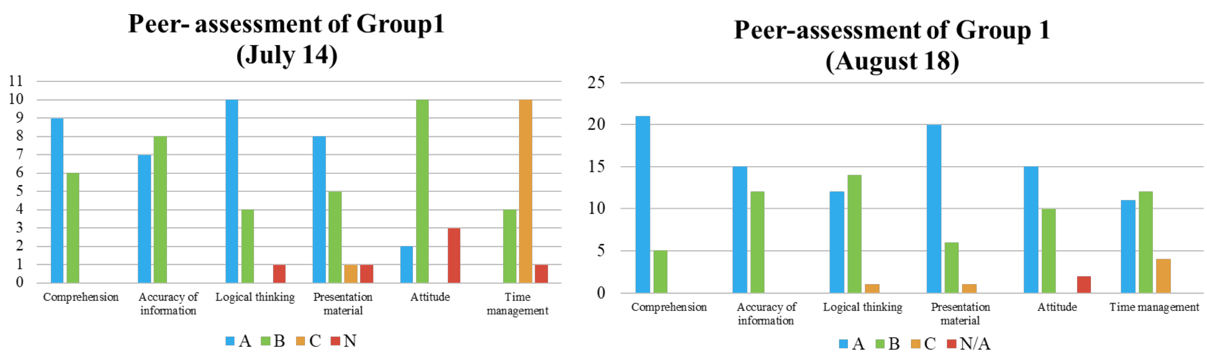


**Figure 2:** Comparative peer-assessments of group 1

Source: Authors

Similarly, based on the results of assessment 3, figure 3 illustrates the consolidated comparative changes in the effective use of presentation material by the six groups. It reflects that five out of six groups showed improvement in the effective use of presentation materials during the maturation stage compared to the ideation stage. In contrast, one group scored almost the same in both stages. These groups gained substantial skills to use graphs, charts, figures, info-graphics, audio-visual aids, etc. to illustrate better and put forward the identified problems and the proposed ideas.

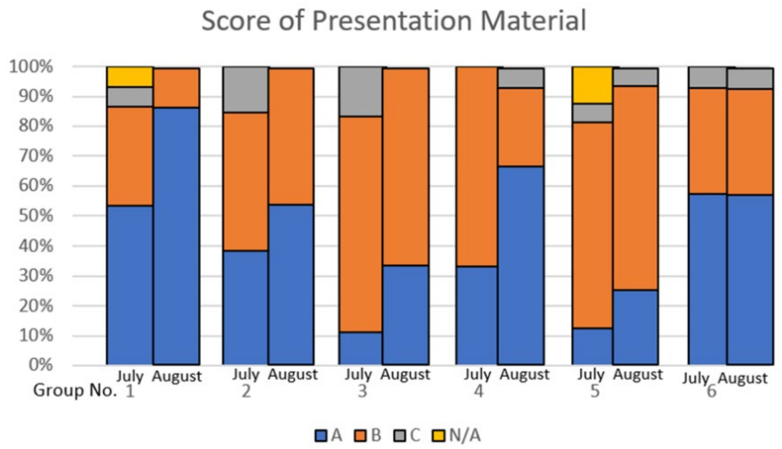


**Figure 3:** Consolidated comparative assessment of groups on the aspect of presentation material

Source: Authors

According to the result of assessment 4, 62% of the group members had worked towards improving the existing products/services in overcoming prevailing gaps and bottlenecks. In comparison, 25% had worked towards developing a completely novel innovation. Similarly, during the SIOH, 63% of the respondents proposed technology-driven solutions, while 31% proposed solutions that used technology but were not technology-driven.

Regarding the mentorship sessions, around 63% of respondents found both types of mentorship helpful, while 26 % found thematic sessions (and 11 % cross-cutting) more helpful. 84% of the respondents found thematic mentors provided precise guidance to the groups.

The SIOH process allowed the groups opportunities for networking and mutual learning. Around 25% of the respondents shared and discussed the problems and ideas with other members and built inter-university networking, while around 31% of the respondents interacted with members of other teams but belonging to their own universities. Members of different groups proactively took part in the team meeting and different mentoring sessions. Around 64% of the respondents helped their group progress by articulating ideas, facilitating problem-solving, and fostering discussions.

Based on these assessments, some of the intangible impacts of SIOH included developing a better understanding of the groups on aspects of entrepreneurship, DRR, and acquisition of new skills, among others. Figure 4 illustrates that 50% and 47% of the group members who participated in the assessment strongly agree and agree, respectively, on the role of SIOH in enhancing their understanding of different aspects of entrepreneurship. 58% of the respondents agreed that SIOH helped them better understand different aspects of DRR.

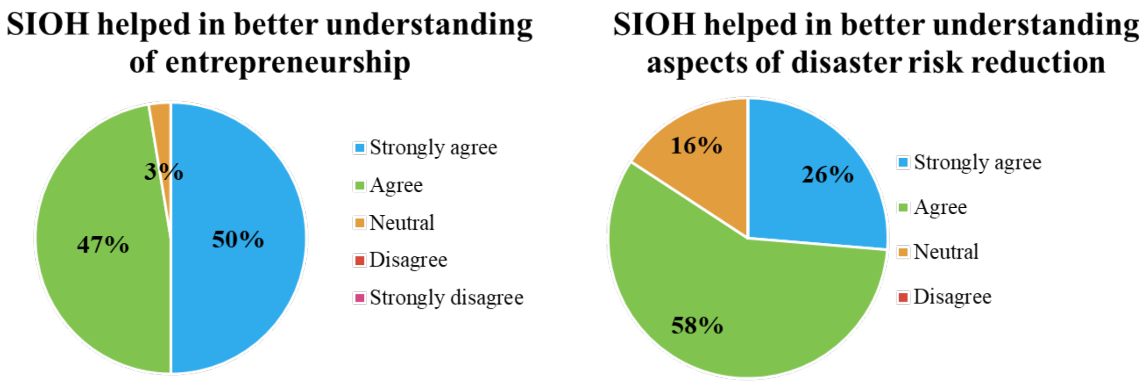


**Figure 4:** Impact of SIOH in enhancing understanding of entrepreneurship and DRR

Source: Authors

It is evident that the SIOH process has resulted in the acquisition of varied skills such as problem-solving, entrepreneurship, application development, time management, interpersonal & leadership, et cetera. Figure 5 represents the new skills acquired by the students and respective percentages of students.

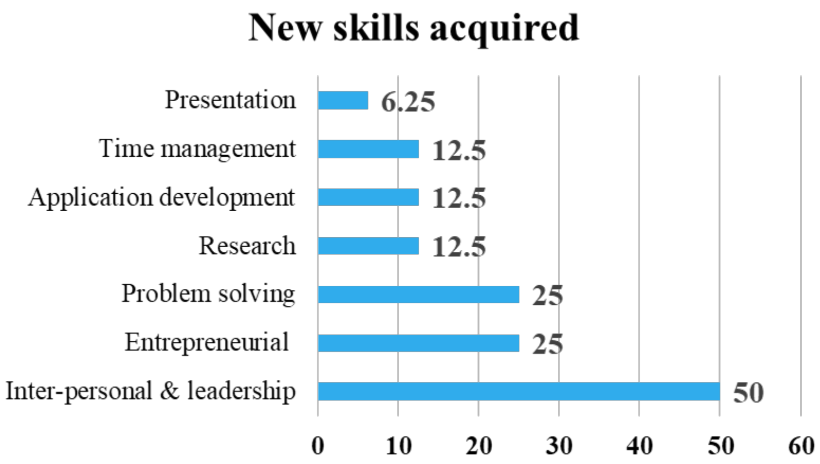


**Figure 5:** Acquisition of new skills by innovators during SIOH

Source: Authors

The survey showed that 84% of the respondents participated in a hackathon for the first time, and around 66% were interested in participating in similar hackathons in the future. This highlights that the SIOH was able to invoke the spirit of inquiry and innovation in the youth. Furthermore, 58% of the respondents were also interested in further exploring and pursuing DRR.

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## 6. DISCUSSION

SIOH envisioned developing innovative products, services, and approaches and exploring and testing the four-step process of multi-disciplinary collaboration to promote innovation for DRR. From this perspective, it was necessary to evaluate not only the performance and success of the innovators in SIOH but also to capture the intangible learning and opportunities such a platform can provide to the young innovators. Thus, apart from the rigorous evaluation of the groups on different aspects discussed earlier, four assessments closely studied the process of SIOH. These included peer-based and self-assessment of different innovator groups. This is not a common feature of any conventional hackathons. The self-assessment allowed the innovators to evaluate their own group's performance. The peer-based assessments allowed them evaluate the performance of other groups. This supported cross-learning and helped the students to better understand the innovation process both as innovators and as peer-evaluators. By undertaking temporal assessments using scoring rubrics, the change in soft skills such as communication, time management, teamwork, leadership skills was effectively gauged. The assessment was useful in understanding the immense potential such platforms have in supporting interdisciplinary collaboration and cross-learning for driving social innovation. The findings of the assessment would aid in enhancing such platforms in the future.

SIOH provided a unique opportunity for innovators to work in diverse groups that were cross-country, inter-university, and inter-disciplinary. This helped the groups foster cross-sectoral mutual learning, acquire new skills, and co-create through a holistic lens of related fields. Unlike the conventional hackathon, which often uses a short-duration 'pressure cooker' environment for the participants to innovate, SIOH was conducted over a longer duration of over two and a half months, where even many first-time innovators participated and co-created. (Hulsheger *et al.*, 2009) as cited in (Uusi-Kakkuri *et al.*, 2016) suggests that at the team level, leaders can play a crucial role in promoting innovation by effectively conveying motivating targets, providing valuable and encouraging feedback that is supportive of innovations. In the case of the SIOH, the group leaders, whom their respective groups mutually proposed, played this important role. They ensured that group members stayed motivated and worked together as a team. This was crucial, as the group members belonged to different countries, universities, disciplines, and academic levels. In addition to this, the groups found the concept of thematic and cross-cutting mentoring sessions to be very effective in hand holding them throughout the duration of the SIOH. The sessions kept the groups motivated and nurtured the ecosystem for deliberations with the experts and field practitioners. They also helped the groups in streamlining their ideas and making them more actionable.

At the same time, because of the virtual nature of the SIOH, some groups experienced the challenges of working in different time zones and ensuring effective intra-group communication and coordination. This is often not the case when an individual works with a known group-member. However, the SIOH aimed to help the innovators overcome these soft-skill-related limitations of coordination and communication, and to better prepare them for real-world working environment.

As recorded by (Sastry and Penn, 2015), the closed ecosystem, provided to the innovators during a conventional hackathon, limits their potential engagement with and understanding of the end-users and the market. SIOH, during its 'market strategy stage' envisaged overcoming this bottleneck by encouraging its innovators to use different tools to study and engage with market players and end-users. (Hulsheger *et al.*, 2009) as cited in (Uusi-Kakkuri *et al.*, 2016) highlights that engaging and communicating with external stakeholders enhances creativity. Almost all the groups undertook surveys to engage with the end-user and beneficiaries of their products/ services (in case of product innovation) or with existing stakeholders & authorities (in case of process innovation). The online survey for better studying the market, end-users, and beneficiaries helped the groups in creating contextualized solutions that were best suited and more acceptable to the end-users. Some of the key stakeholders engaged by different groups included government authorities, non-governmental organizations, private organizations, street vendors, health workers, local communities, etc. In due consideration of the prevailing pandemic, the stakeholder engagements were both physical and virtual, depending on specific groups' local restrictions and requirements. This was possible because of the long duration of the SIOH, which allowed adequate time to groups to engage with stakeholders and improvise on the innovations to make them sustainable and effective. Besides, through cross-cutting mentorship sessions, the innovators got the opportunity to engage with experts and practitioners from diverse fields and academic disciplines.

The experience of SIOH further underscores the prevailing perception of innovation being technology and/or technology-dependent. There is a need to break this perception to encourage young minds and practitioners from non-technical and social fields for co-creation and innovation. However, such a change in perception should be duly supported by providing adequate financial and other support to ideas and innovations that are not technology-driven or dependent but are effective in bringing the envisaged changes in respective fields.

SIOH strived to overcome the earlier identified gap by (Sastry and Penn, 2015) about hackathons often following the 'winner-take-all' approach. Apart from the three finalized groups of SIOH, the other three participating groups got the opportunity to address the gaps and further improve their innovation if they wish to. The interested groups were further supported under the 'Seeds of Innovation Program' of RIKA India. This becomes crucial for motivating young minds and practitioners and building a culture of co-creation and innovation.

## 7. THE WAY FORWARD

From the context of four types of innovations (product, process, position, and paradigm) discussed earlier, SIOH brought to the front that it may not always be possible to categorize the innovations as only one of the four types of innovations. Different groups of SIOH worked on innovative ideas belonging to more than one of these four types. For example, some of the groups working on product innovation, undertook market research and measures to assess how to best introduce their product in the market, which relates to position innovation. The group working on the theme of Safe Cities and Communities, through their product targeted at mitigating social isolation in urban communities, envisaged changing perception of end-users, thus relating indirectly to paradigm innovation. Thus, possibly, there is a need to retrospectively study innovations from a not-so-rigid typology and leave the scope for inclusion of ideas that fall under a hybrid type.

(Chanal, 2012) emphasizes on two methods for knowledge production, namely engagement with field practitioners and endorsing an interdisciplinary approach. A single discipline, alone, cannot adequately understand and address the nuances of existing and emerging societal and environmental challenges. The key to knowledge creation and social innovation lies in interdisciplinarity (ibid). The experience of SIOH demonstrates that by adding more DRR specific themes in similar hackathons in the future, young minds from different disciplines and fields can engage in driving local and cost-effective innovation in DRR and other societal issues. The hackathon can have more thematic sessions for sensitizing the diverse teams on core aspects of DRR and other fields with lack of/inadequate innovations.

Innovation drives and supports sustainable socio-economic needs and growth of society (OECD, 2004). The support and role of partnering universities in the SIOH showcase the possibilities whereby academic institutions can act as thematic incubators for their students belonging to diverse disciplines and academic levels. Similar recommendations are reflected in (Chanal, 2012) reflects similar recommendations and calls for universities to enhance their traditional roles of undertaking research by also playing the role of “innovation-promoting knowledge hubs.” (Unger *et al.*, 2017) discusses the concept of the knowledge triangle prevailing between research, education and innovation. The interlinkages and interaction possible within the knowledge triangle should be further explored and leveraged by the academic and research institutions, private sector and industry, government and other stakeholders.

The cooperation and partnership of academia and industry can nurture social innovation (Chanal, 2012). On similar lines, (Oksanen, 2013) recognizes knowledge, collaboration, and motivation as key factors that support innovation. The case of SIOH where academic institutions and private bodies collaborated for driving innovations in DRR and sustainable development, should be widely promoted and replicated with necessary tweaking. These can be very helpful for addressing and finding solutions to local problems of an area duly identified by the local administration and government bodies, or local NGOs. Various measures/models for strengthening the linkage of knowledge triangle between research, education and innovation include, amidst others, “academic start-ups and incubators; open science/innovative platforms; public-private partnership models; geographical and sectoral mobility of innovators; promotion of industry-focused programs and skills” (Unger *et al.*, 2017). SIOH considered some of these crucial aspects. As it was the first such initiative by the organizers, SIOH was open to participation to only five partner universities as a pilot model for promoting social innovation. To further achieve the envisaged goals, SIOH or other similar innovative platforms should be open to a larger number of universities to reach out to more young innovators. Besides this, SIOH provided a virtual geographical and sectoral intermingling of the young innovators and mentors during the ongoing pandemic.

Apart from the initiative of SIOH, RIKA India has collaborated with some of the academic institutions to promote and establish thematic incubators (Bajwa *et al.*, 2021). These themes include "women leadership in DRR and climate change; smart city and climate change adaptation; urban sustainability and design" (ibid). Such mechanisms need further exploration and endorsement for driving and fostering social innovation. There is a need to institutionalize such existing platforms that nurture young minds and practitioners to collaborate and co-create for social change. (Oksanen, 2013) characterizes an innovative space as one which nurtures and supports collaboration & communication; is flexible enough for modifications to facilitate diverse activities and experiments; capable of providing a socio-technical intellectual ecosystem; attracts and supports the flow of innovative ideas; and reflects the key values of openness, sustainability and collaboration.

## REFERENCES

ABC News. (2019). 'How dare you':? This is Greta Thunberg's passionate cry for climate action. Retrieved December 29, 2020 from https://www.youtube.com/watch?v=N94eP2jKQWw

Albris, K., Lauta, K. C. & Raju, E. (2020). Disaster Knowledge Gaps: Exploring the Interface Between Science and Policy for Disaster Risk Reduction in Europe. *International Journal of Disaster Risk Science, 11*(1): 1-12. Retrieved December 31, 2020 from https://link.springer.com/article/10.1007/s13753-020-00250-5

Bajwa S, Dabral. A., Chatterjee, R. & Shaw, R. (2021). Co-designing Knowledge Innovation through Thematic Incubators for Disaster Risk Reduction and Sustainable Development. *Sustainability*, *13*(4). From https://www.mdpi.com/2071-1050/13/4/2044

Callegaro, A. (2017). Why innovation and technology aren't the same. UNHCR. Retrieved December 29, 2020 from https://www.unhcr.org/innovation/innovation-technology-arent-the-same/#:~:text=Innovation%20is%20a%20human%2Dcentered,innovation%20doesn't%20equal%20technology.

Chanal, V. (2012). Building knowledge for innovation management: The experience of Umanlab research team. *VINE, 42*(3/4). Retrieved May 15, 2021 from https://www.emerald.com/insight/content/doi/10.1108/03055721211267512/full/html

Dabral A, Sasaki. K., Nizhamudong, Y., Chatterjee, R. & Shaw, R. (2021). Innovation in earthquake early warning system: A case study of EQ Guard. In *Emerging Technologies for Disaster Resilience*. Springer. Retrieved December 30, 2020 from https://link.springer.com/chapter/10.1007/978-981-16-0360-0_3

Flores M, Golob, M., Maklin, D., Herrera, M., Tucci, C., Al-Ashaab, A, ... Pineda, K. F.. (2018). How Can Hackathons Accelerate Corporate Innovation? In I. Moon, G. M. Lee, J. Park, D. Kiritsis, & G. Cieminski, *Advances in Production Management Systems. Production Management for Data-Driven, Intelligent, Collaborative, and Sustainable Manufacturing. IFIP Advances in Information and Communication Technology. APMS 2018* (Vol. 535, pp. 167-175). Springer. Retrieved December 27, 2020 from https://link.springer.com/chapter/10.1007%2F978-3-319-99704-9_21#citeas

Gegenhuber, T. (2020). Countering Coronavirus With Open Social Innovation. Retrieved December 29, 2020 from Standford Social Innovation Review: https://ssir.org/articles/entry/countering_coronavirus_with_open_social_innovation

Hackerearth. (n.d.). The complete guide to organizing a successful hackathon. Retrieved December 27, 2020 from Hackerearth: https://www.hackerearth.com/community-hackathons/resources/e-books/guide-to-organize-hackathon/

IJL, Keio University, RIKA India. (2020). Social Innovation Online Hackathon. Retrieved December 27, 2020 from https://rikaindia.com/wp-content/uploads/2020/08/Final-report-SIOH.pdf

Izumi, T., Shaw, R., Ishiwatari, M., Djalante, R. & Komino, T. (2019). 30 Innovation for DRR. Retrieved December 29, 2020 from https://apru.org/wp-content/uploads/2019/03/30-Innovations-for-Disaster-Risk-Reduction_final.pdf

Izumi, T., Shaw, R., Djalante, R., Ishiwatari, M. & Komino, T. (2019). Disaster risk reduction and innovations. *Progress in Disaster Science, 2*. Retrieved November 28, 2020 from https://www.sciencedirect.com/science/article/pii/S259006171930033X

Komssi, M., Pichlis, D., Raatikainen, M., Kindström, K. & Järvinen, J. (2015). Whatare Hackathons for? *IEEE Software, 32*(5), 60-67. Retrieved December 30, 2020 from https://ieeexplore.ieee.org/document/6809711

McKercher, K. A. (2017). Understanding the differences between commercial and social innovation | Part 1 of 2. Retrieved December 29, 2020 from https://medium.com/@kamckercher/understanding-the-differences-between-commercial-and-social-innovation-part-1-of-2-c4ed576e31da#:~:text=Commercial%20innovation%20rarely%20focuses%20on,those%20who%20need%20support%20most.

Murray, R., Caulier-Grice, J. & Mulgan, G. (2010). The Open Book of Social Innovation. NESTA, The Young Foundation. Retrieved December 29, 2020 from https://media.nesta.org.uk/documents/the_open_book_of_social_innovation.pdf

Murray, V. , Maini, R., Clarke, L. & Eltinay, N. (2017). Coherence between the Sendai Framework, the SDGs, the Climate Agreement, New Urban Agenda and World Humanitarian Summit, and the role of science in their implementation. Retrieved December 28, 2020 from https://www.preventionweb.net/publications/view/53049

OECD. (2004). Science and Innovation Policy: Key challenges and opportunities. Retrieved December 30, 2020 from http://www.oecd.org/science/inno/23706075.pdf

Oksanen, K., & Ståhle, P. (2013). Physical environment as a source for innovation: investigating the attributes of innovative space. *Journal of Knowledge Management*, *17*(6): 815-827. Retrieved May 20, 2021 from https://www.emerald.com/insight/content/doi/10.1108/JKM-04-2013-0136/full/html

Rahman, A. & Fang. C. (2019). Appraisal of gaps and challenges in Sendai Framework for Disaster Risk Reduction priority 1 through the lens of science, technology and innovation. *Progress in Disaster Science*, *1*. Retrieved December 31, 2020 from https://www.sciencedirect.com/science/article/pii/S2590061719300067

Rodrigues, M., & Franco, M. (2019). The Corporate Sustainability Strategy in Organizations: A Systematic Review and Future Directions. *Sustainability*, *11*(22). Retrieved December 28, 2020 from https://www.mdpi.com/2071-1050/11/22/6214

Sastry A, & Penn, K. (2015). Why Hackathons Are Bad for Innovation. Retrieved December 30, 2020 from Fast Company: https://www.fastcompany.com/3054023/why-hackathons-are-bad-for-innovation

Shaw, R. (2020). Thirty Years of Science, Technology, and Academia in Disaster Risk Reduction and Emerging Responsibilities. *International Journal of Disaster Risk Reduction*, 414-425. Retrieved December 28, 2020 from https://link.springer.com/article/10.1007/s13753-020-00264-z

Thomas, V. & López, R. (2015). Global Increase in Climate-Related Disasters: ADB Economics Working Paper Series. Asian Development Bank. Retrieved December 28, 2020 from https://www.adb.org/sites/default/files/publication/176899/ewp-466.pdf

Tidd, J & B essant, J. (2005). Managing Innovation: Integrating Technological, Market and Organizational Changes (*3rd ed.*). John Wiley & Sons, Ltd.

United Nation. (2017). New Urban Agenda. Retrieved December 28, 2020 from https://unhabitat.org/sites/default/files/2019/05/nua-english.pdf

United Nations Office for Disaster Risk Reduction. (2007). Hyogo Framework for Action. Retrieved December 28, 2020 from https://www.undrr.org/publication/hyogo-framework-action-2005-2015-building-resilience-nations-and-communities-disasters

United Nations Office for Disaster Risk Reduction. (2015). Sendai Framework for Disaster Risk Reduction (2015-30). Retrieved December 28, 2020 from https://www.preventionweb.net/files/43291_sendaiframeworkfordrren.pdf

Unger, M., & Polt, W. (2017). The Knowledge Triangle between Research, Education and Innovation- A Conceptual Discussion. Foresight and STI Governance. Retrieved May 16, 2021 from https://cyberleninka.ru/article/n/the-knowledge-triangle-between-research-education-and-innovation-a-conceptual-discussion/viewer

Uusi-Kakkuri, P., Brandt, T., & Kultalahti, S. (2016). Transformational leadership in leading young innovators- a subordinate's perspective. *European Journal of Innovation Management, 19(*4). Retrieved May 20, 2021 from https://www.emerald.com/insight/content/doi/10.1108/EJIM-12-2014-0118/full/html

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# Sociodemographic Influences on Public Interest in Natech Risk Information: Insights from Japan and S. Korea

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**Abstract** Disaster risk communicators have long contemplated the significance of sociodemographic dimensions in better understanding and characterising an audience's perceptions. Indeed, various societal and personal factors have been considered as predictors of individual risk attitudes, perceptions and behaviours for an array of hazard types. However, such risk communication issues have only recently started to be explored within the emerging field of conjoint natural and technological disasters, called Natech. In this context, delineating the sociodemographic profile of individuals and appreciating the implications of these aspects on Natech risk communication can assist risk managers in tailoring effective risk communication strategies. This study investigates, among other items, the effects of residents' gender, age, household size, income and educational level on their perceptions of information disclosure concerning Natech risk. The approach draws upon the framework of the Situational Theory of Problem Solving in an attempt to conceptualise the complex issue of information deficiency. Taking into account individuals' situational perception elements, the research focuses on certain cross-situational, sociodemographic features that serve as external, determining factors that shape their problem-solving motivation. Data has been collected from households near industrial parks in Osaka and Kobe in Japan and Yeosu, Suncheon, Gwangyang and Ulsan in S. Korea. The results of our regression analysis indicated mostly weak and insignificant effects, except for gender and age that suggested negative and positive influences to individuals' communicative attitudes, respectively. The implications of the institutional differences between the two countries are also discussed within the sphere of chemical and Natech risk communication.

**Keywords:** Risk communication, Natech, Risk information disclosure, Situational theory, Sociodemographic factors

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## INTRODUCTION

Over the years, research scholars have highlighted the exchange of information between experts and communities as the *sine qua non* for stakeholder involvement and risk governance (Renn and Walker 2008; Aven and Renn 2010; Renn and Klinke 2013), and particularly so in the context of industrial, nuclear and environmental accidents (Shapiro 2005; Palenchar 2008). Risk communication and information disclosure have recently started to attract more academic attention in the Natech accident risk discourse (Figueroa 2013; Suarez-Paba *et al*. 2020). Natech constitutes a special type of event that entails technological accidents triggered by a natural hazard and involves the release of hazardous materials (Cruz and Suarez-Paba 2019; Suarez-Paba *et al*. 2019; UNDRR-APSTAAG 2020). They are considered low-probability but high-consequence events with severe impacts on the regional population, environment and economy. Typical examples of Natech include the Fukushima nuclear accident following the Great East Japan Earthquake and Tsunami (GEJET) 2011 (Cruz and Krausmann 2013) and the oil spills that occurred during Hurricanes Katrina and Rita (Cruz and Krausmann 2009).

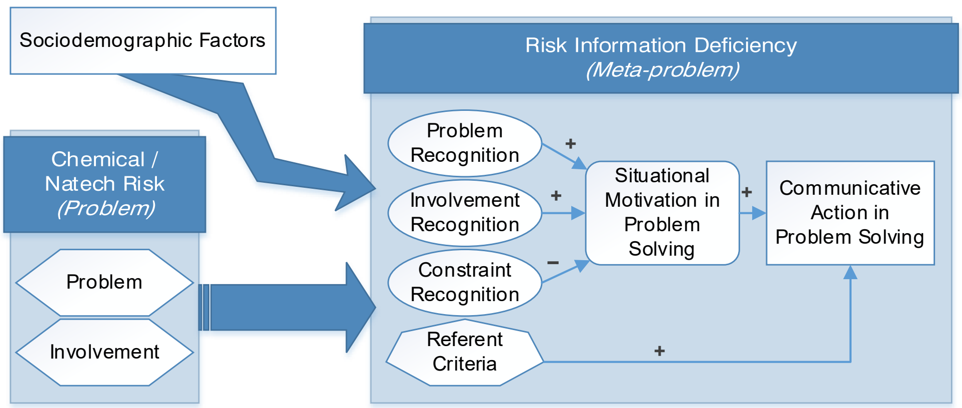


**Figure 1.** Conceptualisation of Sociodemographic Determinants and Risk Information Deficiency

Disclosure of hazard and risk information allows communities to enhance their preparedness against potential disasters through sharing crucial information with the public. Also, disclosure paves the way for the civic discourse about the decision-making processes involved in risk management (Gutteling and Wiegman 1996; Aven and Renn 2010). Analysing this idea within the specific context of chemical and Natech accidents, Figure 1 describes two kinds of 'problems' from the perspective of risk communication. On the one hand, individuals perceive the underlying Natech accident risk itself as the initial problem that directly or indirectly affects their lives to various perceived degrees. This issue is typically the subject of risk perception studies that explore how risk is socially understood and experienced (Wachinger and Renn 2010). On the other hand, if chemical and Natech risk communication is limited—or even non-existent—individuals may find themselves lacking necessary hazard or risk information about the potential accidents, which is otherwise crucial for their effective preparedness and response to a potential event. In this regard, information deficiency presents a secondary problem that directly stems from the initial accident risk. Individuals then form their own perceptions about this issue in terms of its acknowledged severity, personal views, associated challenges and so forth.

Kim and Grunig (2011) approached this problematic situation from a public relations and mass communications standpoint, defining this discrepancy as a *cognitive meta-problem* that follows the initial perceptual problem: *'one's perception that something is missing and that there is no immediately applicable solution to it'* (p. 128). This conceptualisation presents a unique opportunity to study the issue of Natech risk information deficiency through the lens of Situational Theory[3]. Even though perception about this meta-problem is not the same as the Natech risk perception *per se*, it can be argued that they are related: the higher the concern about a potential Natech accident, the more salient the issue of information deficiency becomes to the individual. The argument is that by utilising the interpretative framework provided by the Situational Theory of Problem Solving (STOPS) (J.-N. Kim and Grunig 2011), risk communicators can identify and understand the behaviour of publics with increased communicative activeness. These types of publics are more likely to diligently search for, review and synthesise available information and, furthermore, reciprocate the efforts and engage in two-way communication (Grunig and Kim 2017). Therefore, focusing on communicative actors allows risk managers to learn more about the community's demands, fears and (mis-)perceptions concerning both the risk information deficiency and the underlying risk in order to effectively address them and take their interests into consideration in the decision-making process (Grunig 2018).

Furthermore, developing an effective methodology to identify and categorise stakeholder groups has been the Holy Grail and a recurring topic of debate among risk communication and perception researchers for several decades. Creating a reliable segmentation method aims to tailor risk communication strategies to targeted audiences for the purposes of increasing a communication plan's efficacy and maximising the yield of invested resources. In this context, sociocultural and demographic factors have frequently come under scrutiny as potentially potent and robust predictors of individuals' risk attitudes, perceptions and behaviours for an array of natural and technological hazard types (*e.g.*, Savage 1993; Sund *et al.* 2017; for a review see Wachinger and Renn 2010). Hence, sociodemographic influences have been widely regarded as valuable inputs for disaster risk managers and policy-makers in their quest to understand and predict disaster risk perception.

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[3] The Situational Theory posits that publics can be identified and segmented from a larger population according to the level of activeness or passiveness of their communication behaviour. Grunig conceptualised the original Situational Theory of Publics (STP) in the '60s as a framework to understand when people communicate and what is the role of information in their decisions. Kim and Grunig (2011) then introduced the Situational Theory of Problem Solving (STOPS) as an extension and generalisation of STP that explains why and how individuals communicates during a problematic situation. For a detailed review of the historical development of the situational theory, interested readers are referred to Kim and Grunig (2011) and Kim and Krishna (2014).

Nonetheless, this risk perception research is still in its infancy with very limited studies so far within the emerging field of Natech communication (Cruz and Suarez-Paba 2019). Yu *et al*. (2017) was one of the first studies to focus on households' Natech risk perception and evacuation behaviour during the GEJET 2011 around an oil refinery complex in Sendai, Japan. Demographic characteristics did not prove to be strong predictors of Natech risk perception based on their findings, but the authors proposed that further investigation is required. Quite recently, Slack *et al*. (2020) investigated hazard perceptions in conjunction with institutional trust vis-à-vis Hurricane Harvey in 2017 by surveying households along the Texas Gulf Coast, of the United States. They utilised demographic attributes rather as supplementary controls for their primary research focusing on institutional distrust, but—as with the aforementioned study—their model coefficients did not suggest strong effects.

Given the little research available and considering the inconclusive results of previous studies on the subject of sociodemographic determinants of Natech risk perception, we follow a novel approach that is based on a communicative framework (for reasons explained above), rather than on the Psychometric Paradigm (see *e.g*., Slovic *et al*. 1981; Slovic 2000) or the Cultural Theory of Risk (see *e.g*., Douglas and Wildavsky 1982; Breakwell 2007) that have been used so far. Our main research question is: *Do sociodemographic factors influence citizens' situational perception and motivation to communicate with each other about the issue of Natech risk information deficiency?* More specifically, we venture to explore whether and how households' sociodemographic characteristics affect their perceptions of the meta-problem of chemical and Natech risk information deficiency. By doing so, we intend to shed some light on the influence of sociodemographic variables on situational perception elements about this issue.

In a basic attempt to reveal any underlying institutional parameters, we looked at households near industrial complexes in two countries that share a relatively similar sociocultural background: Japan and South Korea. The cultural dimensions of Hofstede (2001) (*i.e*., collectivism/individualism and masculinity/femininity) are used to support our argument about the similarities of the two societal structures in terms of their organisational cultures (see *e.g*., G. H. Hofstede 2001; House *et al.* 2004; G. Hofstede *et al.* 2010). Without disregarding, of course, the discrepancies when comparing the superordinate cultural groups (Park *et al.* 2016), the predominant characteristic of Japan and S. Korea generally appears to be collectivism. However, Japan seems to score higher on masculinity in contrast to the rather feminist organisational culture of S. Korea (S. H. Kim and Kim 2016). Perhaps more important for our purposes though is the fact that Japan and S. Korea bear a stark difference in terms of chemical and Natech risk communication. S. Korea consolidated and updated its risk management and communication regulations with respect to technological accidents under a comprehensive law titled Chemical Controls Act. A recent amendment refined existing fragmented and outdated articles as well as introduced more detailed provisions regarding public disclosure of chemical information (Ministry of Environment, Republic of Korea 2018). In contrast, despite its deep and advanced disaster education culture regarding natural hazards and regardless of international trends (*e.g*., Sendai Framework for DRR - UNISDR 2015), Japan has yet to introduce any specific regulatory framework that includes standards for public disclosure of information related to chemical risks. Based on this situation, we selected the two countries for our study to explore any effects of the differences in the regulatory frameworks that govern chemical and Natech risk communication on the situational variables under study.

The rest of this article is organised as follows. Section 2 offers a brief overview of the perceptual and cognitive elements of STOPS used in our approach, and then summarizes the findings of previous research on the influence of sociodemographic determinants on risk perception. Section 3 presents the research hypotheses and data collection methods. Section 4 describes the multivariate analysis methods employed. Section 5 includes the analysis results, while Section 6 synthesizes and discusses the key research findings and considers policy implications. The final section offers a summary, and considers the study's limitations and future research prospects.

## 1. LITERATURE REVIEW

### 2.1 Perceptual and Cognitive Variables of Situational Motivation

Situational approaches that use latent constructs (*e.g.,* individual behaviour, cognition) have proven advantageous in analysing the dynamic nature of publics (J.-N. Kim, Ni, and Sha 2008; Chon 2019). This research endeavour employs the four perceptual and cognitive variables of the Situational Theory of Problem Solving (STOPS), namely Problem Recognition (PR), Constraint Recognition (CR), Involvement Recognition (IR) and Referent Criterion (RC), along with Situational Motivation in Problem Solving (SM) (J.-N. Kim and Grunig 2011), to address the issue of Natech risk information deficiency. Researchers have used the situational variables in the past to effectively identify communicatively active public segments (Ni and Kim 2009; Y. Kim *et al.* 2016), as well as to plan communication strategies and predict individuals' communicative behaviours (Chon 2019).

STOPS posits that individuals assume a communicatively active behaviour in terms of acquiring, selecting and transmitting information when they become committed to problem solving (J.-N. Kim and Grunig 2011). This Communicative Action in Problem Solving (CAPS) is dictated by the individual's situational motivation along with any available referent criteria, that is, past experiences, subjective knowledge or expectations applicable to the issue (see Figure 1 for a visual representation). Situational motivation is conceptualised in turn as the product of the three antecedents; problem, involvement and constraint recognition. The first element refers to the perceived severity of the situation, the second to the perceived personal relationship with the problematic situation, and the last to the perceived barriers that limit one's ability to communicate about the problem (J.-N. Kim and Grunig 2011; J.-N. Kim and Krishna 2014). Translating STOPS into the context of Natech risk communication, individuals perceive the meta-problem stemming from the risk information deficiency, their personal connection with it and the challenges that limit their ability to take action to resolve it. Based on their knowledge, subjective judgmental rules (*e.g.,* moral or cultural issues) and expectations about how Natech risk information should be handled, their situational motivation drives them to engage in communicative action.

Finally, STOPS has been successfully applied in multiple fields, including health communication and post-incident public relation crisis communication among others (J.-N. Kim and Krishna 2014). Its potential only begun to be explored in the field of chemical risk communication. Furthermore, it has been used in various sociocultural settings, including Asian countries and particularly S. Korea (J.-N. Kim *et al*. 2012; Chon 2019).

### 2.2 Sociodemographic Factors and Risk Perception

Our attention focuses on cross-situational elements, namely sociodemographic features of involved citizens, as external influential factors that may—or may not—shape the individual's situational perception and problem-solving motivation. Since studying the individuals' opinions concerning the issue of risk information disclosure so systematically is a relatively novel endeavour, the demographic determinants of situational perception have not been thoroughly documented and understood yet. At first glance, the topic may be examined from a public relations perspective focusing on the motivation to communicate and its situational antecedents, while an approach based on risk perception is also warranted due to the specific nature of the issue.

In the former case, researchers working with Situational Theory examined sociodemographic factors that were hypothesised to define individuals' situational perception towards a given problem, with rather modest results. Kim *et al*. (2012), for example, tested the effects of gender, age, education level and income on individuals' situational perception for topics that receive mass media coverage only to find a significant, moderate influence of age on reducing problem and involvement recognition. Correspondingly, Lovari *et al*. (2012) studied the influence of similar demographics on situational perception for civic issues (*i.e*., unemployment, safety, transportation), finding a statistically significant association and small effect between age and problem recognition. This time, a positive direction was found, meaning that age slightly increased problem recognition. As a general rule, Situational Theory academics have argued that cross-situational variables, such as demographic characteristics of individuals, do not exert any substantial effects in comparison to the situational factors (Grunig 1997; J.-N. Kim *et al*. 2009; 2012), which has also been confirmed in the aforementioned studies.

Perhaps more interesting, however, is the fact that the specific origin of the problem under question is intrinsically tied to risk perception about the underlying chemical and Natech accident risk. This rationale explains why it is important to reconsider the effects of sociodemographic factors on situational perception in the context of risk. Actually, the

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literature about the influence of key demographic characteristics on risk perception is plentiful. Researchers introduced a wide range of contributing factors from physical attributes (*e.g.*, gender and age) to socioeconomic aspects (*e.g.*, education, marital status and income level). Nonetheless, the results were not always definitive, while even the direction of some relationships depended on the particular case study.

Possibly the most studied demographic determinant is gender, as Rowe and Wright (2001, 384) remark. A consistent motif in the risk perception studies is that males typically tend to regard risks as smaller and less problematic compared to females (Savage 1993; Slovic 1999). This finding was confirmed in the case of man-made hazards, namely radioactive waste disposal and global warming (Davidson and Freudenburg 1996). Later research also supported this finding across various types of risk, including natural hazards among others (Sund *et al.* 2017), or with reference to disaster preparedness measures for floods (Cvetković *et al*. 2018). Nonetheless, findings have not always revealed an increased risk perception by women. For example, Slack *et al*. (2020) observed that gender had no statistically significant influence on an individual's level of worry about future impacts of tropical storms. Several researchers noted the ambiguity of this factor's effect on risk perception for a variety of natural hazards, ranging from volcanic and seismic to hydro-meteorological. Their respective analyses revealed that previous exposure to such hazards was actually the underlying cause of fluctuation in risk perception levels (Kunz-Plapp and Werner 2006; Barberi *et al*. 2008; Wachinger and Renn 2010).

Another demographic characteristic commonly included in risk perception studies is age. Despite the number of studies looking at the relationship between these two aspects, major inconsistencies seem to emerge from the findings (Wachinger and Renn 2010; Cvetković *et al.* 2018; D. K. D. Kim and Madison 2020; Slack *et al*. 2020). For instance, one study on single-family homeowners residing in Florida found that age was actually correlated with reduced hurricane risk perceptions (Peacock *et al.* 2005). Furthermore, Huang *et al*. (2012), reported an association between older individuals and lower risk perception in the case of Hurricane Ike, and reasoned that perhaps older people anticipated smaller personal impact from that particular hazard. On the other hand, other researchers, such as Sjöberg (2004), demonstrated a positive correlation between older individuals and risk associated with nuclear waste. It is clear that consensus has not yet been reached on this matter. As far as Natech risk is concerned, researchers pointed out that older persons residing near an industrial area in Sendai reported higher degrees of concern about their lives and properties being affected by an accident following the Great East Japan Earthquake, even though age—the study noted—did not appear to be a persistent and strong determinant (Yu *et al*. 2017).

Concerning the effects of individuals' educational attainment on risk perception, Wachinger *et al*. (2013) concluded that people with different educational levels show differences in risk perception regarding natural hazards. Other studies suggest an inverse correlation between the two: highly educated people demonstrated decreased perceived risk (Savage 1993; Rowe and Wright 2001; Sund *et al*. 2017; Cvetković *et al*. 2018; D. K. D. Kim and Madison 2020) for

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various risk domains, including natural hazards. Nonetheless, there have been instances where research efforts failed to discover any significant correlations between risk perception and level of education (Sjöberg 2004). Sundblad *et al*. (2007) also considered the potential effects of education attainment on risk perception about climate change, arguing that a higher educational level may increase a person's sense of control and therefore reduce perceived risk. This seems to be the case in terms of chemical hazards, as well. One study found evidence to associate higher education with less concern about chemical risk and more favourable attitudes towards related technologies (Kraus, 1992 cited in Rowe and Wright 2001), while another study revealed that higher educational level reduced the perceived risk associated with radioactive waste disposal (Flynn *et al*. 1993 cited in Rowe and Wright 2001). Lastly, Sund *et al*. (2017) noted that education could also be connected to individuals placing excessive value on the "correctness" of probabilities and consequences of potential accidents, which in turn may increase or decrease the associated perceived risks based on the level of risk misperception within the general population. Considering the particular topic of this research, however, it is noteworthy that Kim and Madison (D. K. D. Kim and Madison 2020) identified a positive correlation between educational level and information-seeking efficacy in terms of flood risk.

Furthermore, income has been proposed as an additional influential sociodemographic factor, but once again the findings have been mixed. Lower income levels have been linked to an increase in risk perception for technological and natural hazards in the past (Savage 1993). Fothergill and Peek (2004) suggested that individuals with lower income have elevated risk perceptions because of restricted control, potential technological ignorance, lack of social integration that provides them access to risk communication mechanisms, and amplified fear of losing their houses and livelihoods. More recent studies also support this inverse correlation between risk perception and income level in the context of natural hazards (Sund *et al*. 2017; D. K. D. Kim and Madison 2020). Nonetheless, there have been cases where a significant association between these factors could not be supported by the results (Sjöberg 2000; Cvetković *et al*. 2018). While a few studies have pointed to a significant relationship between income and risk perception (Donner and Rodríguez 2008; M. K. Lindell and Hwang 2008), the literature review conducted by Wachinger and Renn (2010) led them to conclude that economic factors generally (with the exception of homeownership) do not seem to have a significant influence either on risk perception or willingness to adopt preparedness measures.

Household size was also tested as a determining factor of risk perception and protective action. In the context of tropical storms, larger families showed decreased likelihood of evacuating their houses (Dash 2002). Later research also confirmed this inverse relationship between household size and evacuation likelihood with statistically significant, strong predictors, but revealed that household composition might play an important role as well (Dash and Gladwin 2007). In detail, larger households with children showed a higher propensity to evacuate during a hurricane, while larger households with elderly members were less likely to do so (Dash and Gladwin 2007; Solis *et al*. 2009). Such a negative relationship between family size and hurricane evacuations in Florida was demonstrated by Solis *et al*. (2009), although results were statistically insignificant. In the context of Natech risk, however, Yu *et al*. (2017), in their study on the evacuation behaviour following the oil refinery explosion, could not find any significant evidence to either support or reject this correlation.

One of the—admittedly—less-investigated factors in risk perception research is having dependents in the household. Kim and Madison (2020) expected a positive relationship between risk perception and families with dependents, based on the premise that it is within human nature for care-givers to feel a greater responsibility to protect those they take care of (be it children or elderly). Nonetheless, they could not find any statistically significant results to support this hypothesis when investigating the 2016 Louisiana floods in the United States. Moreover, Solis *et al.* (2009) examined the influence of the number of children and the existence of pets on household evacuation behaviour. Their statistically significant results suggested that households with more children were more likely to evacuate during major hurricanes in 2005 in Florida, but the opposite was true for households with pets. As far as marital status is concerned, studies have failed to find any conclusive and statistically significant results to support either a positive or negative correlation (Basolo *et al.* 2009; Xu *et al.* 2018). However, there has been evidence suggesting that single individuals are more likely to prepare emergency supplies in case of flood (Cvetković *et al.* 2018).

As explained above, social and individual factors—aside from gender—do not seem to play a significant role but may act as mediators or amplifiers between the connections of risk perception, public trust and disaster preparedness (Wachinger *et al.* 2013). Yet, the interest in the correlation between sociodemographic variables and risk perception still grows, despite the unfruitful research efforts so far. Lindell (2013) acknowledges that, although these variables continue to be unreliable predictors, their potential in helping experts better understand stakeholders' risk perception is great. If nothing else, it is exactly these inconclusive research findings that fuel interest in discovering any underlying linkages between individual sociodemographic aspects and risk perception. This interest is particularly strong in the emerging field of Natech risk, where the influence social and individual factors exert on people's risk perception and protective actions has only recently started to be examined (*e.g.* Yu *et al.* 2017; Slack *et al.* 2020).

## 2. METHODOLOGY

### 3.1 Research Aim and Hypotheses

This study explores whether and how households' sociodemographic characteristics affect their perceptions about the meta-problem of Natech risk information deficiency. Japan and S. Korea are both highly industrialised countries, with some of their largest industrial complexes being located along their eastern coastlines. S. Korea—unlike Japan—is not located in a seismically active region, and the geomorphology of the greater region may be protecting it from potential devastating tsunamis, yet both countries are subject to large tropical storms originating from the Pacific Ocean, heavy rainfalls and landslides almost at a yearly rate. Hence, it can be argued that both countries are at a relatively high risk of Natech accidents happening.

As explained earlier, the main research aim is as follows: *Do sociodemographic factors influence citizens' situational perception and motivation to communicate with each other about the issue of Natech risk information deficiency?* Considering the infancy of Natech risk communication and perception research and the novelty of the STOPS framework in the risk communication field, this study adopts an exploratory approach. Its modest aim is to investigate at an introductory level the sociodemographic influences on situational variables. Thus, the focus is primarily on developing hypotheses for future work. Specifically, this research investigates eight factors: gender, age, educational level, annual household income level, the existence of a spouse, of children and finally, and whether the respondent lived in Japan or S. Korea.

For the purposes of this study, a 'positive effect' on the situational variables is conceptualised as a contribution to the factors that in turn increase the individuals' communicative activeness concerning the meta-problem of Natech risk information deficiency. In detail, an increase in the variables of situational motivation (along with its respective antecedents) and referent criteria is considered as positive. It should be noted that, due to the intrinsic negative aspect of Constraint Recognition, such a 'positive influence' on Constraint Recognition from any sociodemographic factor is hypothesised as an inverse relationship between the two variables and *vice versa*.

The following assumptions are formed based on the literature review from the standpoint of risk perception. Males are likely to underestimate risks; therefore, the subsequent information deficiency problem is not regarded as prevalent, which is hypothesised to reduce the individual's communicative activeness about it. Moreover, older citizens have been facing the risk and the associated information deficiency problem for longer, and thus, they are expected to perceive it as more severe, but find it more difficult to resolve it. Similarly, education is anticipated to increase individuals' awareness about the risk and subsequently about the lack of information. However, higher levels of education may also provide the means to do something about the problem. Additionally, the larger the household is, the more individuals are exposed to the risk; hence, the perceived situation is hypothesised to be exacerbated. Conversely, a higher income level means more resources are available to effectively cope with the situation, so the problem is not expected to be perceived as large. Hypotheses are similar in the case of the existence of a spouse and children. Having a (co-)dependent household member is anticipated to increase concerns about the meta-problem without delineating any immediately available solution to it, which in turn impels communicative action. Finally, Koreans are expected to be comparatively less concerned about the meta-problem because they have a regulatory framework about chemical risk information disclosure in effect. The chemical risk communication mechanisms in place are hypothesised to provide some ideas about how this issue could be resolved, while reducing the perceived challenges and inviting communication.

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**Table 1.** Research Hypotheses

| Variable | Gender | Age | Education | Income | H. Size | Spouse | Children | Country |
|---|---|---|---|---|---|---|---|---|
| ***PR*** | $H1_a$: – | $H2_a$: + | $H3_a$: + | $H4_a$: – | $H5_a$: + | $H6_a$: + | $H7_a$: + | $H8_a$: – |
| ***IR*** | $H1_b$: – | $H2_b$: + | $H3_b$: + | $H4_b$: – | $H5_b$: + | $H6_b$: + | $H7_b$: + | $H8_b$: – |
| ***CR*** | $H1_c$: + | $H2_c$: + | $H3_c$: – | $H4_c$: – | $H5_c$: – | $H6_c$: – | $H7_c$: – | $H8_c$: – |
| ***RC*** | $H1_d$: – | $H2_d$: + | $H3_d$: + | $H4_d$: – | $H5_d$: + | $H6_d$: + | $H7_d$: + | $H8_d$: + |
| ***SM*** | $H1_e$: – | $H2_e$: + | $H3_e$: + | $H4_e$: – | $H5_e$: + | $H6_e$: + | $H7_e$: + | $H8_e$: + |
| *Notes: Problem Recognition (PR), Involvement Recognition (IR), Constraint Recognition, Referent Criterion (RC) and Situational Motivation (SM).* | | | | | | | | |

Source: Original work

The arguments above can be formulated in a more operationalised format (Table 1). Gender has a negative effect on Problem Recognition ($H1_a$), Involvement Recognition ($H1_b$), Referent Criteria ($H1_d$) and Situational Motivation ($H1_e$), and a positive effect on Constraint Recognition ($H1_c$). Age has a positive effect on all Problem Recognition ($H2_a$), Involvement Recognition ($H2_b$), Constraint Recognition ($H2_c$), Referent Criteria ($H2_d$) and Situational Motivation ($H2_e$). Education has a positive effect on Problem Recognition ($H3_a$), Involvement Recognition ($H3_b$), Referent Criteria ($H3_d$) and Situational Motivation ($H3_e$), and a negative effect on Constraint Recognition ($H3_c$). Income has a negative effect on all Problem Recognition ($H4_a$), Involvement Recognition ($H4_b$), Constraint Recognition ($H4_c$), Referent Criteria ($H4_d$) and Situational Motivation ($H4_e$). Household size has a positive effect on Problem Recognition ($H5_a$), Involvement Recognition ($H5_b$), Referent Criteria ($H5_d$) and Situational Motivation ($H5_e$), and a negative effect on Constraint Recognition ($H5_c$). Likewise, the existence of a spouse has a positive effect on Problem Recognition ($H6_a$), Involvement Recognition ($H6_b$), Referent Criteria ($H6_d$) and Situational Motivation ($H6_e$), and a negative effect on Constraint Recognition ($H6_c$), and children has a positive effect on Problem Recognition ($H7_a$), Involvement Recognition ($H7_b$), Referent Criteria ($H7_d$) and Situational Motivation ($H7_e$), and a negative effect on Constraint Recognition ($H7_c$). Finally, the country of residence has a negative effect on Problem Recognition ($H8_a$), Involvement Recognition ($H8_b$) and Constraint Recognition ($H8_c$), and a positive effect on Referent Criteria ($H8_d$) and Situational Motivation ($H8_e$).

### 3.2 Data Collection

Data were collected via self-administered, anonymous household questionnaire surveys. A seven-point Likert-type scale ranging from 1 = 'Strongly Disagree' to 7 = 'Strongly Agree' was used to code the responses for the situational variables. At least three items per latent construct were included as a rule. The wording of the questions was based on measurement items tested and validated in previous applications of STOPS (J.-N. Kim *et al*. 2012; Chen *et* *al*. 2017) with small adjustments where needed (see Table 2 for the survey measurement items). The initial version of the questionnaire was reviewed by a panel of 30 experts. After minor modifications to the items other than the verified STOPS measures, the questionnaire was translated by bilingual experts from English into Japanese and Korean, while a back-translation verified its effectiveness.

**Table 2.** STOPS Measurement Items

| Problem statement | ***There is a lack of publicly available information about potential chemical accidents at the industrial park in the area.*** | |
|---|---|---|
| Problem Recognition (PR) | PR1 | *I think this is an important problem.* |
| | PR2 | *Government institutions should take action to solve this problem.* |
| | PR3 | *Concerning this problem, I think there is a large gap between the way things should be and the way they are now.* |
| Problem Recognition (IR) | IR1 | *This problem could have serious consequences for me.* |
| | IR2 | *This problem could make a difference in my daily life.* |
| | IR3 | *There is a strong relationship between myself and this problem.* |
| Constraint Recognition (CR) | CR1 | *I believe I can improve the situation regarding this problem.* |
| | CR2 | *My opinions matter to those in the government, who are working on this problem.* |
| Referent Criterion (RC) | RC1 | *I have a clear idea about how to deal with this problem.* |
| | RC2 | *I have an idea about how the government should approach this problem.* |
| | RC3 | *I believe there are examples from other regions in Japan on how to deal with this problem.* |
| Situational Motivation (SM) | SM1 | *I am curious about this problem.* |
| | SM2 | *I frequently think about this problem.* |
| | SM3 | *I want to better understand this problem.* |

Source: Original work based on Kim *et al*. 2012; Chen, Hung-Baesecke, and Kim 2017

With the intent of collecting data from individuals exposed to a potential Natech accident, households within 2km from industrial installations were selected for this study. Areas with prominent industrial parks, neighbouring residential districts were targeted in both countries, specifically districts in Higashinada (Kobe) and Sakai-Senboku (Osaka) in Japan, and Yeosu, Suncheon, Gwangyang and Ulsan in S. Korea. For the Japanese sample, 2,630 questionnaires were distributed using post mail services resulting in *N*=330[4] responses (12.47% response rate). Participation was completely voluntary without any financial incentive. The Korean sample (*N*=300; 100% response rate) was collected via an online survey employing the Tillion panel, the largest survey panel in the country, using locational restrictions. Participation was again

[4] 327 valid replies after discarding 2 unanswered questionnaires and 1 unengaged respondent (*i.e*., answered '7' throughout the questionnaire).

voluntary, but a small financial compensation in the form of promotional coupons was provided to participants. Data collection periods were January 26-March 8 in 2018 for the Japanese sample and March 9-18, 2020 for the Korean.

## 3. ANALYSIS

The Japanese dataset required treatment for the missing values. The 327 responses were reduced to 317, after passing the Little's MCAR test, by excluding respondents whose questionnaire fill-out rate did not reach 90%. The remaining dataset was tried again using Little's MCAR test, justifying data imputation for the observed variables of each latent construct with the respective variable median[5] (Hair *et al*. 2010). The resulting Japanese dataset was then joined with the Korean. Preliminary reliability analysis for the combined dataset ($N$=617) exhibited robust latent construct validity for the five situational variables, as demonstrated by the Cronbach's $\alpha$ values that were above the .60 threshold. In detail: PR, $\alpha$= .839; IR, $\alpha$= .857; CR, $\alpha$= .601 after the exclusion of 1 problematic item; RC, $\alpha$= .718; and SM, $\alpha$= .812. Next, the values for each of the five situational variables were calculated as the mean of their respective constituent, observed variables. Finally, listwise deletion was employed once again, this time based on the responses to the demographic variables, in order to produce the final dataset for the regression analyses.

Prior to building the regression models, a check for any multicollinearity among the independent variables was performed. Variance inflation factors (VIFs) were smaller than 2.51 across all models, which is well under the threshold of 5 that would point to any serious problems of multicollinearity. Moderate, statistically significant correlations, nonetheless, were observed between country and age (- .507, $p$ <0.01), education (- .381, $p$ <0.01), household size (- .370, $p$ <0.01), spouse (- .349, $p$ <0.01) and children (- .462, $p$ <0.01), when correlation analysis was performed on the sociodemographic determinants. According to Belsley *et al*. (1980), fairly high statistical correlations among predictors are not always problematic in regression analysis. In this vein, predictors were included despite their significant, moderate correlation in order to control for them in the respective models. Durbin-Watson tests indicated no signs of dependency between observations for any model. Preliminary tests displayed no issues of non-linearity or homoskedasticity for any of the five models, suggesting thus that model specification could progress.

A series of Multiple Linear Regression analyses was conducted in order to test the formulated hypotheses and assess the effects—or lack thereof—of the sociodemographic factors on each of the situational variables. One model for each of the five dependent, situational variables was specified. In each model, all factors were entered in order to account

[5] This technique is not expected to alter the variable mean (Hair *et al*. 2010), since the percentage of missing information per variable did not exceed 2.3% (suggested threshold 10%).

for their effects regardless of the statistical significance of their respective coefficients. The general model is given by the expression as follows:

$$Y_{SitVar} = f(Gender, Age, Education, Income, Household\ Size, Spouse, Children, Country)$$

## 4. RESULTS

First, the demographic profile for the Japanese and Korean samples was delineated with respect to their gender, age, level of education, annual household income level, number of household members, whether they had a spouse and children (Table 3). Even though at first glance the ratio of the Japanese and Korean sub-categories of the dataset seems to be well-balanced (a decent 55/45), a more detailed examination of their compositions reveals that the Japanese and Korean sub-categories of the dataset are quite different. Indeed, while almost 3 in 5 Japanese respondents were male, females comprise the majority in the Korean sub-group. The discrepancy becomes more prevalent concerning age. Almost 60% of the respondents are above 60 years old among Japanese respondents, whereas Korean respondents are no older than 59. Similarly, all Korean respondents had at least graduated from a vocational/technical school in contrast to Japanese 40% of whom had finished only elementary and high school education. Considering the annual household income level, the groups appeared to be fairly similar, with only slightly more Koreans identifying themselves in the middle tier. The remaining three categories display significant divergencies. Households of Japanese respondents seem to be much smaller comparatively, with only 20% of them exceeding 3 members, while more than half of the Korean households have at least 4 members. Additionally, 70% of Japanese respondents had a spouse compared to 96.8% of Koreans. Finally, a similar situation was observed with respect to children living in the household; almost 9 out of 10 Korean households had children, compared to only 4 in 10 within the Japanese group.

Concerning the five situational variables under study, Table 4 offers a brief overview of the descriptive statistics for the combined dataset. Bearing in mind that the midpoint of the 7-point scale used in this study was 4, the following can be deduced. First, problem and involvement recognition both have rather elevated means (*i.e.* 5.8 and 5.3 respectively), while their values of Skewness and Kurtosis suggest peaks at higher values—particularly so for PR with a comparatively smaller $\sigma$, too. The values for the other three variables indicate more equally distributed responses. Two more points are worth noting here. Referent criteria was the only variable with positive skewness, while the only variable embedded with a negative meaning, constrained recognition, also received relatively high responses.

**Table 3.** Summary of Sample Characteristics

| **Category** | **Country** | | **Total** | |
|---|---|---|---|---|
| | **Japan** | **S. Korea** | | |
| | 54,85% | 45,15% | 485 | 100% |
| Gender | | | | |
| Female (1) | 41,35% | 53,42% | 227 | 46,80% |
| Male (2) | 58,65% | 46,58% | 258 | 53,20% |
| Age | | | | |
| 19 or younger (1) | 0,38% | 0,00% | 1 | 0,21% |
| 20 – 29 (2) | 1,88% | 2,74% | 11 | 2,27% |
| 30 – 39 (3) | 10,15% | 26,48% | 85 | 17,53% |
| 40 – 49 (4) | 11,28% | 34,25% | 105 | 21,65% |
| 50 – 59 (5) | 16,92% | 36,53% | 125 | 25,77% |
| 60 – 74 (6) | 42,11% | 0,00% | 112 | 23,09% |
| 75 or older (7) | 17,29% | 0,00% | 46 | 9,48% |
| *Educational Level* | | | | |
| Elementary School (1) | 2,63% | 0,00% | 7 | 1,44% |
| High School (2) | 36,47% | 0,00% | 97 | 20,00% |
| Vocational / Technical School (3) | 15,04% | 21,00% | 86 | 17,73% |
| Bachelor Degree (4) | 37,22% | 73,52% | 260 | 53,61% |
| Master Degree / PhD (5) | 8,65% | 5,48% | 35 | 7,22% |
| Annual Household Income Level | | | | |
| Low (0) | 38,35% | 15,07% | 135 | 27,84% |
| Middle (1) | 34,96% | 57,53% | 219 | 45,15% |
| High (2) | 26,69% | 27,40% | 131 | 27,01% |
| Household Size | | | | |
| 1 Member (1) | 19,17% | 1,83% | 55 | 11,34% |
| 2 Members (2) | 38,35% | 21,00% | 148 | 30,52% |
| 3 Members (3) | 23,68% | 26,48% | 121 | 24,95% |
| 4 Members (4) | 13,16% | 40,18% | 123 | 25,36% |
| 5 Members (5) | 4,14% | 10,05% | 33 | 6,80% |
| 6 Members (6) | 1,13% | 0,46% | 4 | 0,82% |
| 7 or more (7) | 0,38% | 0,00% | 1 | 0,21% |
| Spouse | | | | |
| No (0) | 30,08% | 3,20% | 87 | 17,94% |
| Yes (1) | 69,92% | 96,80% | 398 | 82,06% |
| Children | | | | |
| No (0) | 58,27% | 13,24% | 184 | 37,94% |
| Yes (1) | 41,73% | 86,76% | 301 | 62,06% |
| *N= 485* | | | | |

Source: Original work

**Table 4 .** Descriptive Statistics of the Situational Variables

| *Situational Variable* | *Mean* | *Std. Deviation* | *Skewness[1]* | *Kurtosis[2]* |
|---|---|---|---|---|
| *Problem Recognition (PR)* | 5.82 | .97 | -1.095 | 1.747 |
| *Involvement Recognition (IR)* | 5.29 | 1.16 | - .761 | .557 |
| *Constraint Recognition (CR)* | 4.36 | 1.30 | - .250 | - .454 |
| *Referent Criteria (RC)* | 3.77 | 1.20 | .164 | - .446 |
| *Situational Motivation (SM)* | 4.63 | 1.20 | - .465 | .162 |
| *[1] Std. Error= 0.111 and [2] Std. Error= 0.221.* <br> *N= 485* | | | | |

Source: Original work

The results from the regression analyses for the five models are summarised next. Looking at the last two columns of Table 5, it becomes apparent that models $R_1$ and $R_2$ for predicting problem and involvement recognition are not statistically significant at the 95% confidence interval. Hence, conclusions concerning the influence of any of the sociodemographic factors on these two situational variables (*i.e.*, $\boldsymbol{H1_a}$ through $\boldsymbol{H2_e}$) cannot be confidently drawn. Furthermore, the interpretative power of all models is quite small, even considering relatively low explanatory power standards typically found in psychological research (see Cvetković *et al.* 2018). $R^2$ values range from .047 to .12, meaning that the best performing model $R_4$ accounts only for 12% of the total variance observed in the referent criteria.

**Table 5.** Regression Model Fit Results Summary

| *Model* | *Situational Variable* | **R** | **R²** | **R² adj.** | **F** (8, 476) | ***p*** |
|---|---|---|---|---|---|---|
| $R_1$ | *Problem Recognition (PR)* | .176 | .031 | .015 | 1.899 | .058 |
| $R_2$ | *Involvement Recognition (IR)* | .175 | .031 | .014 | 1.886 | .060 |
| $R_3$ | *Constraint Recognition (CR)* | .303 | .092 | .077 | 6.034 | .000 |
| $R_4$ | *Referent Criteria (RC)* | .346 | .120 | .105 | 8.081 | .000 |
| $R_5$ | *Situational Motivation (SM)* | .218 | .047 | .031 | 2.964 | .003 |
| *N= 485* | | | | | | |

Source: Original work

Moving on to the regression coefficients (Table 6), we observed that none of the estimated coefficients for education, income, household size, having a spouse or having children is statistically significant in any model. Therefore, hypotheses $\boldsymbol{H3_c}$ through $\boldsymbol{H7_c}$, $\boldsymbol{H3_d}$ through $\boldsymbol{H7_d}$ and additionally $\boldsymbol{H3_e}$ through $\boldsymbol{H7_e}$ cannot be confidently confirmed or rejected on account of insignificant evidence. On the other hand, respondents' gender appears to slightly increase constrain recognition ($\boldsymbol{H1_c}$) (*B*=.34, *p*<.01) and reduce situational motivation ($\boldsymbol{H1_e}$) (*B*= - .32, *p*<.01), thus supporting the original hypotheses. In terms of age, the initial assumption that it increased constraint recognition (***H2****c*) (*B*= - .15, *p*<.05) was actually rejected, whereas its increasing effect on referent criteria (***H2****d*) (*B*=.12, *p*<.05) was confirmed. Surprisingly, the only statistically significant and strong effects were observed from the variable of country on constraint recognition (***H8****c*) and referent criteria (***H8****d*), confirming the expected relationships. Both of these hypotheses were supported with standardised coefficients *B*= - .72 (*p*<.001) and *B*=.84 (*p*<.001), respectively. It should be noted that all statistically significant effect sizes, except for the ones of country on CR and RC, were rather small, while all remaining hypotheses not discussed here are inconclusive due to a lack of statistically significant results.

**Table 6.** Regression Coefficients

| *Situation. Var.* | *Gender* | *Age* | *Education* | *Income* | *H. Size* | *Spouse* | *Children* | *Country* |
|---|---|---|---|---|---|---|---|---|
| *PR* | - .168 | .003 | .090 | - .034 | .009 | .035 | .205 | - .340** |
| *IR* | - .177 | - .077 | .070 | - .037 | - .039 | .233 | .248 | - .167 |
| *CR* | .337** | -.153** | .068 | - .132 | - .112 | - .094 | .154 | - .716*** |
| *RC* | - .177 | .123** | - .030 | - .001 | .107 | .122 | - .116 | .836*** |
| *SM* | - .318** | .081 | .085 | - .022 | .036 | .159 | .049 | .262 |

*N= 485*
*** Coefficient is significant at the.01 level (2-tailed).*
**** Coefficient is significant at the.001 level (2-tailed).*
*Notes: Problem Recognition (PR), Involvement Recognition (IR), Constraint Recognition, Referent Criterion (RC) and Situational Motivation (SM).*

Source: Original work

## 5. DISCUSSION

Our inquiry was based on the conceptualisation of Natech risk information deficiency as a cognitive meta-problem that individuals are called to address with respect to enhancing their preparedness against potential accidents. Thus, this study ventured to explore whether and how households' sociodemographic characteristics affected their situational perceptions and communicative attitudes. A series of multiple linear regression models were used in order to test the specified hypotheses to assess their validity. Out of the 40 hypotheses in total, only six evidenced statistically significant results that could warrant conclusions: in total, five hypotheses were confirmed, and one was rejected due to observing an inverse relationship.

Despite approaching the subject from a fresh perspective grounded in the public relations field, this study, essentially, did not contribute any radically new revelations with respect to the effects of sociodemographic determinants. Instead, our results resonated with the conclusions from previous risk perception studies in the context of Natech (Yu *et al*. 2017; Slack *et al*. 2020) and risk communication in general (Wachinger and Renn 2010; Wachinger *et al*. 2013): effects proved mostly weak and insignificant. In general, the cross-situational impotence of sociodemographic characteristics in comparison to the perceptual variables of STOPS (Grunig 1997; J.-N. Kim *et al*. 2009; 2012) was confirmed in this study. Nevertheless, our risk communication-oriented approach invites an interesting discussion about the findings.

Specifically, gender seemed to have a positive relationship with constraint recognition and a negative relationship with situational motivation for problem solving. As hypothesised based on the risk perception literature, males appear to be less motivated to communicate about the Natech risk information deficiency issue, while they perceive more obstacles in pursuit of information. Research has shown that males tend to underestimate risks in various contexts (*e.g*., Savage 1993; Sund *et al*. 2017), and perhaps this reduced perceived severity of the initial chemical risk is what leads to a subsequently lower cognitive meta-problem appraisal and interest in a solution. This reasoning would explain the negative effect on situational motivation, as this factor is defined by problem, involvement and constraint recognition. Moreover, perhaps the comparatively lower interest of male respondents also magnifies the perceived limitations, simply because individuals have not invested themselves in analysing the issues in order to overcome them.

In terms of the effects of age, our findings seem to align more with the literature that regards age as a dampening factor for risk perception (Peacock *et al*. 2005; Huang *et al.* 2012). Along with age, there seems to come experience in how to resolve the meta-problem of Natech risk information deficiency. Older individuals appear to have more referent criteria readily available about how this problem should be handled. Following the conceptualisation of STOPS (J.-N. Kim and Krishna 2014), this may be due to more experiences accumulated over the years, as well as established expectations about how Natech risk information deficiency could be resolved. Of course, there is no established association between Natech risk perception and the communicative behaviour towards the issue of risk information deficiency, yet we could argue that the alleviating effects of reducing perceived limitations in resolving the meta-problem contribute in turn to lessening the perceived severity of the whole situation.

On the other hand, the variable of country demonstrated some interesting findings. Korean respondents appear to perceive themselves as less constrained in resolving the meta-problem of Natech risk information deficiency, whilst they have referent criteria they consider readily applicable to the issue. Results were strong and statistically significant in this regard. There even seems to be a positive, alleviating effect on problem recognition, although conclusions could not be statistically supported. Now, even though our methodological approach does not warrant a cross-cultural comparison at the national level between Japan and S. Korea, we included this factor in our analysis as a control for any underlying institutional parameters, particularly bearing in mind the difference in the chemical risk management regulatory frameworks of the two countries. Although we can only speculate at this point given these circumstantial findings, we could entertain the idea that the recently introduced Chemical Controls Act, which includes chemical risk information disclosure provisions, actually succeeds in creating a more inviting chemical and Natech risk communication environment compared to Japan. Korean respondents seem to be more communicatively active towards resolving the issue of Natech risk information disclosure, and perhaps this is due to the existence of a regulatory environment.

Of course, the central point of our reasoning is a fairly similar, collectivistic organisational culture among the two countries (see *e.g*., G. H. Hofstede 2001; House *et al*. 2004; G. Hofstede *et al*. 2010) that does not significantly skew the observed relationships. However, contemplating the arguments about the dissimilarities of the two organisational cultures (S. H. Kim and Kim 2016; Park *et al*. 2016), a *ceteris paribus* assumption for the sociocultural parameters at play cannot be upheld. Moreover, any conclusions based on the comparison between the Japanese and Korean sub-groups in our survey respondents must be treated with extra caution considering the sample discrepancies presented in the dataset. Furthermore, we cannot exclude any hidden factors we may have omitted or understated in our approach. Nevertheless, these preliminary results may pave the way for future research that will test more rigorously this argument against various cross-cultural influences.

## 6. CONCLUSIONS

Going beyond risk perception studies that have traditionally approached the relationship between risk communication and sociodemographic determinants through the psychometric and cultural theory paradigms, we borrowed the interpretative framework of STOPS to investigate situational variables instead. We framed the lack of Natech risk information as a cognitive meta-problem that stems from the original, underlying Natech accident risk. Individuals perceive this issue and, according to the purposeful communication narrative of STOPS, become motivated to communicate and overcome it. In this context, this study set to investigate the potential effects of sociodemographic factors in shaping individuals' situational perceptions and communicative behaviour concerning the issue of Natech risk information deficiency. We collected data from households near prominent industrial parks in Osaka and Kobe in Japan, and Yeosu, Suncheon, Gwangyang and Ulsan in S. Korea, to assess the effects of factors such as gender, age, household size, income and educational level. The results of our regression analysis indicated mostly weak and insignificant effects, except for gender and age that suggested negative and positive influences on individuals' communicative attitudes, respectively. The implications of the institutional differences between the two countries were also discussed within the sphere of chemical and Natech risk communication.

As one of the very few studies in the emerging field of Natech risk communication, we hope the findings of this research can contribute to formulating and focusing directions for further investigations. However, there are some drawbacks in this study that should be discussed here with an outlook to future research. There was no intention of conducting a cross-cultural study that would involve sociocultural constructs, and would focus on comparing the two samples, even at a national level. Arguably, our approach combined responses from individuals of different sociocultural backgrounds, and so introduced—inevitably—some culture-specific biases. We acknowledge that our efforts to address this issue with the introduction of a single control variable are far from optimal. In this respect, this research topic would greatly benefit from a full-fledged cross-cultural study that would incorporate sociocultural dimensions to effectively capture and disambiguate their influences on the situational variables. Moreover, as pointed out in the results section, we did not optimise our sampling method in pursuit of more representative population samples that would permit generalisations and a comparison at the national level between Japan and S. Korea. In contrast, we opted for rather technical criteria, targeting households under immediate risk from a potential Natech accident at the neighbouring industrial facility. Resource limitations did not permit the implementation of a sampling strategy that would simultaneously control for the location and the demographic profile of respondents, thus resulting in notable demographic discrepancies between the two samples. Hence, future studies are encouraged to investigate the topic using different sampling techniques based on demographic criteria (e.g., stratified sampling), especially if aiming for inter-group comparisons. Finally, our study did not explore the potential influence of survey participation incentives on the quality of responses in an opinion questionnaire about disaster risk communication and perception. Although our study employed both data collection strategies (i.e., incentives and not), one for each sample, our findings do not allow us to draw conclusions concerning this matter. Considering that participation incentives might, hypothetically, affect the representation of certain sub-groups within the sample and—by extension—their perceptions, additional research is needed to further investigate these issues.

## REFERENCES

Aven, Terje, and Ortwin, Renn. 2010. *Risk Management and Governance: Concepts, Guidelines and Applications*. Risk, Governance and Society. Berlin Heidelberg: Springer-Verlag. //www.springer.com/jp/book/9783642139253.

Barberi, Federica, Matthew Davis, Roberto Isaia, Rosella Nave, and Tullio Ricci. 2008. 'Volcanic Risk Perception in the Vesuvius Population'. *Journal of Volcanology and Geothermal Research*, April. https://doi.org/10.1016/j.jvolgeores.2007.12.011.

Basolo, Victoria, Laura J. Steinberg, Raymond J. Burby, Joyce Levine, Ana Maria Cruz, and Chihyen Huang. 2009. 'The Effects of Confidence in Government and Information on Perceived and Actual Preparedness for Disasters'. *Environment and Behavior 41* (3): 338–64. https://doi.org/10.1177/0013916508317222.

Belsley, David A., Edwin Kuh, and Roy E. Welsch. 1980. *Regression Diagnostics: Identifying Influential Data and Sources of Collinearity*. Wiley.

Breakwell, Glynis M. 2007. *The Psychology of Risk*. Cambridge: Cambridge University Press. https://doi.org/10.1017/CBO9780511819315.

Chen, Yi-Ru Regina, Chun-Ju Flora Hung-Baesecke, and Jeong-Nam Kim. 2017. 'Identifying Active Hot-Issue Communicators and Subgroup Identifiers: Examining the Situational Theory of Problem Solving'. *Journalism & Mass Communication Quarterly 94* (1): 124–47. https://doi.org/10.1177/1077699016629371.

Chon, Myoung-Gi. 2019. 'Government Public Relations When Trouble Hits: Exploring Political Dispositions, Situational Variables, and Government–Public Relationships to Predict Communicative Action of Publics'. *Asian Journal of Communication 0* (0): 1–17. https://doi.org/10.1080/01292986.2019.1649438.

Cruz, Ana Maria, and Elisabeth Krausmann. 2009. 'Hazardous-Materials Releases from Offshore Oil and Gas Facilities and Emergency Response Following Hurricanes Katrina and Rita'. *Journal of Loss Prevention in the Process Industries 22* (1): 59–65. https://doi.org/10.1016/j.jlp.2008.08.007.

Cruz, Ana Maria, and Elisabeth Krausmann. 2013. 'Vulnerability of the Oil and Gas Sector to Climate Change and Extreme Weather Events'. *Climatic Change 121* (1): 41–53. https://doi.org/10.1007/s10584-013-0891-4.

Cruz, Ana Maria, and Maria Camila Suarez-Paba. 2019. 'Advances in Natech Research: An Overview'. *Progress in Disaster Science* 1 (May): 100013. https://doi.org/10.1016/j.pdisas.2019.100013.

Cvetković, Vladimir M., Giulia Roder, Adem Öcal, Paolo Tarolli, and Slavoljub Dragićević. 2018. 'The Role of Gender in Preparedness and Response Behaviors towards Flood Risk in Serbia'. *International Journal of Environmental Research and Public Health 15* (12): 2761. https://doi.org/10.3390/ijerph15122761.

Dash, Nicole. 2002. 'Decision-Making under Extreme Uncertainty: Rethinking Hazard-Related Perceptions and Action'. *ProQuest ETD Collection for FIU*, January.

Dash, Nicole, and Hugh Gladwin. 2007. 'Evacuation Decision Making and Behavioral Responses: Individual and Household'. *Natural Hazards Review 8* (3): 69–77. https://doi.org/10.1061/(ASCE)1527-6988(2007)8:3(69).

Davidson, Debra J., and Wiluam R. Freudenburg. 1996. 'Gender and Environmental Risk Concerns: A Review and Analysis of Available Research'. *Environment and Behavior 28* (3): 302–39. https://doi.org/10.1177/0013916596283003.

Donner, William, and Havidán Rodríguez. 2008. 'Population Composition, Migration and Inequality: The Influence of Demographic Changes on Disaster Risk and Vulnerability'. *Social Forces 87* (2): 1089–1114. https://doi.org/10.1353/sof.0.0141.

Douglas, Mary, and Aaron Wildavsky. 1982. *Risk and Culture: An Essay on the Selection of Technological and Environmental Dangers*. 1st ed. University of California Press. https://www.jstor.org/stable/10.1525/j.ctt7zw3mr.

Figueroa, Pablo M. 2013. 'Risk Communication Surrounding the Fukushima Nuclear Disaster: An Anthropological Approach'. *Asia Europe Journal 11* (1): 53–64. https://doi.org/10.1007/s10308-013-0343-9.

Fothergill, Alice, and Lori A. Peek. 2004. 'Poverty and Disasters in the United States: A Review of Recent Sociological Findings'. *Natural Hazards 32* (1): 89–110. https://doi.org/10.1023/B:NHAZ.0000026792.76181.d9.

Grunig, James E. 1997. 'A Situational Theory of Publics: Conceptual History, Recent Challenges and New Research'. In *Public Relations Research: An International*

*Perspective*, edited by Danny Moss, Toby MacManus, and Dejan Verčič, 3–47. London: International Thomson Business Press.

Grunig, James E. 2018. 'Strategic Behavioral Paradigm'. In *The International Encyclopedia of Strategic Communication*, by Robert L. Heath and Winni Johansen, 1–6. American Cancer Society. https://doi.org/10.1002/9781119010722.iesc0171.

Grunig, James E., and Jeong-Nam Kim. 2017. 'Publics Approaches to Health and Risk Message Design and Processing'. *Oxford Research Encyclopedia of Communication*, May. https://doi.org/10.1093/acrefore/9780190228613.013.322.

Gutteling, Jan M., and Oene Wiegman. 1996. *Exploring Risk Communication*. Advances in Natural and Technological Hazards Research. Springer Netherlands. https://doi.org/10.1007/978-94-017-1523-2.

Hair, Joseph F., Jr, William C. Black, Barry J. Babin, and Rolph E. Anderson. 2010. *Multivariate Data Analysis*. 7 edition. Upper Saddle River, NJ: Pearson.

Hofstede, Geert H. 2001. *Culture's Consequences: Comparing Values, Behaviors, Institutions and Organizations Across Nations*. 2nd ed. Thousand Oaks, CA: SAGE.

Hofstede, Geert, Gert Jan Hofstede, and Michael Minkov. 2010. *Cultures and Organizations: Software of the Mind, Third Edition*. 3rd Edition. New York: McGraw-Hill Education.

House, Robert J., Paul J. Hanges, Mansour Javidan, Peter W. Dorfman, and Vipin Gupta. 2004. *Culture, Leadership, and Organizations: The GLOBE Study of 62 Societies*. 1st Edition. Thousand Oaks, Calif: SAGE Publications, Inc.

Huang, Shih-Kai, Michael K. Lindell, Carla S. Prater, Hao-Che Wu, and Laura K. Siebeneck. 2012. 'Household Evacuation Decision Making in Response to Hurricane Ike'. *Natural Hazards Review 13* (4): 283–96. https://doi.org/10.1061/(ASCE)NH.1527-6996.0000074.

Kim, Do Kyun David, and T. Phillip Madison. 2020. 'Public Risk Perception Attitude and Information-Seeking Efficacy on Floods: A Formative Study for Disaster Preparation Campaigns and Policies'. *International Journal of Disaster Risk Science 11* (5): 592–601. https://doi.org/10.1007/s13753-020-00307-5.

Kim, Jeong-Nam, and James E. Grunig. 2011. 'Problem Solving and Communicative Action: A Situational Theory of Problem Solving'. *Journal of Communication 61* (1): 120–49. https://doi.org/10.1111/j.1460-2466.2010.01529.x.

Kim, Jeong-Nam, Y. R. Jung, S. C. Park, and M. Dutta. 2009. 'Gossiping Science: Lay Diffusers of Science Knowledge and Information'. In *Chicago, IL: Applied Communication Division, National Communication Association.*

Kim, Jeong-Nam, and Arunima Krishna. 2014. 'Publics and Lay Informatics: A Review of the Situational Theory of Problem Solving'. *Annals of the International Communication Association 38* (1): 71–105. https://doi.org/10.1080/23808985.2014.11679159.

Kim, Jeong-Nam, Lan Ni, Sei-Hill Kim, and Jangyul Robert Kim. 2012. 'What Makes People Hot? Applying the Situational Theory of Problem Solving to Hot-Issue Publics'. *Journal of Public Relations Research 24* (2): 144–64. https://doi.org/10.1080/1062726X.2012.626133.

Kim, Jeong-Nam, Lan Ni, and Bey-Ling Sha. 2008. 'Breaking down the Stakeholder Environment: Explicating Approaches to the Segmentation of Publics for Public Relations Research'. *Journalism & Mass Communication Quarterly 85* (4): 751–68. https://doi.org/10.1177/107769900808500403.

Kim, Seung Hyun, and Sangmook Kim. 2016. 'Social Desirability Bias in Measuring Public Service Motivation'. *International Public Management Journal* 19 (3): 293–319. https://doi.org/10.1080/10967494.2015.1021497.

Kim, Young, Andrea Miller, and Myoung-Gi Chon. 2016. 'Communicating with Key Publics in Crisis Communication: The Synthetic Approach to the Public Segmentation in CAPS (Communicative Action in Problem Solving)'. *Journal of Contingencies and Crisis Management 24* (2): 82–94. https://doi.org/10.1111/1468-5973.12104.

Kunz-Plapp, Tina, and Ute Werner. 2006. 'Understanding Risk Perception from Natural Hazards: Examples from Germany'. In *RISK21 - Coping with Risks Due to Natural Hazards in the 21st Century: Proceedings of the RISK21 Workshop, Monte Verità, Ascona, Switzerland, 28 November - 3 December 2004*, edited by Walter J. Ammann, Stefanie Dannenmann, and Laurent Vulliet, 21:101–8. CRC Press.

Lindell, Michael. 2013. 'North American Cities at Risk: Household Responses to Environmental Hazards'. In *Cities at Risk: Living with Perils in the 21st Century*, edited by Helene Joffe, Tiziana Rossetto, and John Adams, 109–30. Advances in Natural and Technological Hazards Research. Dordrecht: Springer Netherlands. https://doi.org/10.1007/978-94-007-6184-1_7.

Lindell, Michael K., and Seong Nam Hwang. 2008. 'Households' Perceived Personal Risk and Responses in a Multihazard Environment'. *Risk Analysis 28* (2): 539–56. https://doi.org/10.1111/j.1539-6924.2008.01032.x.

Lovari, Alessandro, Valentina Martino, and Jeong-Nam Kim. 2012. 'Citizens' Relationships with a Municipality and Their Communicative Behaviors in Negative Civic Issues'. *International Journal of Strategic Communication 6* (1): 17–30. https://doi.org/10.1080/1553118X.2011.634870.

Ministry of Environment, Republic of Korea. 2018. *Chemicals Control Act*.

Ni, Lan, and Jeong-Nam Kim. 2009. 'Classifying Publics: Communication Behaviors and Problem-Solving Characteristics in Controversial Issues'. *International Journal of Strategic Communication* 3 (4): 217–41. https://doi.org/10.1080/15531180903221261.

Palenchar, Michael J. "Risk Communication and Community Right to Know: A Public Relations Obligation to Inform" (2008). School of Advertising and Public Relations Publications and Other Works. *Public Relations Journal, January*. https://trace.tennessee.edu/utk_advepubs/1.

Park, Junsu, Do-Yeong Kim, and Chong Zhang. 2016. 'Understanding Cross-National Differences in Risk Through a Localized Cultural Perspective'. *Cross-Cultural Research 50* (1): 34–62. https://doi.org/10.1177/1069397115609560.

Peacock, Walter Gillis, Samuel David Brody, and Wes Highfield. 2005. 'Hurricane Risk Perceptions among Florida's Single Family Homeowners'. *Landscape and Urban Planning*, Research on the Built and Virtual Environments, *73* (2): 120–35. https://doi.org/10.1016/j.landurbplan.2004.11.004.

Renn, Ortwin, and Andreas Klinke. 2013. 'A Framework of Adaptive Risk Governance for Urban Planning'. *Sustainability 5* (5): 2036–59. https://doi.org/10.3390/su5052036.

Renn, Ortwin, and Katherine D. Walker, eds. 2008. *Global Risk Governance: Concept and Practice Using the IRGC Framework*. International Risk Governance Council Bookseries. Springer Netherlands. https://doi.org/10.1007/978-1-4020-6799-0.

Rowe, Gene, and George Wright. 2001. 'Differences in Expert and Lay Judgments of Risk: Myth or Reality?' *Risk Analysis 21* (2): 341–56. https://doi.org/10.1111/0272-4332.212116.

Savage, Ian. 1993. 'Demographic Influences on Risk Perceptions'. *Risk Analysis 13* (4): 413–20. https://doi.org/10.1111/j.1539-6924.1993.tb00741.x.

Shapiro, Marc D. 2005. 'Equity and Information: Information Regulation, Environmental Justice, and Risks from Toxic Chemicals'. *Journal of Policy Analysis and Management 24* (2): 373–98. https://doi.org/10.1002/pam.20094.

Sjöberg, Lennart. 2000. 'Factors in Risk Perception'. *Risk Analysis 20* (1): 1–12. https://doi.org/10.1111/0272-4332.00001.

Sjöberg, Lennart. 2004. 'Explaining Individual Risk Perception: The Case of Nuclear Waste'. *Risk Management 6* (1): 51–64. https://doi.org/10.1057/palgrave.rm.8240172.

Slack, Tim, Vanessa Parks, Lynsay Ayer, Andrew M. Parker, Melissa L. Finucane, and Rajeev Ramchand. 2020. 'Natech or Natural? An Analysis of Hazard Perceptions, Institutional Trust, and Future Storm Worry Following Hurricane Harvey'. *Natural Hazards 102* (3): 1207–24. https://doi.org/10.1007/s11069-020-03953-6.

Slovic, Paul. 1999. 'Trust, Emotion, Sex, Politics, and Science: Surveying the Risk-Assessment Battlefield'. *Risk Analysis 19* (4): 689–701. https://doi.org/10.1111/j.1539-6924.1999.tb00439.x.

Slovic, Paul. 2000. *The Perception of Risk*. London; Sterling, VA: Earthscan.

Slovic, Paul, Baruch Fischhoff, Sarah Lichtenstein, and F. J. C. Roe. 1981. 'Perceived Risk: Psychological Factors and Social Implications [and Discussion]'. *Proceedings of the Royal Society of London. Series A, Mathematical and Physical Sciences* 376 (1764): 17–34.

Solis, Daniel, Michael H. Thomas, and David Letson. 2009. 'Determinants of Household Hurricane Evacuation Choice in Florida'. In *2009 Annual Meeting: Selected Papers*. Atlanta, Georgia: Southern Agricultural Economics Association. https://econpapers.repec.org/paper/agssaeana/45338.htm

Suarez-Paba, Maria Camila, Mathis Perreur, Felipe Munoz, and Ana Maria Cruz. 2019. 'Systematic Literature Review and Qualitative Meta-Analysis of Natech Research in the Past Four Decades'. *Safety Science* 116 (July): 58–77. https://doi.org/10.1016/j.ssci.2019.02.033.

Suarez-Paba, Maria Camila, Dimitrios Tzioutzios, Ana Maria Cruz, and Elisabeth Krausmann. 2020. 'Toward Natech Resilient Industries'. In *Disaster Risk Reduction and Resilience*, edited by Muneta Yokomatsu and Stefan Hochrainer-Stigler, 45–64. Disaster and Risk Research: GADRI Book Series. Singapore: Springer. https://doi.org/10.1007/978-981-15-4320-3_4.

Sund, Björn, Mikael Svensson, and Henrik Andersson. 2017. 'Demographic Determinants of Incident Experience and Risk Perception: Do High-Risk Groups Accurately Perceive Themselves as High-Risk?' *Journal of Risk Research 20* (1): 99–117. https://doi.org/10.1080/13669877.2015.1042499.

Sundblad, Eva-Lotta, Anders Biel, and Tommy Gärling. 2007. 'Cognitive and Affective Risk Judgements Related to Climate Change'. *Journal of Environmental Psychology 27* (2): 97–106. https://doi.org/10.1016/j.jenvp.2007.01.003.

UNDRR-APSTAAG. 2020. 'Asia-Pacific Regional Framework for NATECH (Natural Hazards Triggering Technological Disasters) Risk Management'. Geneva, Switzerland: United Nations Office for Disaster Risk Reduction – Asia-Pacific Science, Technology and Academia Advisory Group. https://www.undrr.org/publication/asia-pacific-regional-framework-natech-natural-hazards-triggering-technological.

UNISDR. 2015. 'Sendai Framework for Disaster Risk Reduction 2015-2030'. UNISDR/GE/2015-ICLUX EN5000 1st edition. Geneva, Switzerland: United Nations Office for Disaster Risk Reduction.

Wachinger, Gisela, and Ortwin Renn. 2010. 'Risk Perception and Natural Hazards'. CapHaz-Net WP3 Report. Stuttgart, Germany: DIALOGIK Non-Profit Institute for Communication and Cooperative Research.

Wachinger, Gisela, Ortwin Renn, Chloe Begg, and Christian Kuhlicke. 2013. 'The Risk Perception Paradox--Implications for Governance and Communication of Natural Hazards'. *Risk Analysis: An Official Publication of the Society for Risk Analysis 33* (6): 1049–65. https://doi.org/10.1111/j.1539-6924.2012.01942.x.

Xu, Dingde, Li Peng, Shaoquan Liu, and Xuxi Wang. 2018. 'Influences of Risk Perception and Sense of Place on Landslide Disaster Preparedness in Southwestern China'. *International Journal of Disaster Risk Science 9* (2): 167–80. https://doi.org/10.1007/s13753-018-0170-0.

Yu, Junlei, Ana Maria Cruz, and Akihiko Hokugo. 2017. 'Households' Risk Perception and Behavioral Responses to Natech Accidents'. *International Journal of Disaster Risk Science 8* (1): 1–15. https://doi.org/10.1007/s13753-017-0116-y.

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Original paper

# Identification of Interruptions in Urban Drainage Systems and Their Sustainable Solutions for Alleviating Flood Risk in Mumbai, an Indian Megacity

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**Abstract** Indian cities, in recent times, have been grappling with pressing natural disasters such as urban flooding and the dichotomy of acute water shortage. 24x7 water supply is a distant dream for the authorities involved. With an ever-increasing population leading to greater water demands, stormwater is increasingly considered an 'asset,' a resource that needs to be harvested. Mumbai, India's financial capital, being prone to chronic flooding, is a colossal problem for the country's economy. This review paper aims to identify direct and indirect interruptions in the stormwater drainage system of Mumbai, which in turn is leading to chronic flooding issues. This research identifies causative factors for flooding and observes that dilapidated and old-fashioned drainage systems are major hindrances in flood-free Mumbai. The traditional approach to urban infrastructure management needs to be reviewed and re-imagined. The identified interruptions in the drainage system were, thus, studied in detail to finally suggest some sustainable solutions, based on analysis and learnings from international success stories of cities having similar problems.

**Keywords:** Interruptions in Drainage, Mumbai, Flood, SuDS, sustainable

## 1. INTRODUCTION

Flood is the most frequently occurring disaster worldwide (EDMAT, 2019) and the biggest disaster in India, killing thousands in the last few years as per the National Institute of Disaster

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Management (India). The intensity and frequency of these floods have been increasing steadily, resulting in amplified damage to life and the economy.

According to the IPCC, 2019, rare extreme flooding events may begin to occur annually. Some coastal areas are already seeing frequent higher sea levels during high tides and storm surges, thereby risking many low-lying cities and islands. Coastal migration and urbanization make flooding events even more damaging. The number of people living at low elevations is projected to increase threefold by 2100. Without serious adaptation measures, flood risks may increase by 2 to 3 orders of magnitude. Rising sea levels threaten to erase coastal mega-cities such as Bangkok, Shanghai, and Mumbai (Climate Risk Index, 2020).

Coastal cities of Mumbai, Kolkata, Surat, and Chennai are under major threat. A total of 4 billion people will be hit by sea-level rise, melting ice, and glaciers (IPCC, 2018). Mumbai is the most vulnerable city regarding flood risks associated with anthropogenic activities (Dhiman *et al*., 2018). Mumbai currently ranks as the 5$^{th}$ largest city (in terms of the population) globally (UNDESA, 2016). Mumbai has experienced several major extreme weather events within the past decade that have effectively brought the city to a standstill and caused severe human and economic losses (Shanghai Manual, 2010).

Mumbai is one of the most talked-about cities of India around the world when it comes to disaster and especially flood risks. Mumbai city is highly prone to disasters because of its natural hazard profile on account of factors such as - being a coastal city, having low-lying and hilly areas and seismicity of the landmass. The vulnerability is amplified due to human actions such as land reclamations, a high population density and encroachment of sensitive areas.

As stated by IPCC, 2019, if India continues to violate the Paris deal on low emissions, the water level will rise up to 100-110cms, leaving no trace of Mumbai behind. There is an urgent need for a paradigm shift from 'response and relief' to 'prevention and mitigation' to make cities resilient (Dhankhar, 2017), and cities cannot simply pipe away flood risks. (Jainer, 2019)

This review paper aims to identify direct and indirect interruptions in the stormwater drainage system in Mumbai, leading to chronic flooding issues. Further on, it focuses on finding sustainable solution options to solve the issue in the complex urban setting of Mumbai.

## 2. METHODOLOGY

As part of this study, the authors looked at disasters in India, highlighting flood as the most occurring disaster in India and throughout the world and Mumbai as the most vulnerable city in the country.

Thus, detailed literature study was undertaken based on reports published by various government bodies and institutions on reasons for flooding in the city post the 2005 deluge. It also encompassed research published on the flooding issues in Mumbai, including national and international journals. It included studies related to the environment, climate change, governance, urban and infrastructure planning, engineering and implementation.

Reconnaissance surveys and interviews conducted in 2009 by the primary author (as a part of post-graduation studies from the School of Planning and Architecture, New Delhi) also form a part of the study.

The study focuses on the identification of causative factors for flooding in Mumbai. It was observed that all major problems related to flooding in the city could be categorized into six interruptions in the stormwater drainage system that have been leading to major flooding events in the city.

Additionally, based on a literature survey, the study touches briefly on some sustainable solutions for these six interruptions based on international success stories. The study concludes, stating the need to focus on the measures that need to be implemented to adopt a global sustainable urban drainage system locally.

Due to the scale of Mumbai city, the review paper is limited to highlighting the drainage issues leading to flooding and the sustainable solution options for them. These solution options have not been simulated or experimented upon in any part of the city.

## 3. PROFILE OF MUMBAI, INDIA

Mumbai is the commercial and financial capital of India and is also India's most populous city. The megacity had a population of 21.3 million (as per UNDESA in 2016). The municipal area of the city had a population of 13.8 million (as per Worldometer, United Nations 2020). It is located along the western coast of India and has the largest port in western India.

Mumbai was formed on two groups of islands, Heptanesia and Salsette islands. It has an average elevation of 10-15 meters above mean sea level. The coastline of the city is low-lying, with some points just one meter above mean sea level. Marquee zones such as the Bandra Kurla Complex (BKC), one of the most prominent commercial hubs with the highest property rates in the country; Worli, one of the most upscale areas; the International Airport of Mumbai are all low-lying areas. The original islands are at a higher level than the reclaimed areas.

The city is prone to multiple disaster risks, such as natural disasters like floods, landslides, cyclones, earthquakes, and manmade disasters like fire, industrial and chemical accidents, terrorist attacks, and riots. Mumbai had its biggest flood event in the year 2005, leading to the loss of hundreds of lives and a financial loss of US$100 million. This flood covered 22% of the developed area of the city. As of today, around 10% area of Mumbai is prone to chronic flooding. More than 55% of the city's population, 11.9 million, live in slum areas and hutments (Jain, 2006). The in-migration has led to excessive urbanization visible in the population growth of 16% in the previous decade. The natural and manmade disasters, rapid urbanization, encroachments on disaster prone areas make Mumbai less resilient to any future disaster events.

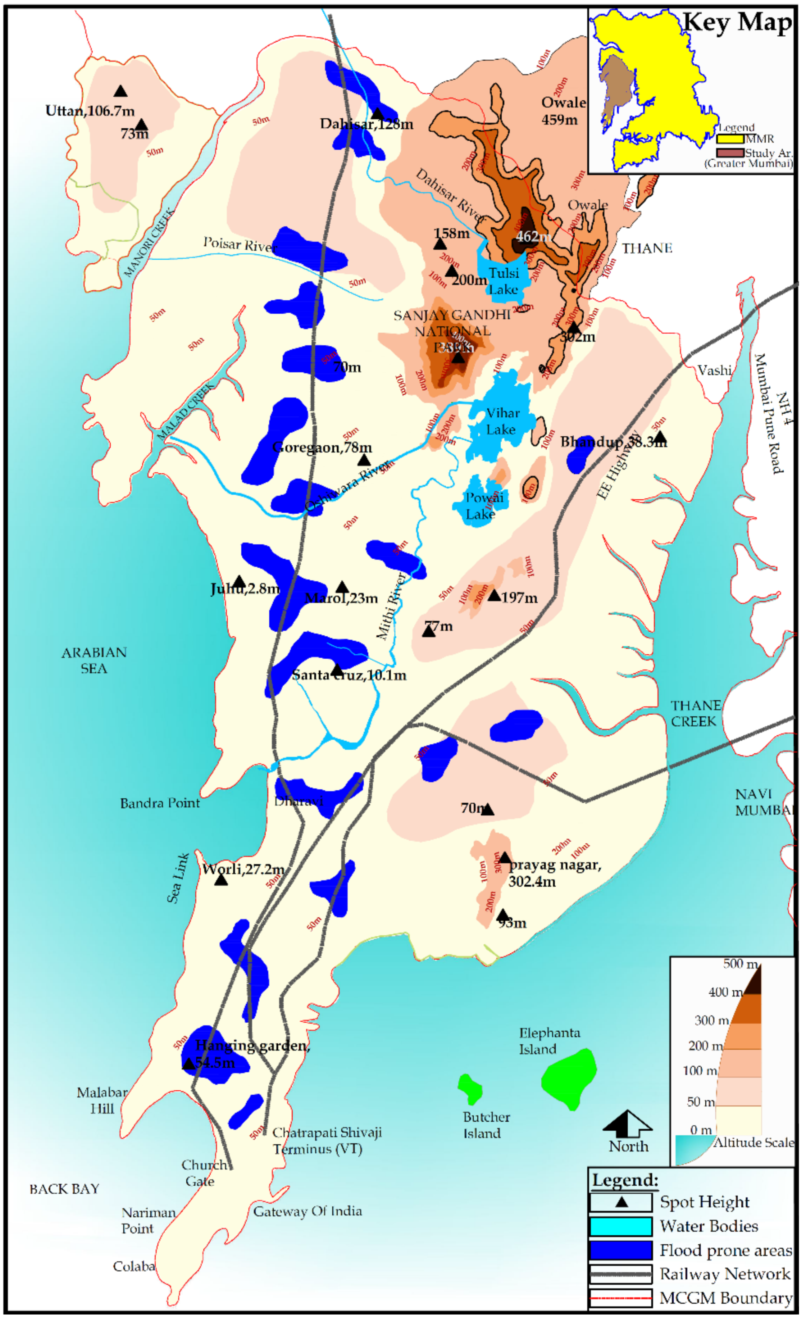


**Figure 1.** Landform, water bodies, and flood-prone areas, Greater Mumbai

Source: Drafted by the primary author based on GoogleEarth 2009, Toposheets and Mumbai an Estuary to a coastal city- SOAK, A Mathur and Da Cunha, 2009 (as a part of studies carried out in School of Planning and Architecture, New Delhi, in 2009)

The drainage system of Mumbai is a mix of simple drains and a complicated network of rivers, creeks, drains, and ponds. Mumbai is also served by five rivers which ultimately discharge into the Arabian Sea. (Bhattacharjee, 2018) A network of closed drains below the roads has evolved in the city whilst there are open drains in the suburbs (Gupta, 2009). According to Bhattacharjee 2018; the occurrence of high tides combined with heavy rainfall, constriction of natural waterways, the clogging of culverts, changes in the direction of natural stream flow, increased coefficients of rugosity due to crowding of structures, reduced hydraulic gradients due to silting, all gave rise to high flood levels and longer periods of inundation. The inadequate drainage system and ineffective spatial planning increase the flood risk in the region (Dhiman, *et al.*, 2018).

## 4. REASONS FOR FLOODS IN MUMBAI

There are several reasons for flooding. Thus engineers, researchers, and authorities have stated various reasons for flooding in Mumbai, especially after the 26th July 2005 deluge. Some of them are listed in Table 1:

**Table 1.** Impact analysis of factors for flooding

| Causative factors for flooding | Reference | Result/Impact |
|---|---|---|
| **Heavy rainfall**, rainfall for longer durations, sea-level rise, and tidal variations | Bobade *et al*., 2019; Dhiman, 2018; Kadave *et al*., 2016; Gupta, 2007; CDP, 2006 | Increased volume of stormwater to be handled |
| Extensive **land reclamation** activities, which were originally low-lying areas, to accommodate the growing population, infrastructure development, encroachments, *etc.* | Bobade *et al*., 2019; Dhiman, 2018; Kadave *et al*., 2016; Gupta, 2007; CDP, 2006 | The reclaimed area between the islands lies below the high-water level obstructing the outlet of natural water flow during rainfall and causing water retention. |
| **Improper development regulations** and lack of enforcement of the plans, zoning regulations leading to rapid urbanization, encroachments on hills, drains, water bodies, mangroves, *etc.* | Bobade *et al*., 2019; Dhiman, 2018; Kadave *et al*., 2016; Gupta, 2007; Bhagat *et al*., 2006; CDP, 2006 | Loss of natural water holding areas; coming up of dense areas in restricted zones, increasing vulnerability; increased runoff coefficient; hampered natural stormwater drainage system; the increased load on city's infrastructure |
| **Dilapidated and faltering drainage** system with incapable stormwater drains | Bobade *et al*., 2019; Dhiman, 2018; Kadave *et al*., 2016; Jain, 2006; CDP, 2006 | Insufficient drainage cross-section to carry floodwaters, leading to chronic waterlogging |
| **Encroachment on river basins** | Bobade *et al*., 2019; Kadave *et al*., 2016; Jain, 2006; Bhagat *et al*., 2006 | Reduction in the catchment area of rivers (reduced cross-section of the river), hampering natural drainage system and choking up the natural and manmade drains |
| **Change in the path of the Mithi River** due to Airport runway | Bobade *et al*., 2019; Kadave *et al*., 2016; | Disturbance in the natural watercourse resulted in increased rainfall run-off |
| **Construction on the mouth of river basins** | Bobade *et al*., 2019; Kadave *et al*., 2016; Jain, 2006; | Led to creation of bottle-necks during heavy rains which in turn resulted in reduction in outfall |
| **Combined sewage and stormwater drainage system** | Bobade *et al*., 2019; CDP, 2006 | Choking of drains due to sullage/ sewage inflows<br>Obstruction due to crossing of utility lines |
| **Poor maintenance of drains** | Bobade *et al*., 2019; Bhagat *et al*., 2006; CDP, 2006 | Encroachments on drains & enhanced silting, reducing water retention capacity of natural water bodies |
| Garbage **dumping in drains** by irresponsible citizens | Bhagat *et al*., 2006 | Choking of drains, obstructing the water flow during rains |
| **Administrative responsibility and Governance** | Bhagat *et al*., 2006 | Multiple administrative and development agencies leading to uncontrolled and unplanned development |

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Thus, the major causative factors of flooding include extensive land reclamation, developments on river basins, heavy rainfall combined with poor design of drainage system, poor maintenance of infrastructure and increased runoff coefficient. These factors act as interruptions in natural and manmade stormwater drainage system. The identified factors need to be appraised at length to establish the hindrances in stormwater flow and discharge, leading to flooding situations.

## 5. INTERRUPTIONS IN STORMWATER DRAINAGE OF MUMBAI

These causative factors affecting the drainage system have been combined to investigate their further implications in flooding.

### 5.1 Land Reclamation

The entire city of Mumbai is geographically admeasuring about 440 sq. km. as per the latest Draft Development Plan 2014, landfills are developed between the seven islands North to South (Arunachalam B., 2005). Once separated by swampy areas, the seven islands were joined over 150 years, starting in the 16th century. The reclamations began to accommodate the increasing population in the fort area. Thereafter, several reclamations were carried out to connect various parcels of land till 1845. The Island city has 32 sq.km of reclaimed area (Fact Finding Committee, Mumbai 2006), whereas the total reclaimed area in Mumbai is 96 sq. km. Reclamations also took place due to dumping of household waste and industrial waste, wanton quarrying, *etc.* (Indian Institute of Technology-Bombay, 2014). The central area comprises mainly the low-lying reclaimed area. (Bhattacharjee, 2018)

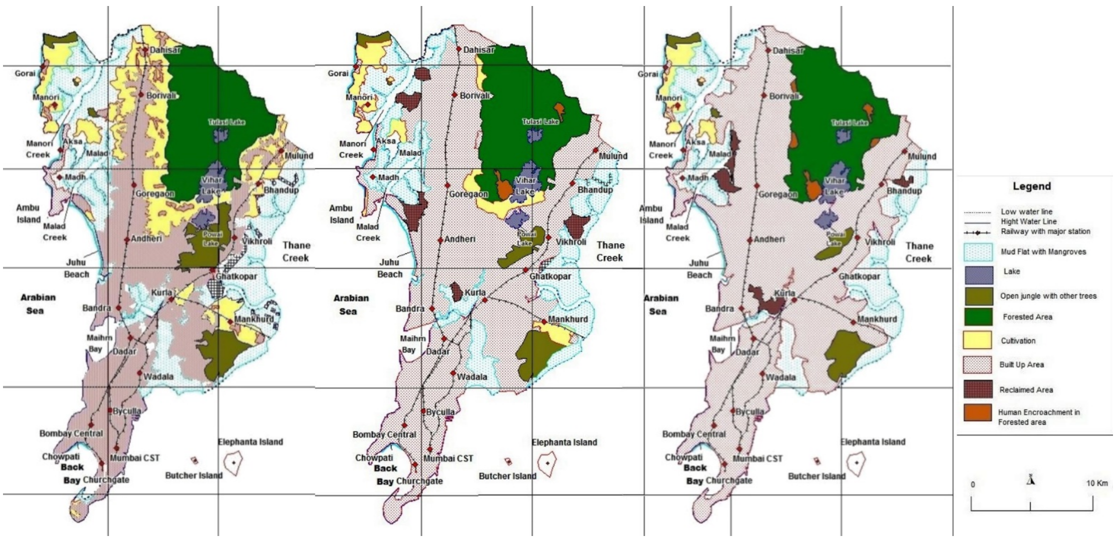


**Figure 2.** Change in landuse and increased development on reclaimed land

Source: Mumbai Technical Support Unit report, 2015

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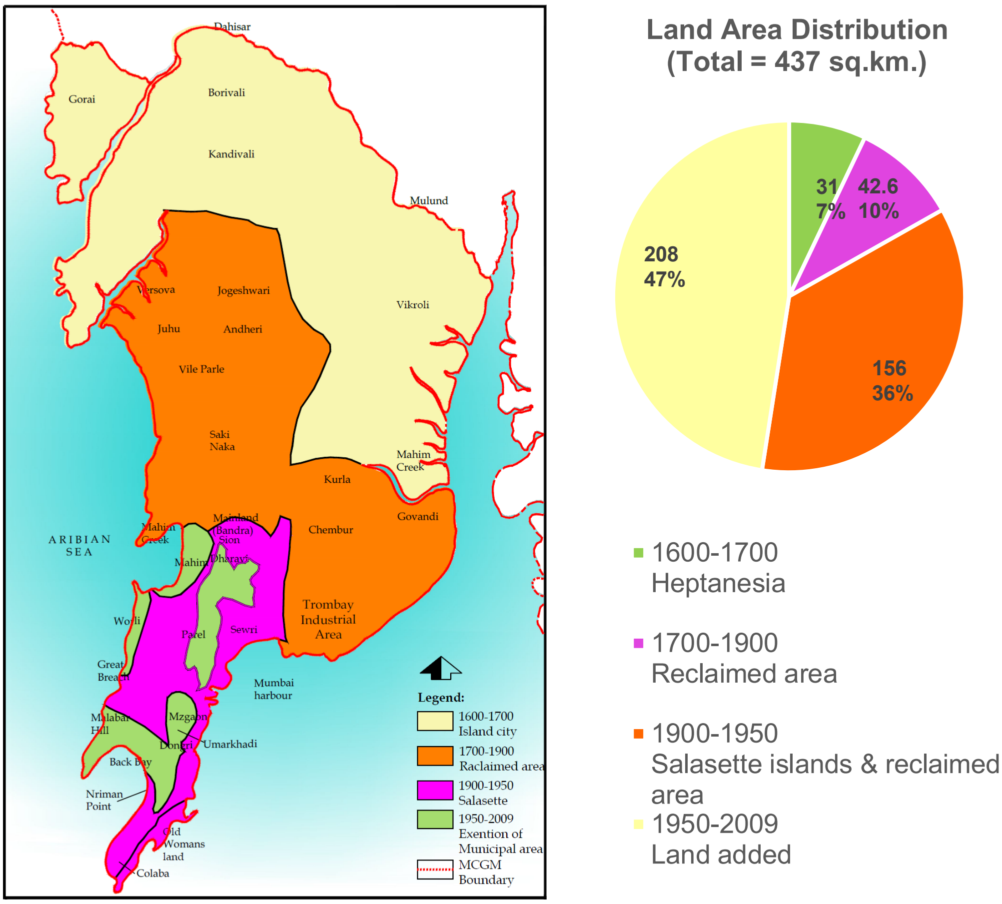


**Figure 3.** Land Reclamation of Greater Mumbai 1600-2009

Source: Drafted by the first author (as a part of studies carried out in School of Planning and Architecture, New Delhi, in 2009) 2009 (Based on City Development Plan (of Mumbai) 2005-25)

Even in the 20th century, Mumbai continued to develop on reclaimed lands. Land reclamation decreased swampy areas and increased concretization, thus reducing the infiltration of rainwater. Concretization also reduced the width of the creeks and estuaries, increasing inundation and waterlogging in every season. The flood-prone areas are currently constantly under a chronic threat of disaster risk. Reclaiming land from the sea has led to changes in the coastline regime, loss of mangroves, upstream flooding of rivers, changes in an undercurrent and tidal wave patterns.

Over 40% of it is reclaimed land from the sea by filling in inland lagoons and marginal seas, just at or above sea level and almost one-fourth of land lies below mean sea level. (Arunachalam B., 2005). Around 22% of the reclaimed area is flood-prone (calculated by author 1 in School of Planning and Architecture, New Delhi in, 2009) as unplanned and unscientific reclamation methods were adopted. These reclamations are in complete violation of the Coastal Regulation Zones. The latest petition filed in the Bombay High Court case, The Conservation Action Trust And supporters ... vs Union of India And 3 Ors on 16 July 2019 has a complete detail of all the violations from time to time. (Bombay High Court, 2019 https://indiankanoon.org/doc/137208673/?type=print)

### 5.2 Developments on River Basins

Mumbai has rivers Mithi, Dahisar, Poisar, Mahul, and Oshiwara which discharge directly into the Arabian Sea. Mithi river acts as the major component for natural drainage, running across the city with a catchment of approximately 108 sq. km. The river originates in the overflowing water from lakes Tulsi, Vihar, and Powai (in the North), from the ridges, valleys of Borivali hills, and the spot where (prior to development) the current L&T factory stands in Powai.

According to a study conducted by Samant H.P. in 1996, an area of over 156 sq. km acted as drainage basins for majority of the streams which discharge into the main creeks of Mumbai. These basins have now been built upon with roads, buildings and slums. This construction is particularly found along the Mithi River and in the Jogeshwari to Kandivli zone. During recent decades, the indiscriminate and unprecedented growth of Mumbai has created ecological hazards and ignored the countryside, which has been turned into a weak margin. (Jain, 2006). Figure 4 shows the reduction in basin area since 1740, and the year 2014 map shows the extent of reclamation which has sealed one end of the Mahim estuary.

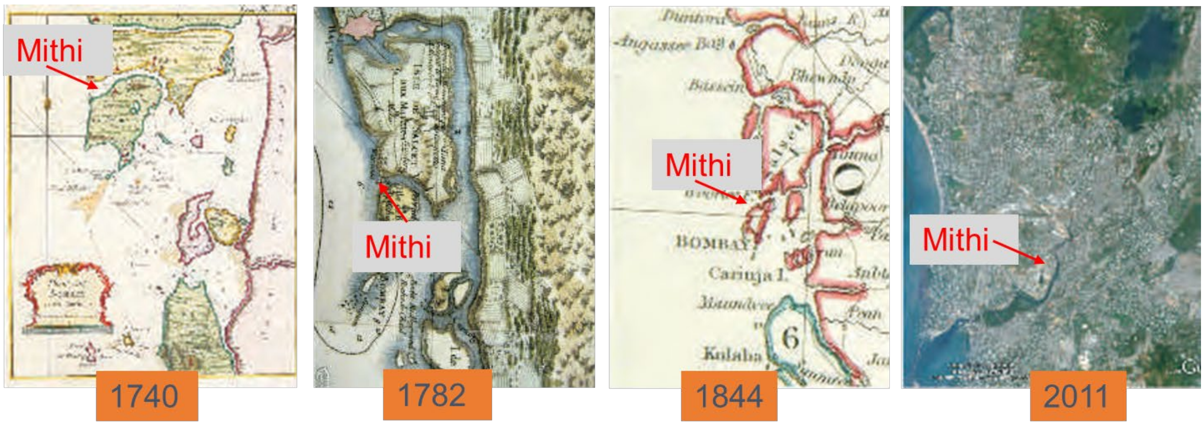


**Figure 4.** The Mithi River and the Mahim Estuary

Source: Kirtane G., 2011

Many large-scale planned developments and encroachments on the Mithi river basin have changed the area's topography. The new sea link has reclaimed the river mouth by about 0.27 sq. km of landfill (Gupta, 2009). The expansion of the International Airport resulted in the Mithi river being passed through a tunnel below the runway. The river was first bifurcated during the construction phase and then reunited, forming a small island which was then utilized for airport extension (Kirtane, 2011). Mudflats acted as holding ponds during 1992-2009 with Bandra Kurla Complex (BKC). The Mithi River in the North reduced to an open drain due to

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severe encroachments and the discharge of industrial effluents into the river. Nearly 54% of the original river flow has been lost to slums, roads, and new developments (Census of India, 2001). Most of the flooding hotspots identified by the municipality lie in the Mithi river basin, which includes Rajiv Gandhi Nagar (a slum in Dharavi), Kothu Wadi (slum and low-income group), Kalina Market, Prem Nagar(slum), and Parsi Chawl(slum). These slum areas are densely packed, increasing the vulnerability.

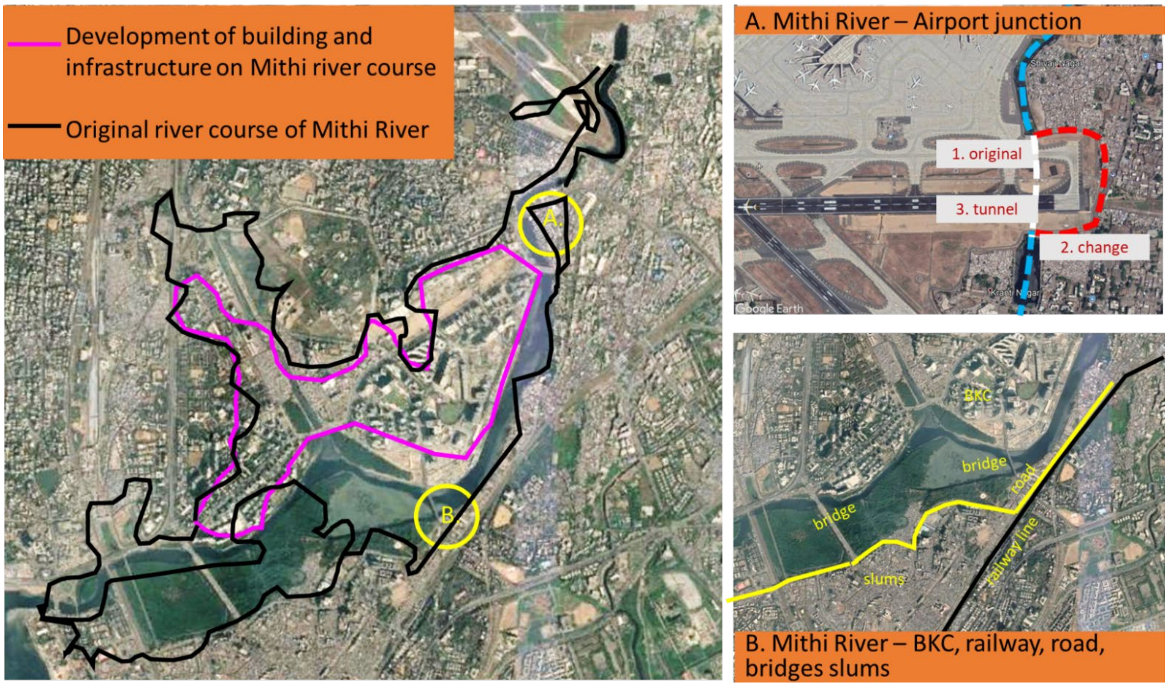


**Figure 5.** Change in the course of Mithi River (1966-2009), Mumbai

Source: Recreated by authors on 2021GoogleMaps (Primary source: Zope *et al.*, 2012)

Other rivers in the northern suburbs which overflowed (during the 2005 floods) are the River Dahisar and the River Poisar (Gupta, 2009). These encroachments act as blockage to rainwater running towards the river. Development (even with permission from the municipality) without proper environmental clearance increases the pressure on the existing drainage system, which is already poor and old fashioned. Mangrove areas along the rivers have been diminished and destroyed, disturbing the natural ecosystems and increasing flood risk. As the planning authorities have permitted construction on floodplains, the consequences of encroachments in the Mumbai area seem to be far worse.

### 5.3 Design and Capacity of Drainage Systems

The city is a combination of natural and manmade drainage systems. Topographically, the city area is a linear central bowl or depression, with low lines of hills on either side. The rain water naturally gravitates and drains into the central depression. (Arunachalam, 2005) This central depression, barely 2-3 meters above mean sea level, is liable to flooding and drained by several rivers, like Mithi, Poisar, Dahisar, and others (Mallad & Mahim Creeks. There is a drastic increase in the pressure on the drainage infrastructure due to change in rainfall patterns, reduction in pervious land area, increased surface run-off, additional sewage load in the combined sewer system and dumping of waste in the drains.

The current piped drainage system of Mumbai is 80-year-old, with about 480 km. of underground drains and laterals, and designed to handle a rainfall intensity of 25mm per hour at low tide with a runoff coefficient of 0.5. The city has 186 natural and manmade outfalls, only 45 of which discharge below the mean sea level, and only three outfalls have floodgates. The rest open directly into the sea. After the 2005 Mumbai floods, an upgraded drainage system was proposed and millions of rupees were sanctioned for the same but it is yet to be implemented.

The stormwater drainage in Mumbai is combined with the sewage system. Only 60% of the city area is covered with a sewage system with the waste being disposed in the Thane creek, Colaba harbor, Arabian Sea, and Malad creek. Sewage system remains absent in the remaining 40% of the city area leading to unattended and unmanaged sewage polluting the seawater. The Maharashtra Pollution Control Board has identified 70 drains that discharge untreated sewage into the waterbodies. The current sewer lines are over-burdened, owing to the high rate of urbanization, pressurizing the already under-designed, overburdened rainwater system. Open defecation is still being practiced due to the lack of toilet facilities in slums, ultimately contaminating water bodies.

According to Arunachalam B., 2005, a future problem not yet realised in terms of gravity is that mains of the underground sewerage are old and obsolete, over 100 years old, and with leaks in many places, often mingling with drinking water pipes running close to the sewerage lines. Since stormwater and sewage outfall into the sea, tidal variation has a major bearing on the drainage system resulting in water logging during heavy rains. Interconnection of sewage and stormwater network is leading to siltation and loss of drainage capacity. (Bhattacharjee, 2018) The earlier the sewage drainage and stormwater drainage are segregated, the cleaner the city environment. (Arunachalam, 2005)

### 5.4 Maintenance of Drainage

The problem of dilapidated, old-fashioned sewage and drainage system is amplified with their maintenance issues. Clogging due to dumping of waste in open drains/nullahs/water bodies, ultimately blocking the connected underground piped drainage. Also, slums along the rivers, for example, Dharavi, are discharging their wastewater directly into the rivers through open nullahs. The total width of the walkway between two houses in the Rajiv Gandhi slum, Dharavi, is three feet, out of which one foot in the center is being used for carrying stormwater and wastewater (illustrated in figure 6).

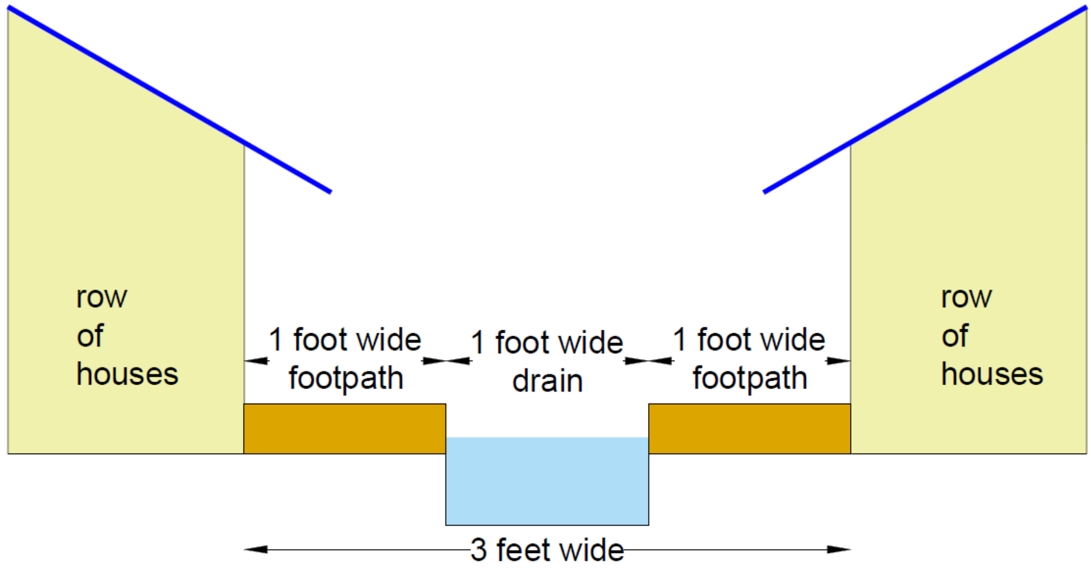


**Figure 6.** Depiction of the pathway with a drain in Rajiv Gandhi Slum of Dharavi, Mumbai

Source: Illustrated by the author as per site visit

Another issue obstructing the flow in drainage infrastructure is street vendors, shops, *etc.*, illegally covering the drains at many points. The drainage system has been historically plagued by poor workmanship in construction, lack of attention to proper repairs, and accumulation of waste, especially where the drains have been punctured. As already discussed, the interconnection of stormwater & sewerage networks adds to the maintenance pressure of these drains. Brihanmumbai Municipal Corporation (BMC), in charge of maintaining and upgrading city infrastructure, has produced reports stating the needed road and drainage upgrades throughout Mumbai. (Stecko, 2007) At some locations, there are makeshift crossover bridges/bunds by the citizens on rivers, hindering the natural flows.

The freshwater pipeline passes just above these soiled rivers at several locations, leading to additional problems during flood events, polluting the potable water line, causing epidemics, and adding to the after-effects of the disaster. Chatterjee, 2005 has highlighted an institutional issue that many municipalities in India today outsource the actual de-silting of drains. Typically, the waste that is cleared out is kept alongside the drains because it would add to the costs to transport them long distances. When it rains heavily, all that waste goes back into the drains through gutters.

Several drives at municipality, community and NGO levels to desilt the drains are being carried out. The issue can be resolved when all the above maintenance aspects are taken up immediately. Institutional arrangements and funds to manage infrastructure needs are also lacking.

## 5.5 Reduction in mangrove areas

Mangroves act as a sponge in floods in an area by absorbing volumes of the excess water. In Mumbai, mangrove ecosystems along the Mithi River and Mahim Creek are being destroyed by construction activity. Mangroves had shrunk by 32% from an area of 235 sq. km in Mumbai in 1924 to only 160 sq. km in 1994. An additional ten sq. km of mangroves are estimated to have been destroyed in Mumbai by 2000 (Jain, 2006). A total loss of 40% till 2005, some to public infrastructure, some to builders and some to encroachment (slums) can be logged in.

One of the major developments that have taken over the mangroves is the Bandra Kurla Complex (BKC) which came up on 3 sq. km of mangrove land. The Environment Ministry of the Government of India had informed the local bodies about its (construction of BKC's) potential disaster and had appealed not to sanction it but no action was taken on time. Similarly, the basins in the western suburbs that flow into the Malad creek have been built upon without accommodating the natural drainage pattern; thus, the overflow has flooded the nearby areas. (Jain, 2006). Earlier, the Mithi River, along the expressway in Ghatkopar area used to flow freely. It has now been reduced to a narrow drain (Jain, 2006). Other major developments on mangrove and mudflats include the solid waste dumping yards, Essel world (theme park), major residential societies and many more.

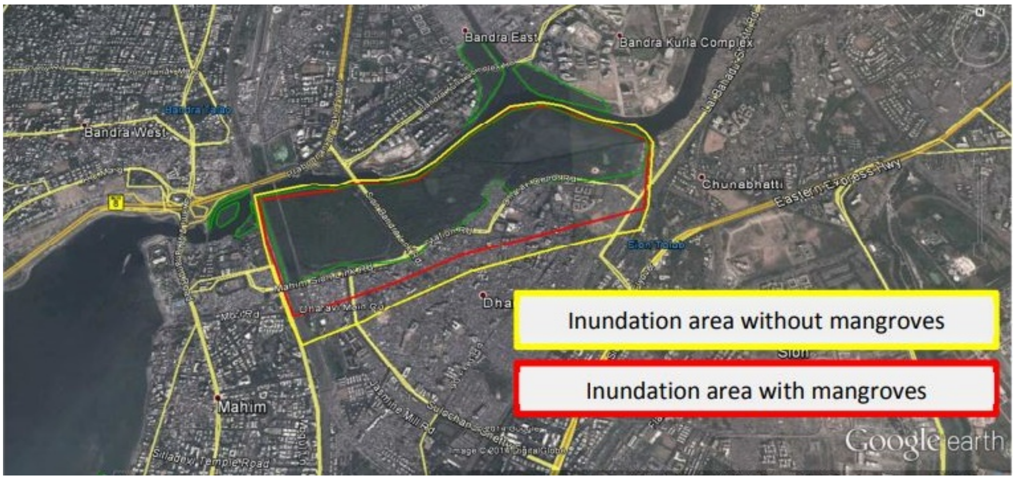


**Figure 7.** Flood inundation map of mangrove forest on Mithi river basin

Source: Khan, M. 2014

Another factor that hampers the effective functioning of mangroves is the dumping of garbage, industrial effluents, and untreated sewage. This issue is amplified during flood events, where rainwater carries along with waste from the city into these mangroves. These pollutants prevent seawater from entering the mangroves, eventually killing them.

According to a simulation carried out by Khan, 2014 along Mithi River, the presence of mangroves reduces the flood-affected area by 21%, as indicated in Figure 7, confirming the

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significance of mangroves at the river bank. There is an urgent case to protect the remaining mangroves, creeks, and green areas and to restore the original drainage basins, water channels, and culverts in the reclaimed areas. Ecological factors should be the basis of future planning and development of Greater Mumbai (and any other Indian city) to avoid future catastrophes. (Jain, 2006)

### 5.6 Increased runoff coefficient

The migration of people from rural to the urban area has led to rapid LULC (land use-land cover) changes to satisfy the population's needs. Thus, there is tremendous growth in urban areas in developing countries all over the world. Being an island city, Mumbai faces a scarcity of land and has limitations for horizontal development (Zope *et al.* 2016). Urbanization reduces the land porosity of an area that absorbs rain waters. Otherwise, it runs off into the already overloaded drainage system, including piped drains, rivers, streams, canals. Impermeable surfaces, sea-level rise, and river discharge threaten 15% of the world's population (Sörensen *et al*. 2016).

The built-up area has increased due to construction of buildings, concretization and macadamisation of roads. This combined with the release of more sewage from the increasing population in buildings and hutments – all add to the gravity of the situation. This is the reason why waterlogging continues for days together in the central depression (of Mumbai) (Arunachalam, 2005). Storm Water Drainage capacity inadequacies are due to an increase in the overall runoff coefficient due to loss of holding ponds and encroachments alongside drains, disturbing catchments runoff (CDP Mumbai, 2005-25, 2006). According to a study conducted by the School of Planning and Architecture, New Delhi (SPA 2009), since 1994-2009, over 1000 plots of public land have been released for construction; 50% of the city's no-development zones have been built upon. The local development authorities have given these permissions. The slum areas are always called as encroachment, but these so-called authorized constructions are now encroaching upon the natural systems existing in Mumbai, which equally are responsible for the chronic flooding in the city.

Another issue is that most detention ponds have been lost to development, and it is estimated that urbanisation has contributed to increased runoff by 2-3 times (Gupta, 2009). The progressive reduction of open lands has substantially reduced the natural percolation areas of water into the ground and thus contribute to the stormwater collecting on the surface. (Arunachalam B., 2005)

As per Figure 8, between 1981 to 2001, increased mixed, residential, and commercial land use led to the shrinkage of wetlands (around 10%). Also, the built-up area has doubled during 1971-2001 to 52%, reducing the forest/vegetation cover, mangroves, *etc.* It needs to be noted that increase in built density of the urban areas is at the expense of cultivated lands, forests, and water bodies. (Applied Geography, Indian Institute of Technology-Bombay, 2019).

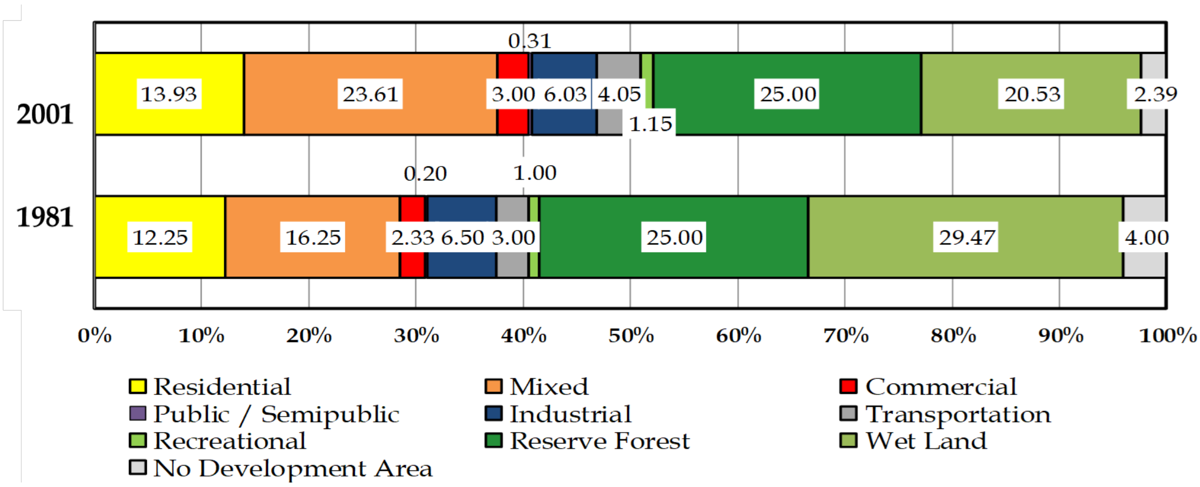


**Figure 8.** Landuse distribution, Mumbai

Source: Mumbai City Development Plan 2005-25

The streams and rivers have been concretized and bund walls have been constructed as flood defense measures. However, this has reduced porosity of the streams. It is considered that runoff coefficient for paved surfaces is 0.95 (Mr. Haestad's International Standard Handbook), which means that more than 50% of the city's area is non-porous, resulting in floods in heavy rainfall. There is an intrinsic relationship among drainage, landuse planning, and ecology, which should be organized and coordinated so that the demands of the growing population, housing, drainage, and water supply are met without comprising the ecology. (Jain, 2006)

In another study conducted by Zope *et al.* 2016, the impacts of LULC and urbanization on flooding have been investigated for a Mumbai catchment of Oshiwara River over 43 years. It showed a 74.84% increase in the built-up area and 42.79% and 62% reduction in open spaces and water bodies respectively.

## 6. DISCUSSION

After the 2005 deluge, the Municipal Corporation of Greater Mumbai came up with an upgraded drainage system design. They have now considered the run off as 100%, considering the hydrological pattern. The rainfall intensity is considered 50 mm per hour with runoff coefficient as 1 in place of earlier design intensity of 25 mm per hour with a runoff coefficient of 0.5. Bobade *et al.,* 2019 have suggested an underground piped drainage system (conventional) stormwater drainage system for Mumbai. Contrary to that, Jain, 2006 has insisted on having a bio-drainage system not just for Mumbai but also for India. Also, Kadave *et al.*, 2016 have suggested combining the conventional and modern solutions to flooding with solutions like cleaning of Mithi River, bores, percolation tanks, planting and preserving mangroves along with new stormwater drains. Alternative ways to manage floods have evolved since traditional methods often harm the riverine ecosystems in urban and rural areas and increase the long-term flood risks. Sörensen *et al*., 2016

Studies establish that 90% of Mumbai's storm drainage is through storm drains, and only 10% is through open lands. This leads to additional challenges and load on an outdated and under capacity storm water drainage infrastructure that is more than 100 years old (Rawoot *et al.,* 2015). It can be observed that the interruptions in the drainage system mentioned above are not limited to the issue of the design capacity of the drainage system. It calls for an integrated water management solution to handle flood issues in Mumbai.

Indian cities frequently face flooding caused by poor drainage, and a severe shortage of water, especially before the monsoons. This is largely a consequence of the adoption of borrowed concepts of urban drainage, together with indiscriminate and unplanned developments in the natural drainage channels (Jain, 2006). The CPHEEO Manual (India), 2019 cites that stormwater is now increasingly being valued as a resource to address water security in urban areas. According to Chan *et al.,* 2018, sponge city can achieve the dual goals of sustainable water use and better flood control. It is influential and revolutionary in its approach to land-use planning; urban water-resource management, urban flood, and climate risk mitigation; ecological enhancement; and social wellbeing. Also, according to Sieker, 2009, there is need for a paradigm shift from conventional drainage approach to a modern approach - from "Getting rid of stormwater as quick as possible" to "Maintaining natural water balance". As per Das, 2012, implementation of the principles of SuDS can help tackle the threat posed by the mismanagement of urban stormwater runoff and regenerate fast depleting groundwater aquifers.

The sustainable urban drainage system (SuDS) aims to mimic natural hydrological processes in an area/ city which is altered due to urbanization. SuDS creates sponge areas and provides an opportunity to capture and treat runoff by intercepting, filtering and degrading pollutants and reducing potentially contaminated runoff volume (CIRIA, 2015). Some of the advantages of SuDS include increased water quantity, improved water quality by preventing pollution, the addition of amenity areas, and increased biodiversity through the introduction of new ecosystems. Over the years, several countries have adopted various versions of SuDS, including the US, UK, New Zealand, China, France, Japan, Singapore, Australia, Netherlands, Denmark, Sweden, Germany, South Africa, and many more. While it was earlier focused only on flood management, its scope has been increasing over the years, with multiple benefits being realized.

## 7. SUMMARY OF INTERRUPTIONS AND THEIR SUSTAINABLE SOLUTION OPTIONS

In the absence of a systematic and sufficient drainage system, the city of Mumbai has been facing flood issues for decades. Although it is time to revive the city's natural drainage system,

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implementing sustainable solutions can be challenging considering the scale of the megacity. As per international success stories, the application of sustainable drainage solutions but based on localized climatic factors, land constraints, Governance, and public response must be taken up as pilot projects initially. The following summary includes likely sustainable solutions for reducing flood issues in the city, with international examples of context similar to Mumbai city.

Firstly, the land reclamations that have already been taken up in the city are major areas of depression. Identification of reclaimed parcels of land which have not been taken up for development and re-creation of marshy/ swampy areas, along the water bodies (lakes, streams, rivers, sea) may be taken up at all possible locations. For example, removal of Deonar landfill area in east Mumbai; creating wetlands at multiple unused locations inside the Essel World Amusement Park. In the Wallasea Island Wild Coast project, UK, a wetland landscape of mudflats and salt marshes, lagoons and pasture was installed for the coastal defense of an originally reclaimed island. The project's environmental benefits included habitat creation, waterborne nutrient processing, and the provision of fish feedings and nursery habitats. In addition, the society at large benefitted from avoided expenditures for flood defence infrastructure and the avoided loss of built assets on Wallasea worth millions. (Davis *et al.*, 2016). Concurrently, the local government must put an immediate end to "authorized" reclamation, and strict checks must be kept on "unauthorized" reclamation (by the ULBs).

Secondly, the encroachments on river basins and buffer zones of water bodies causing hindrance in functioning of the natural drainage system require urgent attention. The local bodies may have to clear the authorized and unauthorized encroachments with planned relocation of developments. For example, the long due redevelopment of slums along Mithi river basin while leaving buffer for the river can be taken up. After this, restoration of all water bodies with urban local bodies, non-profit organizations, citizens can be taken up. Also, all future plans of development on river basins in Mumbai by the local bodies will have to be stopped and a strict check on unauthorized development should be kept. According to an on-ground research and testing carried out by Boogaard, 2015 in the Netherlands, it was demonstrated that most of the bioretention swales and permeable pavements tested met the required hydraulic performance levels even after years in operation and without maintenance. Bioswales, which have been successful in several countries, can be created in the buffer areas of water bodies, limiting the dumping of waste in them. The rivers need to be made pervious again by de-concretizing them. This task can be taken up in phases, along with developing the water bodies for public use.

Another major issue that came to the fore is the mixing of sewage with stormwater leading to increased load on the drainage system and polluting the water bodies at outfalls. While it is challenging to do so, it may be required to disconnect storm water drainage from sewage drains in phases and set up treatment plants with advanced and natural treatment methods and disposal of sewage. A study was carried out by Perales-Momparler *et al.*, 2013 wherein some inner-city sites in the Mediterranean region were retrofitted with SuDS components to promote sustainable stormwater management. Scenario building with climate and SuDS options confirmed that the existing combined sewer networks were insufficient to manage the runoff appropriately, leading to floods in several networks.

The absence of a sewerage system (connections, conveyance, treatment, and disposal) in a major portion of the city pollutes the water bodies, and an open / semi-open stormwater drainage system is a pressing situation. Immediate planning and provision for sewerage connection in the areas where it is absent may have to be carried out for the success of existing and future drainage solutions. Smaller sewage treatment zones can be created to treat the waste close to the source and reuse some part of treated water before discharging it into the water bodies. This can be implemented in the large slum pockets as the slum population constitutes around 55% of the population, which lacks this infrastructure. This will reduce the burden on the already overloaded drainage and sewage system.

Insufficient, dilapidated and over-burdened natural and manmade drainage system is the basis of chronic flooding in the area. Stovin *et al*., 2007, stated that the concept of SuDS retrofit offers an exciting and versatile yet currently underexploited opportunity for stormwater management in urban areas. Goh *et al.,* 2017 worked on simulations for two study areas, Green Walk District and Tengah Subcatchment, under ABC Waters Singapore. Results showed a reduction in peak discharge (22% to 63%) and a delay in peak discharge by up to 30 min. Sustainable drainage solutions such as retention tanks, pervious pavements, green roofs, *etc.*, can be implemented in public buildings and areas, to start with. Then larger private setups can be approached for the same. This will help reduce the load on the existing manmade system, which can be gradually phased out instead of upgrading the piped system.

Local authorities may enforce all new developments to have their stormwater drainage system with zero / minimum discharge into the public/ city drainage. This will reduce the burden on public infrastructure, and retention areas can be created. The collected water can be reused with minimum treatment arrangements. The green roof, a popular method in many countries to reduce runoff and heat island effect, can be made compulsory for these large and new developments. For example, as the Mithi River watershed was the most flood-affected area, public landuses, as shown in Figure 9, can be taken for green infrastructure implementation, especially the Bandra Kurla Complex. Yang *et al.*, 2010 used correlation analysis on development conditions. The results show that an open drainage watershed generated less storm runoff than the conventional drainage watershed, given the similar impervious area in both watersheds. Furthermore, the open surface drainage watershed responded to rainfall in a way similar to its predevelopment natural forest conditions, indicating effective flood mitigation post-development.

Redesign the drainage system with modern methods and recreate the lost detention ponds, which will catch the runoff. Vincent *et al.*, 2017 have carried out a cost-benefit analysis of SuDS with detention storage and have concluded that the use of storage and SuDS provides greater benefits with a larger reduction in flooding, and thus is more cost-effective than using SuDS alone.

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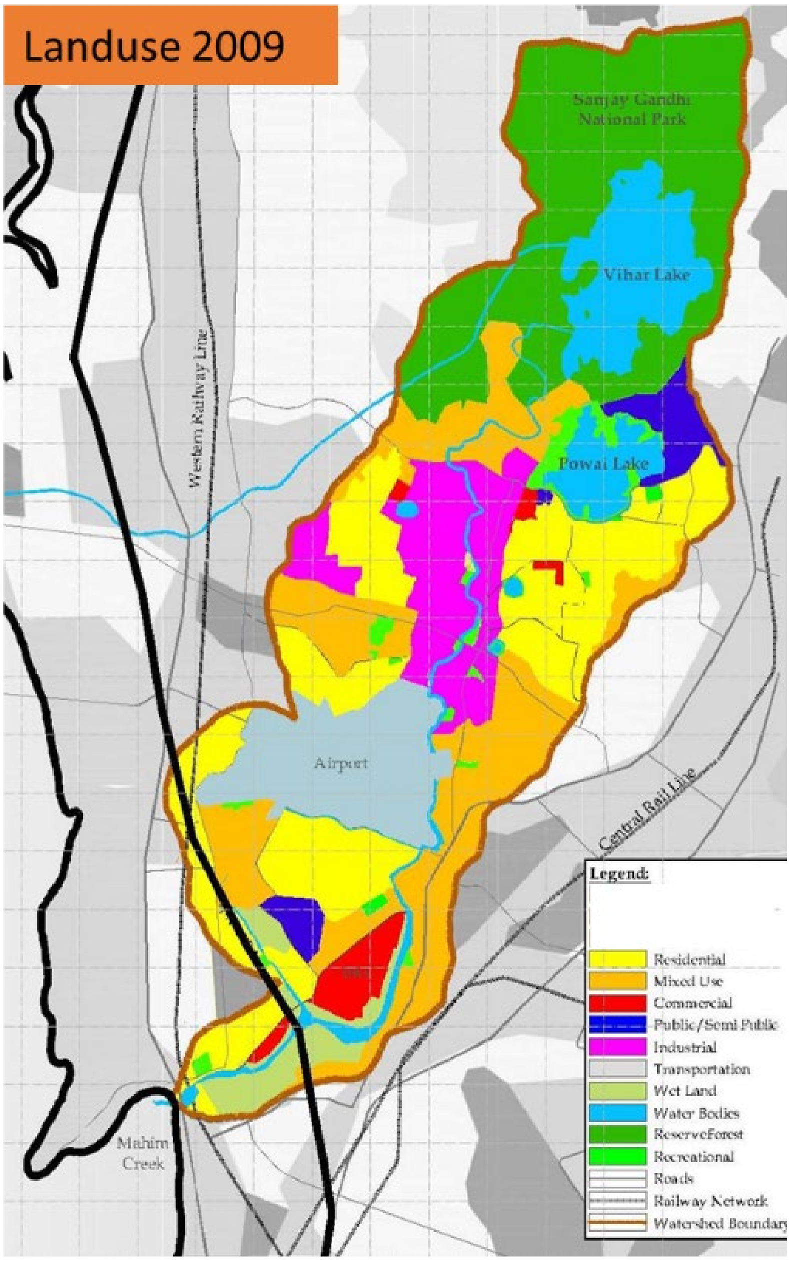


**Figure 9.** Landuse Plan 2009, Mithi River Basin, Mumbai

Source: Redrafted by Author 1 (as a part of studies carried out in School of Planning and Architecture, New Delhi, in 2009 – Original Source: Mumbai City Development Plan 2005-2025 and GoogleEarth 2021)

Also, the increased runoff coefficient and reduction in softscapes need to be compensated with creating / recreation of open spaces while reducing built footprint (through the redevelopment of certain areas), thus increasing percolation areas. This was demonstrated in Augustenborg, a highly populated neighborhood in Sweden, experienced floods caused by overflowing drainage systems. The resulting flooding led to damages, and untreated sewage entered watercourses due to increased pressure on the sewage treatment works. Green roofs, ditches, retention ponds, green spaces and wetlands were created. Thus rainwater run-off decreased by half. Additional benefits included improved water quality, reduced carbon emissions, aquifer recharge, and increased biodiversity. The increase in green space also improved the image of the area. (Davis *et al.,* 2016). Retention ponds/ tanks can be constructed in public parks and all parking spaces can be made pervious.

Lastly, the issue of maintenance of water bodies and piped drainage needs to be taken up seriously by the local authorities. This may be tackled by creating public recreational spaces around the water bodies and conducting public awareness regarding the maintenance of these spaces. It may prove beneficial to encourage stakeholder participation in building and maintaining these recreational spaces. Zakaria *et al.,* 2007 investigated the implementation of BIOECODS (similar to SuDS) in a campus. They concluded that it can be a variable method for water quantity and quality treatment for site runoff and biodiversity maintenance.

## 8. CONCLUSION

This paper discussed causative factors for increased flood events due to climate change, urbanization, inefficient and combined drainage system, and the severity of these frequent flood events. These factors were then discussed in detail, acting as interruptions in the natural and piped stormwater drainage system of Mumbai. The direct interruptions included land reclamation leading to low lying areas, developments on river basins hampering the flow of water bodies, design and capacity of the dilapidated piped drainage systems, and the sewerage system. The indirect interruptions identified included poor maintenance of drainage, reduction in mangrove areas previously acting as flood sponges for the city, and the increased runoff coefficient owing to uncontrolled urbanization. The paper tries to argue that it may be time for Mumbai to shift to sustainable solutions in terms of drainage management. These point towards the requirement of an integrated approach in tackling floods in Mumbai.

It has to be accepted that a focus on resilience building and designing indigenous solutions are needed for effective flood management in Mumbai. With a detailed study of the identified interruptions in the drainage system, suggestions have been made for sustainable solution options based on analysis and learnings from similar international success stories. SuDS may be capable of solving the flood problems in Mumbai and many other Indian cities. It may also prevent a lot of other cities from becoming chronic victims of flooding. It needs to be noted that even SuDS has its own set of constraints and challenges which need to be addressed before adopting it. The study carried out does not focus on climatic factors, governance issue, citizen's participation and acceptance of these new sustainable solutions, the scarcity of land in Mumbai city, the apprehension in shifting to a new format of infrastructure, and many more. Thus, it is recommended to create a localized version of SuDS that can cater to the climatic and sub-climatic zones, its integration with other infrastructure, stakeholder acceptance, institutional arrangements for implementation, *etc.* India has realized the potential of SuDS through world scenarios but is yet to accept the modern solution.

**REFERENCES**

Arunachalam B. (2005) Drainage Problems of Brihan Mumbai. *Economic and Political Weekly*, *40* (36).

Bhattacharjee S. (2018) Storm Water Drainage in Mumbai. Mumbai Reader. Urban Design Research Institute, Mumbai, India.

Bobade M. N., Dolas S. D., Gadgul A. A., Gurme M. R. and Kote A. S. (2019) Sustainable Underground Water Drainage System for Mumbai City. *International Journal of Engineering Research & Technology (IJERT) 8* (6). ISSN online: 2278-0181

Bhagat R. B., Guha M. and Chattopadhyay A. (2006) Mumbai after 26/7 Deluge: Issues and Concerns in Urban Planning. *Population and Environment, 27*: 337–349. DOI: 10.1007/s11111-006-0028-z

Boogaard F.C. (2015) Stormwater characteristics and new testing methods for certain sustainable urban drainage systems in The Netherlands. *Doctor of Philosophy, F.C.Boogaard, Delft University of Technology, Delft.* ISBN 978-94-6259-745-7. DOI: https://doi.org/10.4233/uuid:d4cd80a8-41e2-49a5-8f41-f1efc1a0ef5d

Chan F.K.S., Griggiths J.A., Higgitte D., Xua S., Zhug F., Tanga Y., Xuh Y. and Thorne C.R. (2018) "Sponge City" in China—A breakthrough of planning and flood risk managemen t in the urban context. *Land Use Policy, 76*: 772-778. DOI: https://doi.org/10.1016/j.land usepol.2018.03.005.

Chatterjee P. Mopping up in Mumbai. World Report. (2005) *THE LANCET, 366* (9488): 795. DOI: https://doi.org/10.1016/S0140-6736(05)67196-6

CIRIA (2015) The SUDS Manual; Dept. of Environment, Food and Rural Affairs, CIRIA: London, UK; ISBN 9780860177609.

Das, R. (2012) Sustainable Urban Drainage Systems - A possible solution to the problems of Flash Floods in New Delhi, India. -. *CE5WEMb – Water and Environment Management, University of Birmingham*. https://www.researchgate.net/publication/22832 7252

Davis M., Krüger I. and Hinzmann M. (2016) Coastal Protection and SuDS – Nature-Based Solutions, Policy Brief No. 4, November 2015.

Department of Urban Planning, School of Planning and Architecture, New Delhi. (2009) Managing Disaster Risks Mumbai Megacity 2009, Studio Project Report.

Dhankhar, V. (2017) Urban Flooding in India: Lessons Learnt and Roadmap for Future. *Architecture Time Space and People*, *17*(11): 32-40.

Dhiman R., VishnuRadhan R., Eldho, T. I. and Inamdar A. (2019) Flood risk and adaptation in Indian coastal cities: recent scenarios. *Applied Water Science*, *9*(5) DOI: https://doi.org/10.1007/s13201-018-0881-9

EDMAT (2019): OFDA/CRED International Disaster Database, *Université catholique de Louvain – Brussels – Belgium.*

Eckstein D., Künzel V., Schäfer L. and Winges M. (2019) Global Climate Risk Index 2020 - Who Suffers Most from Extreme Weather Events? Weather-Related Loss Events in 2018 and 1999 to 2018. *Germanwatch*, www.germanwatch.org/en/cri; ISBN 978-3-943704-77-8

Goh, P. X., Radhakrishnan, M., Zevenbergen, C. and Pathirana A. (2017) Effectiveness of Runoff Control Legislation and Active, Beautiful, Clean (ABC)Waters Design Features in Singapore. *Water*, *9*(8): 627. DOI: 10.3390/w9080627

Government of India: Ministry of Housing and Urban Affairs. (2019) Manual on Storm Water Drainage System Volume–I Part A: Engineering Design, First Edition. *Central Public Health and Environmental Engineering Organization (CPHEEO)*.

Government of Maharashtra. (2006) Fact Finding Committee on Mumbai Floods-Volume I and II.

Gupta K. (2007) Urban flood resilience planning and management and lessons for the future: a case study of Mumbai, India. *Urban Water Journal*, *4*(3), 183 – 194.

Gupta K. (2009) Flood Disaster Mitigation and Management: A Synthesis and Key Lessons. *Disaster & Development: Journal of the National Institute of Disaster Management, 3*(2) Special Issue: Urban Floods-II, 163-175

Indian Institute of Technology, Bombay (IIT-B). (2014) Report on Integrated Impact Assessment of Mithi River. Remote Sensing, GIS and Socio - Economic Studies of Mithi Catchment. Mumbai Metropolitan Region Development Authority(MMRDA). https://mmrda.maharashtra.gov.in/documents/10180/11271261/10/2bae8994-b9c2-4c20-9d9f-a6c3abebbc15?version=1.0

Jain A.K. (2006) The concept of bio-drainage in flood prevention and the avoidance of water scarcity. *International Journal of Environmental Studies*, *63*(1): 39-48. ISSN 0020-7233 print: ISSN 1029-0400 online. DOI: 10.1080/00207230500410224

Jainer S. (2020) Urban flooding around the world: Where is India placed? *DownToEarth.* 26 April 2020. Accessed on 26 June 2020. https://www.downtoearth.org.in/blog/water/urban-flooding-around-the-world-where-is-india-placed--70765

Kadave P. T., Kale A. D. and Narwade S. (2016) Mumbai Floods, Reasons and Solutions. *International Journal of Scientific and Research Publications*, 6(3). ISSN 2250-3153

Kapur A. (2005) Disasters in India-Studies in grim reality. Rawat Publications. ISBN: 978-8170339328

Khan M. (2014) Significance of Mangroves in Flood Protection of Coastal area: A Case Study of Mithi River, Mumbai, India. *World Journal of Environmental Biosciences*, *3*(2): 97-108. eISSN 2277- 8047

Kirtane G. (2011) Making the Sewer… A river again. Why Mumbai must reclaim its Mithi. *Observer Research Foundation Mumbai*. Report. https://www.indiawaterportal.org/sites/default/files/iwp2/why_mumbai_must_reclaim_its_mithi_gautam_kirtane_orf_2011.pdf

Maharashtra Pollution Control Board, Mumbai. (2014) Comprehensive Study/ Profiling Of Mithi River. Report.

Mendiratta P. and Gedam S. (2018) Assessment of urban growth dynamics in Mumbai Metropolitan Region, India using object-based image analysis for medium-resolution data. *Applied Geography*, *98*: 110–120. https://doi.org/10.1016/j.apgeog.2018.05.017

Mumbai City Development Plan 2005-2025. (2006) Municipal Corporation of Greater Mumbai. Report.

Mumbai Transformation Support Unit. (2015) Land Reclamation Report.

National Disaster Management Guidelines: Management of Urban Flooding. A publication of the National Disaster Management Authority, Government of India 2010, ISBN: 978-93-80440-09-5

Perales-Momparler S., Jefferies C., Perigüell- Ortega E., Peris-García P. P. and Muñoz-Bonet J.L. (2013) Inner-city SUDS retrofitted sites to promote sustainable stormwater management in the Mediterranean region of Valencia: AQUAVAL (Life+ EU Programme). *Novatech, 2013 - 8th International Conference on planning and technologies for sustainable management of Water in the City, Jun 2013, Lyon, France.* ⟨hal-03303449⟩

Rawoot S., Wescoat Jr. J. L., Noiva K., and Marks A. (2015) Product of research on "Enhancing Blue-Green Environmental and Social Performance in High Density Urban Environments" Mumbai Case Study. *Massachusetts Institute of Technology. Sponsored by the Ramboll Foundation.* https://www.readkong.com/page/mumbai-case-study-ramboll-6548661

Sieker F. and Sieker H. (2009) Reforms towards a paradigm shift and a new technology for storm water management. *German Water Act* 150: 796-802. https://www.researchgate.net/publication/292058986_Reforms_towards_a_paradigm_shift_and_a_new_technology_for_storm_water_management

Sörensen J., Persson A., Sternudd C., Aspegren H., Nilsson J., Nordström J., Jönsson K., Mottaghi M., Becker P., Pilesjö P., Larsson R., Berndtsson R. and Mobini S. (2016) Re-Thinking Urban Flood Management—Time for a Regime Shift. *Water*, *8*(8): 332. DOI: 10.3390/w8080332

Samant, H.P. (1996) Geomorphic Analysis of the Mumbai Mumbra region and its application using GIS. A PhD Thesis, *Indian Institute of Technology Bombay (IIT-B), Mumbai.*

Stovin V. R. and Swan A. D. (2007) Retrofit SuDS—cost estimates and decision-support tools. *Water Management 160*(4): 207–214. DOI: 10.1680/wama, 2007.160.4.207

Stecko S. and Barber N. (2007) Exposing Vulnerabilities: Monsoon Floods in Mumbai, India. Case study prepared for the Global Report on Human Settlements. https://unhabitat.org/sites/default/files/2008/07/GRHS.2007.CaseStudy.Mumbai.pdf

Vincent, S. U.; Radhakrishnan, M.; Hayde, L. and Pathirana A. (2017) Enhancing the Economic Value of Large Investments in Sustainable Drainage Systems (SuDS) through Inclusion of Ecosystems Services Benefits. *Water*, *9*(11): 841. DOI: 10.3390/w9110841

Yang, B. and Li, M.H. (2010) Ecological Engineering in a New Town Development: Drainage Design in the Woodlands, Texas. Ecological Engineering 2010. *36*(12): 1639-1650. https://doi.org/10.1016/j.ecoleng.2010.07.002

Bombay High Court. (2019) The Conservation Action Trust And ... vs Union Of India And 3 Ors. WRIT PETITION (L) NO. 560 OF 2019. Report. https://indiankanoon.org/doc/137208673/?type=print; Accessed on 15th Jan 2021.

Zakaria N.A., Ghani A. AB., Auyb K.R. and Ramli R. (2007) Sustainable Urban Drainage System (SUDS). *2nd International Conference on Managing Rivers in the 21st Century: Solutions Towards Sustainable River Basins.* Riverside Kuching, Sarawak, Malaysia. https://www.researchgate.net/publication/255682863_Sustainable_Urban_Drainage_Systems_SUDS

Zope P.E., Eldhao T.I. and Jothiprakash V. (2012) Effect of Urbanization on the Mithi River Basin in Mumbai: A Case Study. 2012 International SWAT Conference. Indian Institute of Technology, Delhi. https://swat.tamu.edu/media/57025/J1-4-Zope.pdf

Zope P.E., Eldhao T.I. and Jothiprakash V. (2016) Development of Rainfall Intensity Duration Frequency Curves for Mumbai City, India. *Journal of Water Resource and Protection*, *8*(7): 756-765. DOI: 10.4236/jwarp.2016.87061.

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# Understanding Households' Perceptions Regarding the Effect of a Natech Accident on Residential Property Values: The Case of Ichihara City

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**Abstract** This research investigated households' perceptions concerning the effects of a natural hazard-triggered chemical accident (known as a Natech) on residential property values in Ichihara city, Japan, where a Natech accident occurred in 2011 following the Great East Japan earthquake and tsunami. Furthermore, the household survey investigated households' perceptions regarding the effect that the disclosure of risk information concerning potential chemical and Natech accidents on future property values. Data was collected through a stratified random survey of households within three kilometers of the Chiba industrial park in Ichihara City, Japan, where the Natech accident occurred. The household survey findings indicate that the respondents felt that the land price did not decline due to the Natech accident in 2011. However, they consider chemical and Natech accidents a threat to their lives and property. They are concerned that chemical accidents alone or triggered by natural hazards may happen again at the Chiba industrial park and about the potential for the accidents to decline property values in the future. The results also showed that respondents want the government to disclose chemical risk information, but they are also concerned that the disclosure will affect future property values. The study results have implications on Natech risk governance at the community and industry level. The survey results highlighted the need to develop risk communication strategies taking into consideration households concerns, and finding ways to counterbalance the negative effects that the disclosure of risk information may have.

**Keywords:** Natech, Chemical accident, Property values, Risk information disclosure, Great East Japan earthquake

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## 1. INTRODUCTION

The worldwide frequency and severity of natural adversities have demonstrated an expansion in recent decades. Natural disasters such as floods, tsunamis, and earthquakes have had an undeniably effect on lives and properties (Gentle *et al.* 2001). In recent years, earthquakes, floods, and tsunamis have additionally caused chemical accidents. These natural hazard triggered chemical accidents are called "Natechs" (Krausmann *et al.* 2017). For example, after the severe Tohoku earthquake in Japan in 2011, several chemical industrial parks along the northeast Pacific Ocean coast in Japan were severely damaged. In Ichihara city, Chiba Prefecture, 17 liquefied petroleum gas (LPG) storage tanks at the Cosmo Oil Refinery were burnt entirely, resulting in fireballs with an estimated diameter of 600 meters, causing six injuries and damage to nearby vehicles, broken windows, and damaged shutters and roof shingles in nearby residential areas (Koseki *et al.* 2012; Krausmann and Cruz 2013). The earthquake and tsunami also caused Japan's worst nuclear disaster at the Fukushima Daiichi nuclear power plant. The residents of Fukushima prefecture and nearby areas responded with anxiety about the possibility of radiation exposure. The government's risk communication system did not work well since the information was not systematically or consistently provided, and government sources transmitted different information without considering consistency (Kinoshita 2014). Consequently, people did not know who or what to believe.

There is currently no regulation in Japan that explicitly requires industry to disclose hazard and risk information regarding the potential for chemical and Natech accidents to nearby residents. Several interviews with government officials and local residents concerning the disclosure of this type of information to the public revealed the perception that the information could lead to a decline in property values. Up to date, there is little research in Japan that could help support or deny these assumptions. In this study we are interested in understanding the effect of the Natech accident at Ichihara city during the Great East Japan earthquake on household's perception regarding residential property values following the chemical accident triggered by the Great East Japan earthquake. Furthermore, we explore households' perceptions concerning the effect on property values of disclosure of information regarding future chemical and Natech accidents.

## 2. THE RIGHT TO KNOW

Risk communication gains explicit significance in disaster risk management regarding the extensive scale of complex disasters, specifically technological disasters caused by natural hazards. The disclosure of chemical risk is seen as a citizen's right in many developed countries (see, for example, the Emergency Planning and Community Right-to-Know Act (EPCRA) in the United States; and the Seveso III Directive in the European Union), and in fact, it is considered unethical not to inform residents about risks they are being subjected to involuntarily (EPCRA 2012; European Union 2012). Nevertheless, due to several "landmark" accidents, awareness of Natech risk and the need for Natech risk reduction has increased over the past decades. For example, the European Union began taking concrete action following a cyanide spill in the Baia Mare mining disaster in Romania in 2000 and releasing chlorine and other hazardous substances from a flooded chemical facility in the Czech Republic in 2002. On the other hand, the 2011 Fukushima nuclear accident was a wake-up call that put Natech risks on the global agenda.

Although Natech risk awareness has increased during the last few decades, there are currently no regulations requiring Natech risk information disclosure in Japan. According to Ikeda (2013), Japan seems to be slightly lagging behind the European Union and the United States to encourage chemical risk communication. In Japan, little to no information about the chemical risk is provided to people living near industrial parks or in hazard-prone areas due to the fear that disclosure will make residents panic and adversely influence property values. Figueroa (2013) reported that the Japanese position on disaster risk information disclosure had been put under question from the 'bottom-up' through a surge in citizen activism after the Tohoku Earthquake in 2011 and the consequent nuclear accident. After the nuclear power plant accident and other chemical accidents caused by the Great East Japan earthquake and tsunami in 2011, there is an increasing concern about Natech accidents in Japan. The Great East Japan Earthquake demonstrated that generally, well-prepared countries are also at risk of suffering Natech accidents (Koseki *et al.* 2012; Krausmann and Cruz 2013). Risk communication is considered a critical element for managing Natech risk effectively. An ultimate reason for disclosure of risk information is a duty of care, and also, it is the fundamental right of citizens. Although local government authorities in different countries may acknowledge a responsibility to notify residents about their level of exposure to hazards, good intentions may not be appreciated due to the fear that disclosure will antagonistically affect residential property values (Yeo 2004). Therefore, this research aims to understand the effect of the Natech accident at Ichihara city on households' perception regarding property values following the disaster, and their perception regarding the disclosure of information about potential chemical and Natech accidents on future property values. The ultimate goal of this research is to better understand if residential property value is in fact an important concern for resdients when discussing chemical and Natech risk information disclosure. The findings of the study could help government authorities in developing communication strategies that are sensitive to this issue, seeking to counter balance any perceived and real effects.

## 3. PERCEIVED AND REAL CHANGES IN PROPERTY VALUES DUE TO HAZARDS

According to several studies, the decline in property value mostly depends on the residents' perception of the hazardous event and its severity. Zhang *et al.* (2010) indicated that if environmental hazards are perceived as dis-amenities, property values in the proximity of hazard sources would be expected to be lower than those in the less vulnerable areas. Furthermore, if an actual accident/disaster affects or damages an area on a larger scale, there is a high probability that the accident could decrease the property values.

There are however limited studies that have considered residents’ perceptions and concerns regarding the effects of disasters on property values, and much less have focused on chemical and Natech hazards and risk.

A few studies have investigated the impact that proximity of hazardous industrial facilities has on property values (Boxall *et al.* 2005, Grislain-Letrémy and Katossky 2014, and Zhang *et al.* 2010). Some studies suggest that natural and technological hazards have a negative effect on property values, while others indicate no effect. One study investigated the effect of the Fukushima nuclear power plant accident on property values. According to Tanaka and Managi (2016), the Fukushima accident caused widespread pollution of the land by radioactive contamination and decreased the property values in Fukushima prefecture and nearby areas.

On the other hand, several studies have investigated the impact of natural hazards on property markets (Beron *et al.* 1997; Eves and Wilkinson 2014; Lamond 2008; Montz 1993; Rajapaksa *et al.* 2016; Rambaldi *et al.* 2013; Samarasinghe and Sharp 2010; Troy and Romm 2004; S Yeo, 2004; Stephen Yeo 2003; Zhai *et al.* 2003). Some of the researchers found a negative effect, whereas others found no impact on property values. In light of seven investigations of variations in property values before and after flood risk declarations in Australia, Canada, New Zealand, and the United States, Stephen Yeo (2003) found no price effect in two cases, a modest decline in property prices in three cases and a slight increment in property prices in the remaining two.

Despite the substantial literature on environmental hazards' effect on residential property value, the findings are not consistent. There may be many reasons for this inconsistency, such as Naoi *et al.* (2009) indicated that individuals give little contemplation to various hazards and other negative environmental factors in their need framework because they tend to underestimate risk. For example, Zhai *et al.* (2003) found that people generally prefer more affordable property instead of a low risk of flooding (in a case study of the 2000 Tokai flood in Japan). Moreover, Beron *et al.* (1997) reported that if a hazard-prone area is attractive with many amenities, there will be little effect on property values. Furthermore, proximity to the workplace may be more important, than considerations concerning the hazards. In a study regarding industrial facilities, the researchers found that staff may want to live near their workplace (industrial site) to diminish travel times (Kivimäki and Kalimo 1993), so they prefer to live near the hazardous area despite knowing about hazards and potential risks.

A finding from the literature is that a real hazardous event is bound to severely influence property values more than the hazard-prone area designation. In many cases, property values have changed after an event happened, not before the event, even if the risk information has been disclosed. However, in places where demand for housing is strong, even an actual destructive event may have little or no impact on property value. For instance, flooding of Sydney's Georges River Valley in 1986 decreased property values for a few months only. According to Lambley and Cordery (1997), high population growth and subsequent housing deficiency brought about a buoyant market, strikingly flexible to external impact, which tended to obscure any permanent effect upon the market. Evidence from different investigations suggests mixed results regarding the decrease in property market value due to the event occurrence and, or risk information disclosure. As mentioned above, according to the studies, property values decrease if people perceive environmental hazards as dis-amenities. The above studies concerned actual natural disaster occurrence, or the disclosure of natural hazard and/ or risk information. However, few studies have looked into the effect of Natech and chemical accidents on property values. In addition, previous studies have not focused on households' perceptions and their concerns while investigating the effect of disasters on property values. In this study, we are interested in understanding the effect of the Natech accident on households' perception regarding property values, households' concerns and worries regarding the presence and proximity of the hazards (the industrial installation near the coast) to their properties, their views regarding the need for disclosure of information about potential chemical and Natech accidents risks, and their perception concerning the disclosure of such information on future property values.

## 4. METHODOLOGY

Data for this study was collected through a stratified household survey applied in Ichihara City, Chiba Prefecture, Japan. Ichihara city was selected because of the Natech accident that occurred there in 2011 following the Great East Japan earthquake. The sections below will present the details of the Natech accident and the survey design.

### 4.1 Cosmo oil refinery fires in Ichihara City, Japan

To conduct the household survey, a case study area was selected near the Chiba industrial park in Ichihara city, where the Natech accident, involving explosions at the Cosmo Oil Refinery, was triggered by the Great East Japan Earthquake in March 2011. The earthquake triggered a fire and several explosions at the Cosmo Oil Refinery's liquified petroleum gas (LPG) tank farm. All the 17 LPG storage tanks were completely burnt or severely damaged (Koseki *et al.*, 2012). The shockwaves from the explosion broke windows and damaged shutters and roof shingles in nearby residential areas (Koseki *et al.*, 2012; Krausmann and Cruz 2013).

### 4.2 Design of the Household Survey

To examine the households' perceptions regarding the effect of the Natech accident and risk information disclosure on property values, a questionnaire was designed and translated into the Japanese language. The questionnaire included questions in both English and Japanese. The questionnaire had different sections, including a section on socio-demographic characteristics, households' perceptions regarding Natech accidents' effect on property values, and their perceptions about chemical and Natech accident risks. Furthermore, questions regarding the length of time living at the location, and whether they experienced the Natech accident in 2011 were also included. The questionnaire also had subsections focusing on households' concerns and perceptions about industrial park proximity, their demand for risk information and their perceptions about information disclosure effects on future property values.

A list of registered addresses of households (128,316 registered households in 2020) in Ichihara city was collected from the Ichihara post office. The list provided by the Ichihara Post office had more than 100 towns that belong to Ichihara city. From that list provided by the Ichihara post office, six towns within 3 km of the industrial park were selected. The selected towns were Goi, Shiroganecho, Iwasaki, Kimizuka, Gosho, and Tamasaki. After selecting the towns for the survey, we visited the Ichihara city post office and provided them with the list of selected towns and the number of questionnaires to be mailed out in each town. We requested them to send questionnaires to the households living near the industrial park in each town within three kilometers from the Chiba industrial park in Ichihara city. Households within the 3km perimeter for each town were selected randomly. A total of 1400 questionnaires were mailed out to the residents living in the six different towns in Ichihara city near the Chiba industrial park. A return envelope was also enclosed in each questionnaire envelope. Respondents were given one and a half months to fill out the questionnaire and send it back.

## 5. ANALYSIS AND RESULTS

Out of 1400 questionnaires that were mailed to the households, we received 210 responses. So, the overall response rate of the town mail survey was 15%. The response rate is low because the questionnaire survey was voluntary, and no compensation was paid to the survey participants. Another reason may be the type of mailing system used, called "town mail", where the envelopes are not addressed to any person in the household. This system is often used in Japan, which substantially lowers the costs of the mail survey, but results in a low response rate. A similar response rate of 14.3% was reported in the literature in Japan by Kotani and Yokomatsu (2019).

### 5.1 Socio-Demographic Characteristics

Table 1 shows the socio-demographic characteristics of the respondents. Almost 80% of the household respondants were male, and all were Japanese. Most of the respondents, 69.1%, were 60-years-old or older. According to the Statistics Bureau of Japan (2015), the total population of Ichihara city is 274,656, out of which 125,203 (45.6%) people are older than 50-years old. Thus, our sample was older. About 52.4% of the respondents have only high school education, whereas 37.1% of respondents have a bachelor's degree; out of that, 6.3% also have a master's degree. The majority of the respondents had a household size of either 2 or 3 persons, and the average household size was 2.58 persons. 36.7% of the households have children living with them. Most of the respondents (96.7%) were homeowners, and most of them (84.8%) were living in wooden houses. Only 3.8% of the respondents lived in reinforced concrete structures, whereas 4.3% were living in steel frame reinforced concrete structures. Almost all the participants (99.5%) lived in their current house in Ichihara city near the industrial park for many years, and the mean duration of living was 27.4 years. Some of the respondents (18.1%) also owned vacant plots. Almost 25% of the participants marked the average land price of 60,000 yen/m$^2$, whereas 40.2% of the respondents marked the average land price in yen/m$^2$, ranging from 60,000 to 80,000. From the survey participants, 16.2% were living within 1-km from the Chiba industrial park, 48.5% were living within 1-2 km, whereas the remaining 32.3% (excluding 2.9% who did not respond to this question) were living within 2-3 km from the Chiba industrial park. 11.9% of the respondents were working at the Chiba industrial park at the time of the survey.

### 5.2 Households' Perceptions Regarding the Effect of a Natech Accident on Property Values

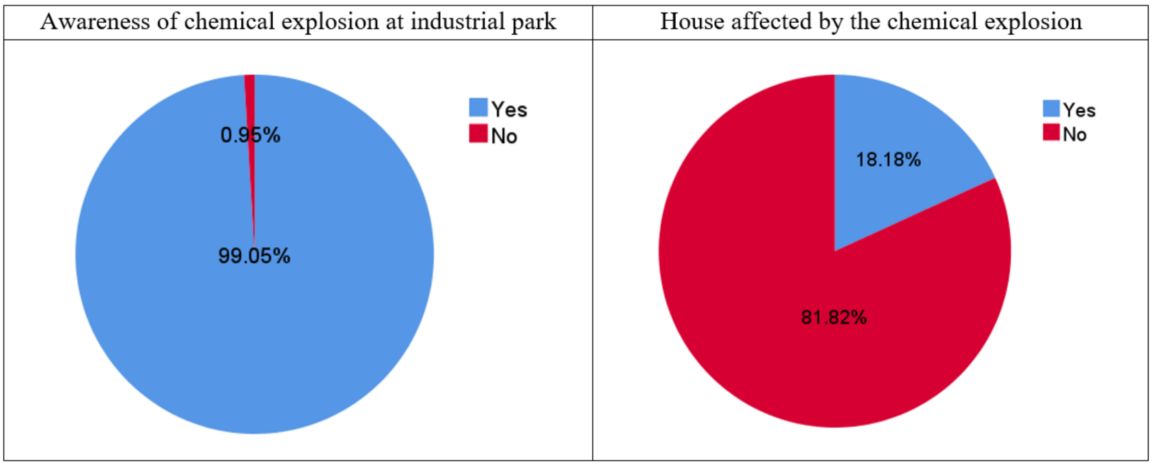


**Figure 1.** Survey participants' awareness of chemical accidents and participants houses affected by the chemical accidents

**Table 1.** Socio-demographic characteristics of the survey participants

| Socio-demographics characteristics of survey participants | | Frequency | Percentage % |
|---|---|---|---|
| Gender | Female | 43 | 20.5% |
| | Male | 167 | 79.5% |
| Age | 30-39 | 8 | 3.8% |
| | 40-49 | 15 | 7.1% |
| | 50-59 | 42 | 20.0% |
| | 60-74 | 94 | 44.8% |
| | >=75 | 51 | 24.3% |
| Level of education | High School | 109 | 51.9% |
| | Technical School | 22 | 10.5% |
| | Bachelor's degree | 64 | 30.5% |
| | Master's degree | 13 | 6.2% |
| | No response | 2 | 1.0% |
| Size of Household | 1 person | 20 | 9.5% |
| | 2 persons | 105 | 50.0% |
| | 3 persons | 49 | 23.3% |
| | 4 persons | 22 | 10.5% |
| | 5 persons | 8 | 3.8% |
| | 6 persons | 6 | 2.9% |
| Children living in the house | Yes | 77 | 36.7% |
| | No | 133 | 63.3% |
| House ownership | Owned | 203 | 96.7% |
| | Rented | 7 | 3.3% |
| Structure of house | Reinforced concrete | 8 | 3.8% |
| | Steel frame reinforced concrete | 9 | 4.3% |
| | Light steel structure | 15 | 7.1% |
| | Wooden | 178 | 84.8% |
| Ownership of vacant plot | Yes | 38 | 18.1% |
| | No | 172 | 81.9% |
| Unit price per square meter of a vacant plot | 60000 yen | 52 | 24.9% |
| | 60000～70000 yen | 42 | 20.1% |
| | 70000～80000 yen | 42 | 20.1% |
| | 80000～90000 yen | 13 | 6.2% |
| | 90000～100000 yen | 12 | 5.7% |
| | More than 100000 yen | 20 | 9.6% |
| | No response | 28 | 13.4% |
| Distance from house to the Chiba industrial park | Less than 500 m | 4 | 1.9% |
| | 500～1000 m | 30 | 14.3% |
| | 1000～1500 m | 41 | 19.5% |
| | 1500～2000 m | 61 | 29.0% |
| | 2000～2500 m | 36 | 17.1% |
| | 2500～3000 m | 32 | 15.2% |
| | No response | 6 | 2.9% |
| Working at Chiba industrial park | Yes | 25 | 11.9% |
| | No | 185 | 88.1% |

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Since the blasts at the Chiba industrial park damaged window glasses, shutters, slate roofs, blew away heat insulators and other light-weighted materials, and stained or damaged vehicles (Krausmann and Cruz 2013) in the nearby residential areas, we asked the survey participants if they were aware of the chemical explosion (Natech accident) that occurred at the Cosmo Oil Refinery in the Chiba industrial park in March 2011 and if their houses were affected by the explosion. Almost 99.5% of the respondents were aware of the chemical accidents induced by the earthquake in 2011 at Cosmo Oil Refinery, as shown in Fig. 1.

The rest of the respondents who were not aware of the explosion were those who moved to Ichihara city after the explosion. Their duration of living in Ichihara city was less than nine years at the time of this survey. Only 18.2% of the participants responded that their houses were directly or indirectly affected (damaged) by the chemical accidents in 2011. Whereas the majority of the participants (81.8%) responded that the accidents did not damage or affect their houses or property.

It is pertinent to mention here that both the affected and non-affected participants lived within 3-km from the Chiba industrial park. From the (total affected = 18.2%) affected participants, 18.4% resided within 1-km, whereas 52.6% lived within 1-2 km from the Chiba industrial park. From the (total non-affected = 81.8%) non-affected participants, 16.3% lived within 1-km, whereas 49.7% lived within 1-2 km from the Chiba industrial park. The rest from both groups were residing within 2-3 km from the Chiba industrial park.

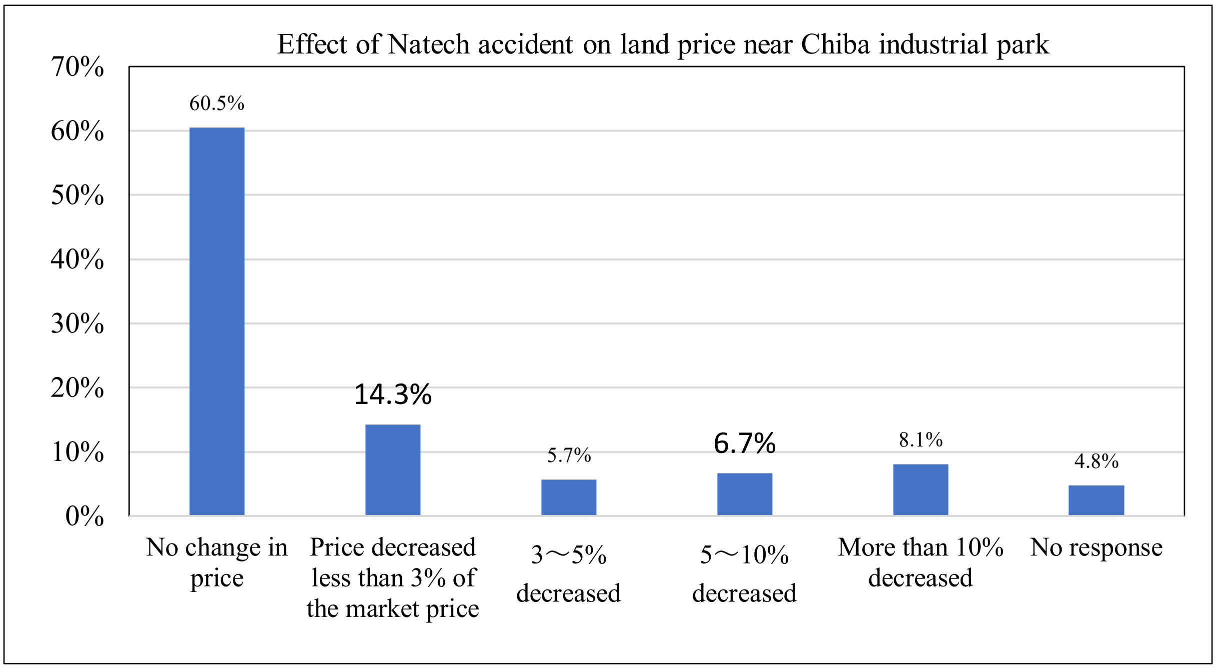
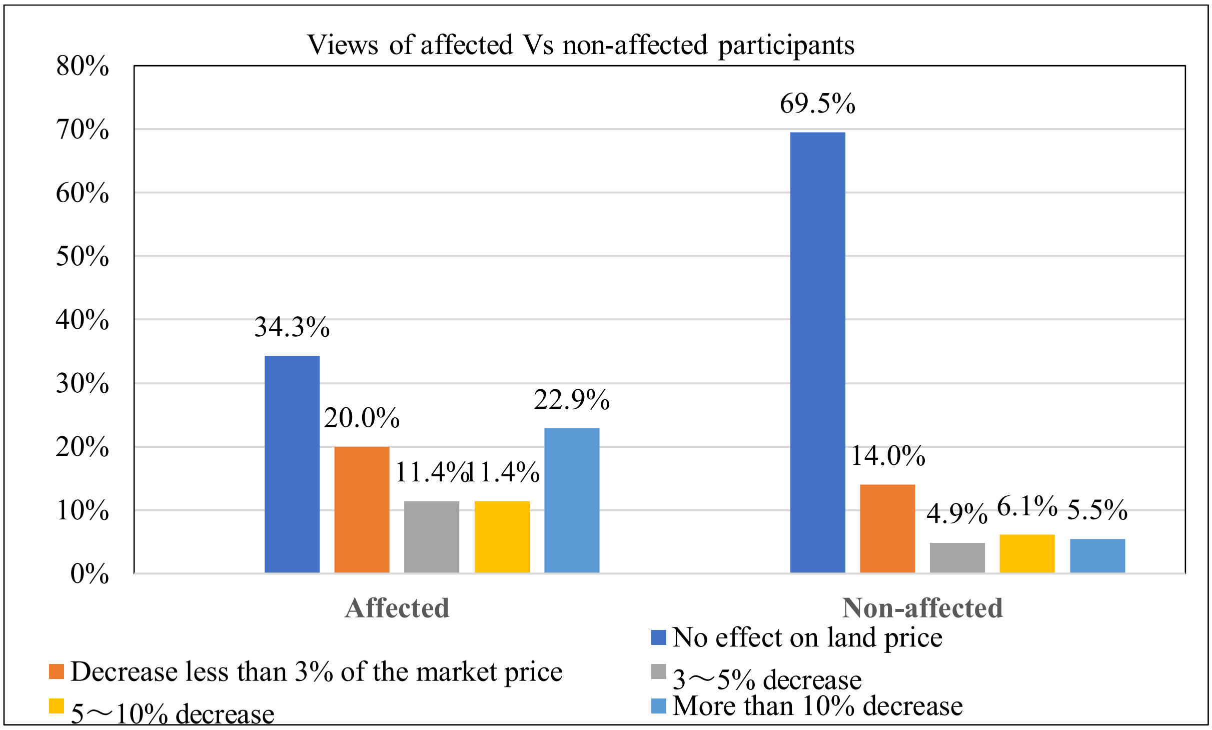



**Figure 2.** Participant’s opinions concerning the effect of the Natech accident on land price

We asked the survey participants to give their opinion, based on their experience of the Natech accident of 2011, regarding the decrease in land price due to the chemical explosion triggered by Great East Japan Earthquake (Natech accident) and identify the percentage decrease in the land price. Most of the respondents (60.5%) thought that the chemical explosion (Natech accident) in 2011 did not decrease the land prices near the industrial park, whereas 34.7% responded that the explosion did decrease the land price in 2011. Of those who believed land prices had declined due to the explosion, 14.3% of them believed that the incident had declined land prices less than 3% of the market price. Whereas 8.1% believed that explosion had decreased land price by more than 10% of the market price, as shown in Fig. 2.




Affected (18.2%, N=38 participants), non-affected (81.8%, N=171 participants), Total = 209

**Figure 3.** Views of affected and non-affected participants about the impact of the Natech accident on land prices

To better understand the impact of the Natech accident on property prices, survey participants were then divided into the affected and non-affected groups. Those whose houses were damaged by the Natech accident are affected (18.2%, N=38 participants), whereas those whose houses were not damaged by accident are non-affected (81.8%, N=171 participants). Out of those affected participants (18.2%) whose houses were damaged by the explosion, most of them responded that the explosion had decreased property values. For example, 20% thought that the land price had decreased by less than 3% of the market price, and 11.4% thought there was a 3～5% decrease. Similarly, 11.4% responded that the land price had decreased 5～10%,

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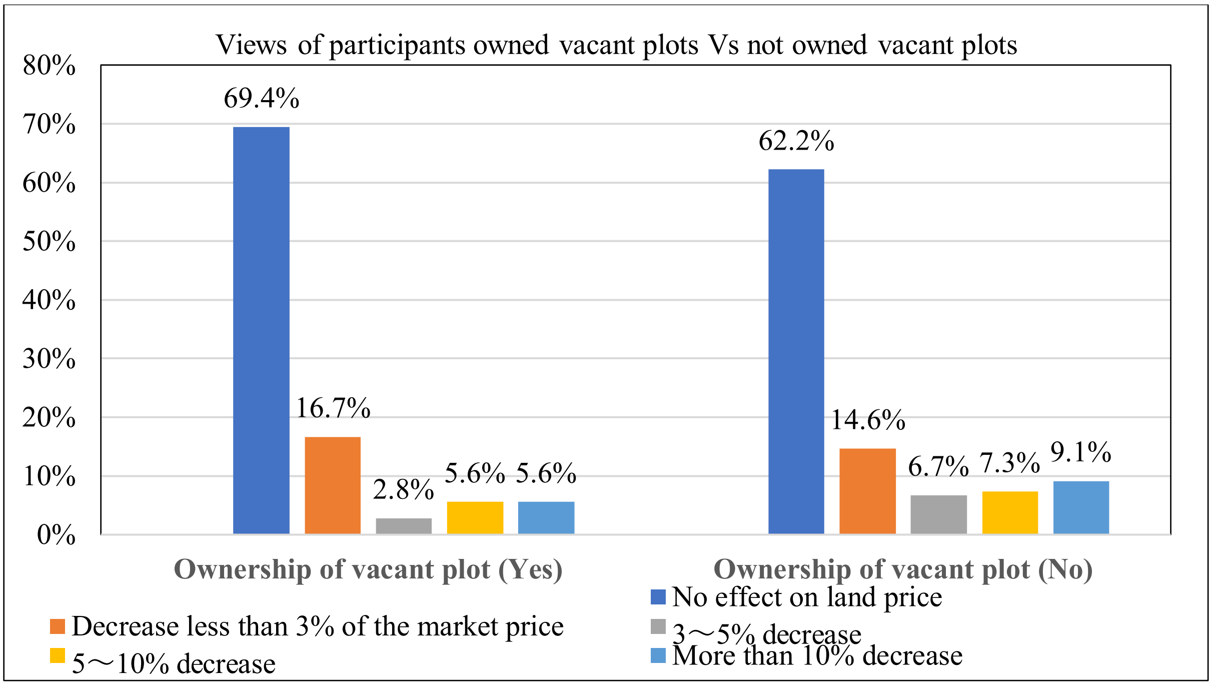
whereas 22.9% of the affected participants thought the land price had decreased by more than 10% of the market price. While the remaining 34.3% of the affected participants responded that the event did not negatively impact property values, as shown in Fig. 3. On the other hand, from the non-affected participants (81.8%), most non-affected participants (69.5%) believed that the accident did not decrease land price. Whereas 14% of the non-affected participants thought that the land price had decreased less than 3% of the market price, 4.9% thought that 3～5% decreased, 6.1% thought 5～10% decreased, and 5.5% believed that more than 10% of the market price decreased.

We asked the participants if they owned any vacant plots in Ichihara city near the industrial park and if the Natech accident decreased their plot price. From the survey participants, 18.1% (N=38 participants) own vacant plots in Ichihara city near the industrial park, whereas the remaining 81.9% (N=172 participants) did not own plots at the time of the survey (15 Jan – 28 Feb 2020). From the 18.1% of participants who owned plots, 69.4% responded that the Natech accident did not decrease the land price, whereas 16.7% thought that the land price had decreased less than 3% of the market price, and 5.6% thought that the land price decrease more than 10% of the market price. While on the other hand, from the 81.9% of respondents who did not own vacant plots, 62.2% reported that the Natech accident did not decrease land price, whereas 14.6% believed that land price decreased less than 3%, and 9.1% believed that it decreased more than 10% of the market price as shown in figure 4.




Plots ownership (Yes=18.1% N=38 participants, No=81.9% N=172 participants), Total = 210

**Figure 4.** Views of plot owners and non-owners about the impact of the Natech accident on land prices

### 5.3 Households' Perceptions Regarding Chemical and Natech Accident Risk

This section will explain survey participants' perceptions, experiences, concerns, and worries about the chemical and Natech accident and potential chemical and Natech accident risk. It will also explain their perception about industrial park proximity, their demand for chemical risk information disclosure and their perception regarding the effect of disclosure on future property values. Participants were asked to rate the statements regarding their perceptions using a standard five-point Likert-type scale ranging from 1 = "Strongly Disagree" to 5 = "Strongly Agree." We chose the 5-point Likert scale because it has higher reliability than the 4-point Likert scale (Croasmun and Ostrom, 2011). Moreover, even-numbered Likert scales require the responder to commit to a given position if the Likert scale has no neutral point (Brown 2000), even if the responder may not have a clear opinion. On the other hand, responders are not obligated to choose one side or the other on an issue if they are given a neutral response option; this may minimize the chances of response bias, which is the tendency to favor one response over others (Randall and Fernandes 1991). Some researchers such as Chisty and Rahman (2020), Adeola and Picou (2017), and Krausmann and Baranzini (2012) have used a 5-point Likert scale to investigate people's perceptions and attitudes.

The main aim of this section is to present the results concerning residents' worries and concerns (see fig 5), residents' perceptions about living in the proximity of an industrial park (see fig 6), their demand for chemical risk information, and their perceptions regarding how the disclosure of chemical and Natech risk information affects property values. Through these questions, this study tried to understand households' experiences, concerns, and worries about chemical and Natech accident hazards, their appetite for risk information disclosure concerning these hazards, and their effect on future property values.

### 5.4 Households Concerns about Chemical and Natech Accidents

We asked the survey participants to indicate their concerns and worries about the chemical and Natech accidents at Chiba industrial park and their opinions about the possibility of a future Natech accident at the Chiba industrial park. From the responses that we received, 70.5% of the survey participants considered the Chiba industrial park explosion a critical problem (mean value=3.79), and they strongly believed that if a large earthquake happens again, there is a high possibility that the Natech accident may occur in the future at the Chiba industrial park (mean value =4.03). Almost 83.9% of the survey participants agreed or strongly agreed with the statement that if an earthquake happens, a Natech accident may occur again at the Chiba industrial park. 56.9% of the survey participants considered chemical and Natech accidents a threat to their life and property (mean value =3.64), as shown in figure 5.

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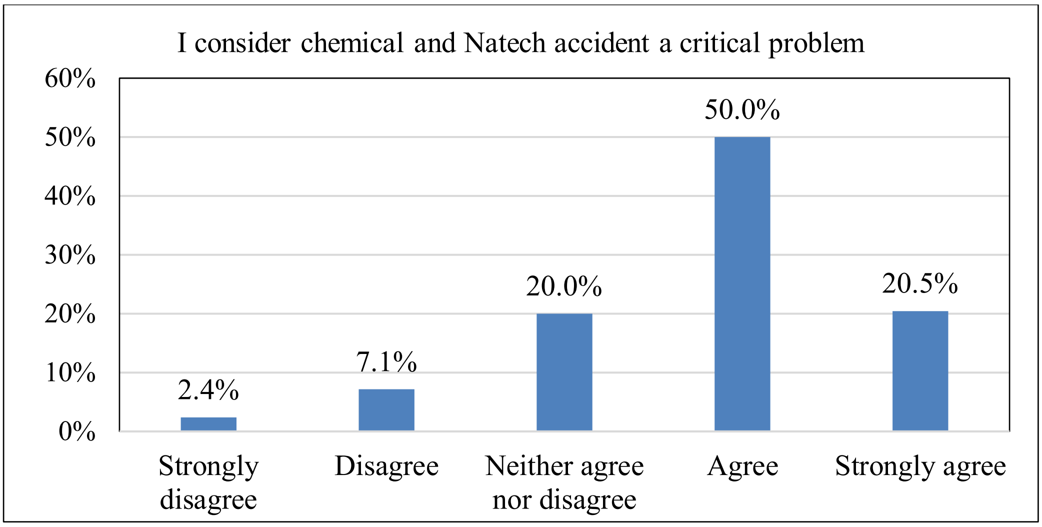


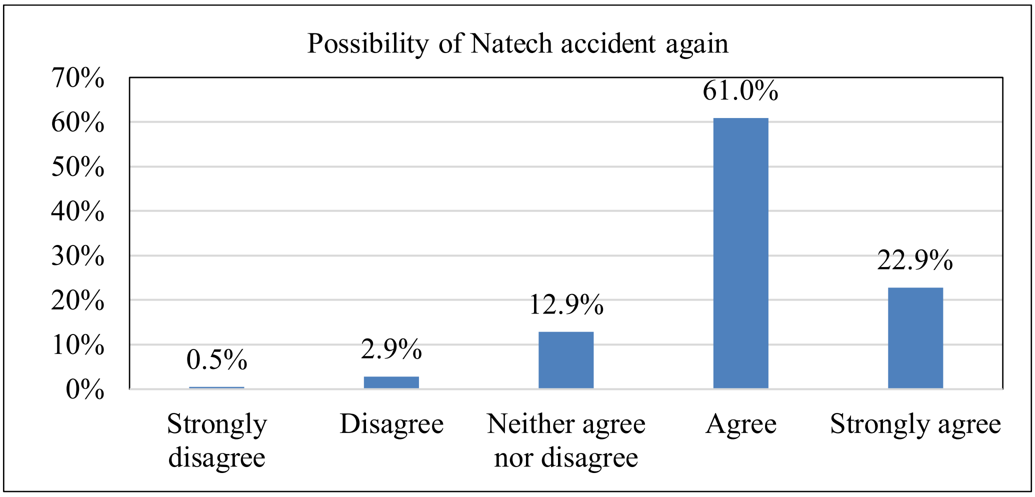


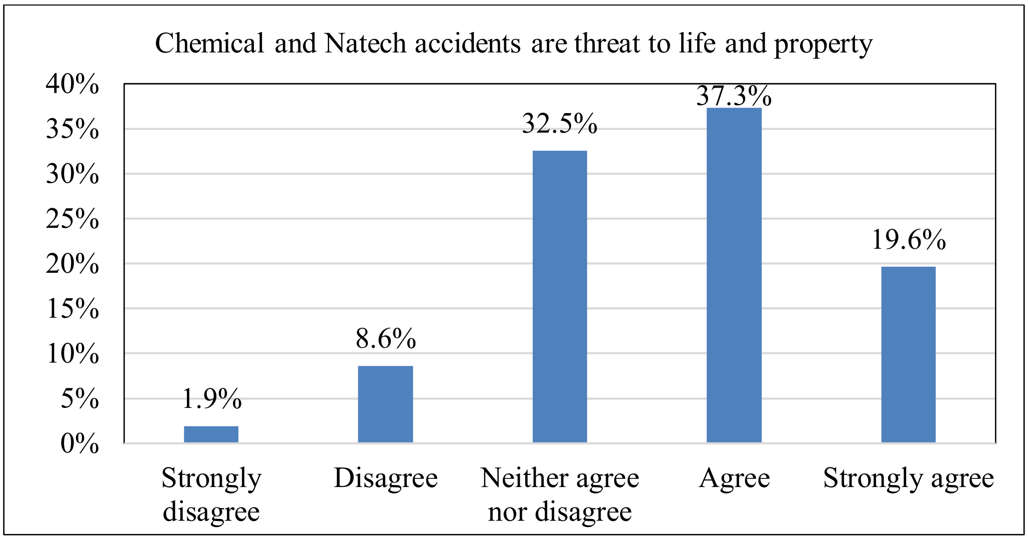


**Figure 5.** Participants concerns about chemical and Natech accidents where Strongly disagree = 1, Disagree = 2, Neither agree nor disagree = 3, Agree = 4, and Strongly agree = 5.

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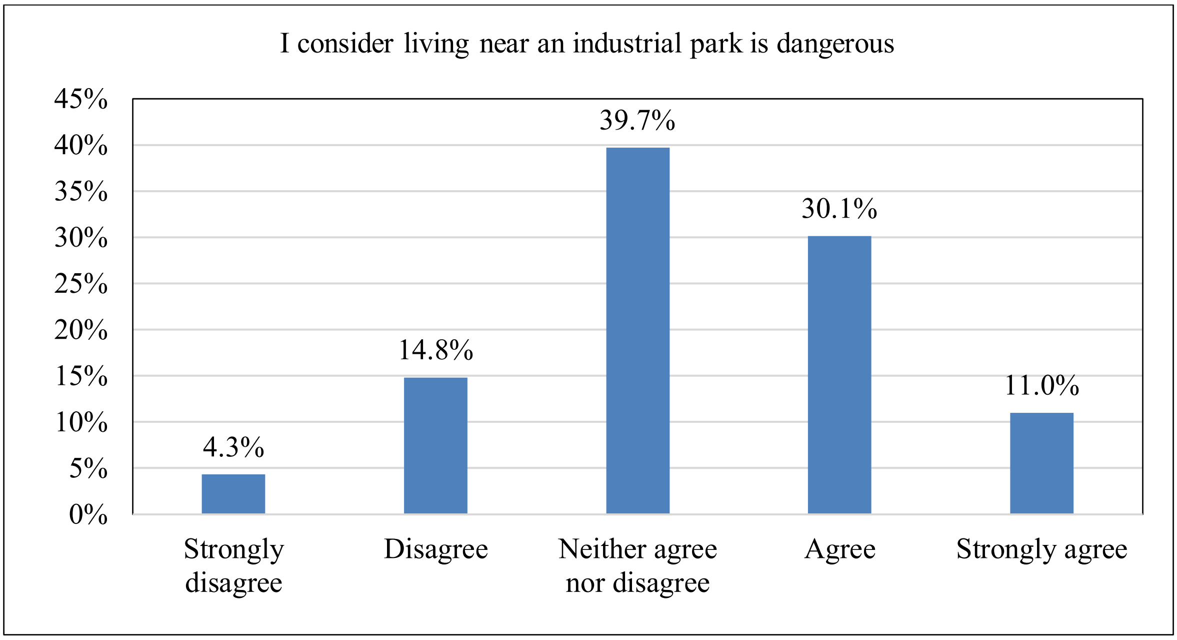
### 5.5 Households' Perceptions Regarding Industrial Park Proximity and Chemical and Natech Accidents Risk



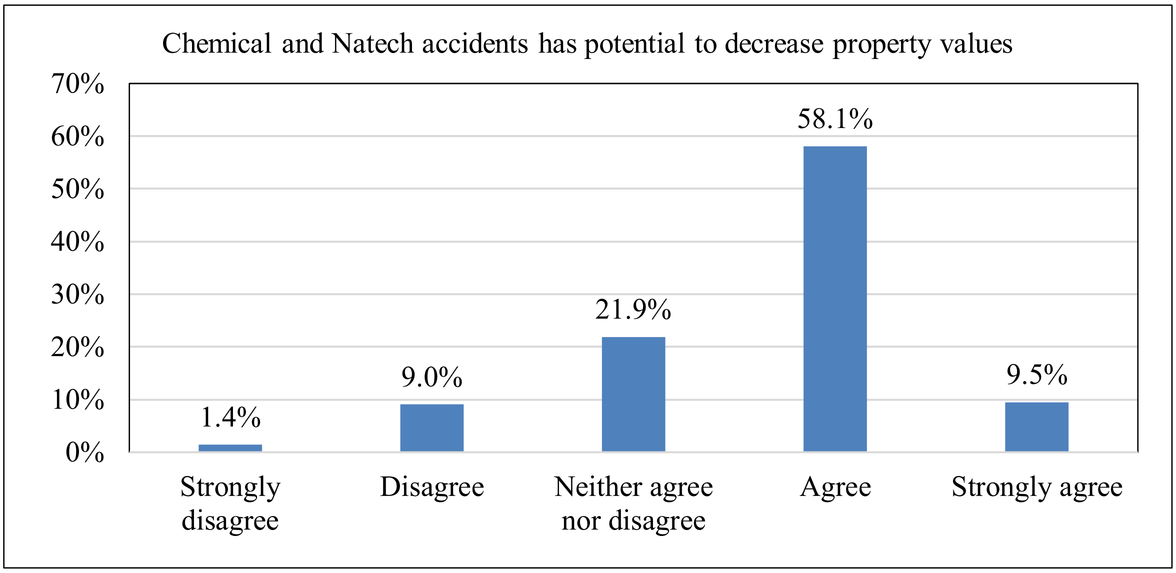




**Figure 6.** Participants perceptions about industrial park proximity and chemical and Natech accidents risk where Strongly disagree = 1, Disagree = 2, Neither agree nor disagree = 3, Agree = 4, and Strongly agree = 5.

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From the survey participants, 41.1% considered living near the industrial park is dangerous (mean value =3.29), whereas 39.7% said they neither agree nor disagree with the statement that living near the industrial park is dangerous, as shown in Fig. 6. Those who consider that living near the industrial park is dangerous, mentioned that they cannot move from their home due to the lack of affordability and emotional attachment to the place. Most of the respondents have been living in the same house for many decades; therefore, it is difficult for them to move to another location. They are concerned that the chemical and Natech accidents has potential to decrease property values in the future near the industrial park (mean value =3.65). From survey participants, 58.1% agreed and 9.5% strongly agreed that chemical and Natech accidents could decrease property values. 21.9% said they neigher agreed nor disagreed, whereas 10.4% disagreed or strongly disagreed with the statement that chemical and Natech accidents have the potential to decrease property values in the future, as shown in figure 6.

### 5.6 Households' Perceptions Regarding the Disclosure of Natech and Chemical Risk Information

The Chiba industrial park's chemical accident in 2011 increased households' awareness of the potential consequences of chemical and Natech accidents, and respondents are now giving priority to chemical risks in their housing decisions (mean value =3.65). We asked the survey participants if they are giving priority to the chemical and Natech risks in their housing decisions after having an experience of a Natech accident; 62.5% of the survey participants agreed or strongly agreed that they are giving importance to the chemical and Natech risk in their housing decisions, whereas 26.9% were neutral with the statement. Regarding chemical risk information disclosure, after experiencing the chemical and Natech accident in 2011, most of the survey participants are now aware of the chemical hazards. They also want to know more about the chemical and Natech risks associated with their places as 44.7% of the survey participants agreed or strongly agreed (mean value =3.28) with the statement that they want to know more about chemical and Natech risks associated with their places, while 33.8% of respondents said they neigher agreed nor disagreed, 16.2% disagreed and 5.2% strongly disagreed. On the one hand, many survey participants want to know more about the chemical and Natech risks associated with their places, while on the other hand, they agreed that if the government discloses chemical risk information publicly, then the property values will decrease in their areas (mean value =3.63). 59.6% of the survey participants thought that the disclosure would decrease property values, 34.6% neither agreed nor disagreed, and 5.8% disagreed with the statement that disclosure will decrease property values, as shown in figure 7.

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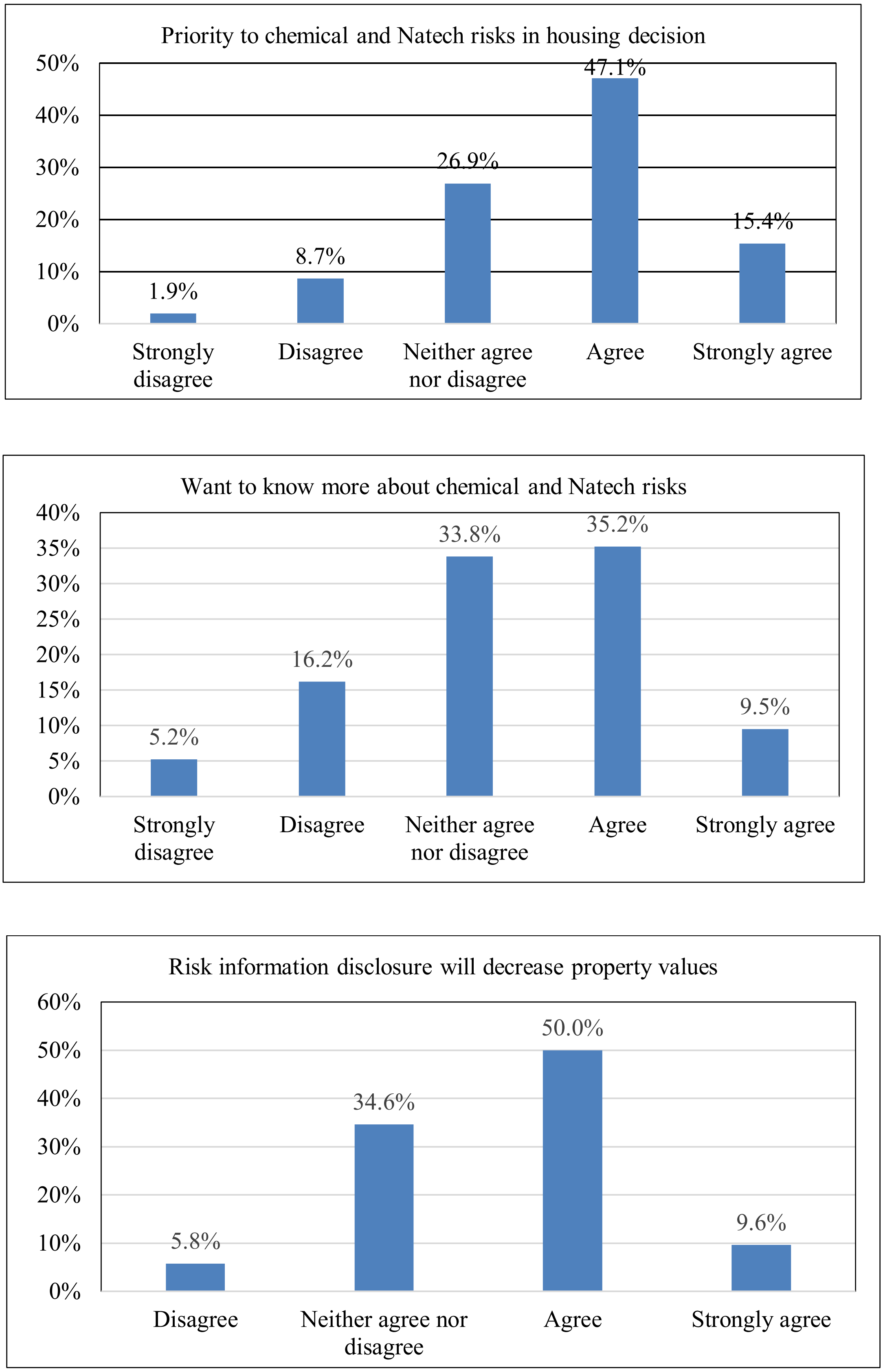


**Figure 7.** Participants' perceptions about chemical and Natech risk information demand and disclosure where Strongly disagree = 1, Disagree = 2, Neither agree nor disagree = 3, Agree = 4, and Strongly agree = 5.

## 6. DISCUSSION AND LIMITATIONS

This study analyzed households' perceptions of the effect of Natech accidents (actual event) on residential property values and their perceptions regarding the effect of Natech and chemical risk information disclosure on residential property values. The study also investigated households' perceptions, concerns, and worries about the chemical and Natech accident risk and their demand for Natech and chemical risk information disclosure. The research aim was to understand the effect of the Natech accident at Ichihara city on households' perceptions regarding property values, and their perceptions regarding the disclosure of information about potential future chemical and Natech accidents on future property values. The ultimate goal of this research was to better understand households' perceived barriers concerning chemical and Natech risk information disclosure which could help government authorities in developing communication strategies for improved disaster preparedness.

Based on the participants' opinions collected during the household survey, most survey participants whose houses were directly affected by the Natech accident (called affected participants) perceived that the Natech accident decreased the property values. In contrast, those whose houses were not affected (called non-affected participants) by the Natech accident believed that the accident did not decrease the property values. The number of affected participants is smaller (18.2%) than the non-affected participants (81.8%). Besides, both the affected and non-affected participants were living within 3-km of the industrial park.

Similarly, most survey participants who own vacant plots in Ichihara city believed that the Natech accident did not decrease the land price in 2011. Most participants think property values did not decrease due to the Natech accident because most households only consider and prioritize natural hazards such as earthquakes, floods, and tsunami compared to Natech and chemical risk. In this sense, one participant added a comment: "People forget the chemical accident. Rather than that, I think flood or tsunami risk affects land prices much more, compared to chemical risk. The influence of smoke pollution from industries is more important than chemical accidents." Another respondant said, "As chemical industries are far away from residential areas, the property prices are not influenced by the chemical accident risks." While past studies have found that the properties located in high environmental hazard prone areas subject to earthquakes, tsunami, and floods, have less market value than the properties located in less hazard-prone areas (Bin *et al.* 2008; Bin and Polasky 2004; Eves and Wilkinson 2014; Hidano *et al.* 2015; Zhai G *et al.* 2003), it is not clear that environmental hazards would dominate when compared to chemical and Natech hazard risks.

Although the participants perceived that the Natech accident in 2011 did not decrease the property values, their perception and awareness of chemical and Natech risks has increased since the accident. Most of the surveyed households considered chemical and Natech accidents to be a threat to their lives and properties. They are concerned that chemical and Natech accidents may happen again at the industrial park, and the chemical and Natech accidents have the potential to decline property values in the future. Although participants consider chemical and Natech accidents a threat to their lives and properties, and consider that living near an industrial park is dangerous, they cannot move from this place for certain reasons. For example, some respondents noted that they could not afford to buy a house somewhere else away from the industrial park where there is no risk of chemical accidents; others expressed that they have sentiments and emotional feelings attached to their current housing location as their ancestors were living there and they are also living in this place for many years. Therefore, it is difficult for them to move from this place.

Most of the surveyed households are now aware of the chemical and Natech risks. They want to know more about the chemical risks associated with their current housing location. However, they are also concerned that if the government discloses the chemical risk information publicly, it will decrease the property values in the areas closer to the industrial park.

The disclosure of chemical risk is seen as a citizen's right in many wealthy countries (see, for example, the Emergency Planning and Community Right-to-Know Act (EPCRA) in the United States; and the Seveso III Directive in the European Union) and in fact considered unethical not to inform residents about risks they are being subjected to involuntarily (EPCRA 2012; European Union 2012). However, the disclosure of chemical and Natech risk information also requires the dissemination of information regarding disaster prevention and preparedness actions that residents can take to reduce potential consequences, and clear plans on how these hazards and their risks are being addressed. This would help to avoid confilicts. In some countries, the disclosure of natural hazard risk information and communication has led to opposition from individuals who perceive that such disclosure may decline the real estate market. For instance, Montz (1993) found that the publication of hazard maps in New Zealand was encouraged by researchers and censured by the real estate agencies because they perceived that the information would decrease property values.

Therefore, in collaboration with the Chiba industrial park's safety managers, the government should educate the residents by organizing seminars, providing them information about the initiatives that have already been taken to avoid chemical and Natech accidents, and enhancing residents' safety. They should strengthen residents' preparedness training for countermeasures against chemical and Natech accidents and then communicate the chemical hazards information along with positive actions that help to rebuild their trust. However, there is no clear formula on what is the best way to communicate chemical risk information to residents. Therefore, further research is needed to find ways to communicate chemical risk information to the residents that do not make them worried but enhance their preparedness level.

It is important to note that this study has some limitations. For instance, the study only investigated households' perceptions, whereas it did not investigate the perceptions of the real estate agents, government officials in Japan, nor safety managers of industrial facilities, which are imperative in formulating effective policy recommendations for chemical risk information disclosure and developing communication strategies for improved disaster preparedness. Also, the study's overall sample size is small as the survey was voluntary, and no incentives were given to the participants. Besides, the survey only covered a limited area in Ichihara city, so the study results cannot be generalized to the whole of Ichihara city and the whole population.

## 7. CONCLUSIONS AND FUTURE WORK

This study has been conducted to understand if the disasters, especially chemical and Natech accidents, negatively impact property values. The study's main purpose was to promote risk information disclosure and develop communication strategies for improved disaster preparedness to protect residents, but the assumption and fear that disclosure will affect property values may bind the government from disclosing chemical risk information. Hence to understand the effect of the Natech accident and chemical risk information disclosure on household's perception regarding residential property values this study has been conducted. The survey collected data from the households living within 3 km from the Chiba industrial park where a Natech accident happened in 2011 following Great East Japan earthquake and tsunami.

The ultimate goal of this research was to better understand households' perceived barriers concerning chemical and Natech risk information disclosure which could help government authorities in developing communication strategies for improved disaster preparedness. While households perceptions were mixed regarding the impact of the Natech accident during the Great East Japan earthquake on property values, depending on whether they had been directly impacted or not, most residents thought that the disclosure of risk information regarding future events could negatively affect property values. Nonetheless, households indicated that they want to be informed, and that chemical and Natech risk information is one of the most important considerations when thinking about future location choices.

The survey results indicated that the Natech and chemical accidents increased the survey participants' perceptions regarding chemical and Natech risk. Most of the participants are now aware of the chemical and Natech risks, and they are worried about the potential consequences of a chemical and Natech accidents. They want the government to disclose chemical risk information, but they seem to be worried that disclosure may affect their area's property values if the information is made publicly available.

Moreover, residents consider the need to have access to chemical risk information. The study highlights the residents' worries and concerns about potential chemical and Natech accident risks and residents' want to have access to chemical risk information. The survey results highlight the need to take chemical risk communication seriously, while a strategy is needed to mitigate against any property value losses. The study results can have implications on Natech risk governance at the community and industry level.

This study can be improved in several aspects for further research, both methodologically and regarding the analysis scope. For example, it would be instructive to analyze the effect of chemical and Natech accidents on property values and residents' perceptions regarding chemical and Natech accidents' effect on the property in other areas where chemical and Natech accidents had occurred in recent years. Since the Natech accident in Ichihara city had occurred several years ago, the effects of the accident may diminish, and residents may forget. Therefore, the analysis of recent chemical and Natech accident on property values and residents' perception of the chemical and Natech accident on property value would help us to better understand whether residents' perceptions about the chemical and Natech accident's effects on property values and the recent chemical and Natech accidents in different regions have similar effects on property values or not. The results can also be further improved by conducting interviews with real estate agents in Ichihara city, which would help get an in-depth understanding of the impact of Natech accidents and chemical risk information disclosure on property values.

Furthermore, the industrial park's safety managers' interviews could also be effective in better understanding the industrial park's initiatives to avoid chemical and Natech accidents, protect citizens, rebuild residents' trust, and ensure a sense of safety and well-being. The interviews from both real estate agents and safety managers would be conducive to developing the policies and programs related to risk communication and disclosure at the local level.

Future research could examine the impact of risk information disclosure on property values in areas where information has already been disclosed. The actual event's experience might have different impacts on people's perceptions and perceptions concerning property values. Hence further research is needed to fill the gaps and make policy recommendations for developing communication strategies for improved disaster preparedness and risk communication in Japan.

## REFERENCES

Adeola, F.O., and Picou, J.S. (2017) Hurricane Katrina-linked environmental injustice: race, class, and place differentials in attitudes. *Disasters*, *41* (2): 228-257. https://doi.org/10.1111/disa.12204

Beron, K. J., Murdoch, J. C., Thayer, M. A., and Vijverberg, W. P. M. (1997) An analysis of the housing market before and after the 1989 Loma Prieta earthquake. *Land Economics, 73*(1): 101-113. https://doi.org/10.2307/3147080

Bin, O., Kruse, J. B., and Landry, C. E. (2008) Flood hazards, insurance rates, and amenities: Evidence from the coastal housing market. *The Journal of Risk and Insurance*, *75* (1): 63-82. https://www.jstor.org/stable/25145263

Bin, O., and Polasky, S. (2004) Effects of Flood Hazards on Property Values: Evidence Before and After Hurricane Floyd, *80* (4): 490-500. https://doi.org/10.2307/3655805

Boxall, P. C., Chan, W. H., and McMillan, M. L. (2005) The impact of oil and natural gas facilities on rural residential property values: A spatial hedonic analysis. *Resource and Energy Economics, 27* (3): 248-269. https:/doi.org/10.1016/j.reseneeco.2004.11.003

Brown, J.D. (2000). What issues affect Likert-scale questionnaire formats? JALT Testing & Evaluation SIG, *4* (1), 27-30. https://hosted.jalt.org/test/PDF/Brown7.pdf

Croasmun, J. T., & Ostrom, L. (2011). Using Likert-type Scales in the Social Sciences. Journal of Adult Education, *40* (1): 19-22. https://files.eric.ed.gov/fulltext/EJ961998.pdf

Chisty, M.A., and Rahman, M.M., 2020. Coping capacity assessment of urban fire disaster: An exploratory study on ward no: 30 of Old Dhaka area. *International Journal of Disaster Risk Reduction*, *51*. https://doi.org/10.1016/j.ijdrr.2020.101878 EPCRA. (2012) The Emergency Planning and Community Right-to-Know Act. https://www.epa.gov/epcra/what-epcra

European Union. (2012) Directive 2012/18/EU of the European Parliament and of the Council of 4 July 2012 on the control of major accident hazards involving dangerous substances, amending and subsequently repealing Council Directive 96/82/EC. Off. J. Eur. Union. 197, 1.

Eves, C., and Wilkinson, S. (2014) Assessing the immediate and short-term impact of flooding on residential property participant behavior. *Natural Hazards*, *71* (3): 1519–1536. https://doi.org/10.1007/s11069-013-0961-y

Elisabeth Krausmann and Daniele Baranzini (2012) Natech risk reduction in the European Union, *Journal of Risk Research*, *15* (8): 1027-1047. https://doi.org/10.1080/13669877.2012.666761

Randall, D., and Fernandes, M. (1991). The social desirability response bias in ethics research. *Journal of Business Ethics*, *10* (11): 805-817. https://doi.org/10.1007/BF00383696

Gentle, N., Kierce, S., and Nitz, A. (2001) Economic Costs of Natural Disasters in Australia. *The Australian Journal of Emergency Management*, *16* (2): 38-43. https://search.informit.org/doi/10.3316/informit.378155558898334

Grislain-Letrémy, C., and Katossky, A. (2014) The impact of hazardous industrial facilities on housing prices: A comparison of parametric and semiparametric hedonic price models. *Regional Science and Urban Economic, 49, 93-107*. https://doi.org/10.1016/j.regsciurbeco.2014.09.002

Hidano, N., Hoshino, T., and Sugiura, A. (2015) The effect of seismic hazard risk information on property prices: Evidence from a spatial regression discontinuity design. *Regional Science and Urban Economics*, *53*, 113–122. https://doi.org/10.1016/j.regsciurbeco.2015.05.005

Ikeda, Y. (2013) The Construction of Risk and the Resilience of Fukushima in the Aftermath of the Nuclear Power Plant Accident, in Steger, B., Gill, T., and Slater, D. H. (Eds.), Japan Copes with Calamity: Ethnographies of the Earthquake, Tsunami and Nuclear Disasters of March 2011. *Bern; New York*: Peter Lang Publishing, 151–175.

Kinoshita, T. (2014) Short History of Risk Communication in Japan. *Journal of Disaster Research*, *9*, 592-597. https://doi.org/10.20965/jdr.2014.p0592

Koseki, H., Li, X., and Mannan, M. S. (2012) Damage to chemical and oil complexes following the 2011 Tohoku earthquakes. *Loss Prevention Bulletin, (*226): 12-15.

Kotani, Hitomu, and Muneta Yokomatsu. 2019. 'Quantitative Evaluation of the Roles of Community Events and Artifacts for Social Network Formation: A Multilayer Network Model of a Community of Practice'. *Computational and Mathematical Organization Theory 25* (4): 428–63. https://doi.org/10.1007/s10588-018-9277-5.

Krausmann, E., and Cruz, A. M. (2013) Impact of the 11 March 2011, Great East Japan earthquake and tsunami on the chemical industry. *Natural Hazards*, *67* (2): 811–828. https://doi.org/10.1007/s11069-013-0607-0

Kivimäki, M., and Kalimo, R. (1993) Risk Perception Among Nuclear Power Plant Personnel: A Survey. *Risk Analysis 13* (4): 421-424. https://doi.org/10.1111/j.1539-6924.1993.tb00742.x

Lambley, D., and Cordery, I. (1997) The Effects of Catastrophic Flooding at Nyngan and Some Implications for Emergency Management. *The Australian Journal of Emergency Management,* *12*(2): 5-9. *https://search.informit.org/doi/10.3316/ielapa.400962315718371*

Lamond, J. E. (2008) The impact of flooding on the value of residential property in the UK. *In Dept. of the build environment and engineering*. https://wlv.openrepository.com/bitstream/handle/2436/31427/Lamond_PhDthesis.pdf?sequence=1&isAllowed=y

Montz, B. E. (1993) Hazard area disclosure in New Zealand: the impacts on residential property values in two communities. *Applied Geography*, *13* (3): 225-242. https://doi.org/10.1016/0143-6228(93)90002-I

Naoi, M., Seko, M., and Sumita, K. (2009) Earthquake risk and housing prices in Japan: Evidence before and after massive earthquakes. *Regional Science and Urban Economics*, *39*(6): 658-669. https://doi.org/10.1016/j.regsciurbeco.2009.08.002

Rajapaksa, D., Wilson, C., Managi, S., Hoang, V., and Lee, B. (2016). Flood Risk Information, Actual Floods, and Property Values: A Quasi-Experimental Analysis. *Economic Record, 92* (S1): 52-67. https://doi.org/10.1111/1475-4932.12257

Rambaldi, A. N., Fletcher, C. S., Collins, K., and McAllister, R. R. J. (2013) Housing Shadow Prices in an Inundation-prone Suburb. *Urban Studies, 50* (9): 1889-1905. https://doi.org/10.1177/0042098012465904

Statistics Bureau Japan (2015). City Population, Ichihara. Accessed from https://www.citypopulation.de/en/japan/chiba/_/12219__ichihara/

Samarasinghe, O., and Sharp, B. (2010) Flood prone risk and amenity values: A spatial hedonic analysis. *Australian Journal of Agricultural and Resource Economics, 54* (4): 457-475. https://doi.org/10.1111/j.1467-8489.2009.00483.x

Tanaka, K., and Managi, S. (2016) Impact of a disaster on land price: evidence from Fukushima nuclear power plant accident. In *Singapore Economic Review*, *61* (1). World Scientific Publishing Co. Pte Ltd. https://doi.org/10.1142/S0217590816400038

Troy, A., and Romm, J. (2004) Assessing the price effects of flood hazard disclosure under the California Natural Hazard Disclosure Law (AB 1195). *Journal of Environmental Planning and Management*, *47* (1). https://doi.org/10.1080/0964056042000189844

Yeo, S. (2004) Are residential property values adversely affected by disclosure of flood risk. In *Staying Afloat: floodplain management conference* of NSW, *Coffs Harbour,* 267-272. https://www.researchgate.net/publication/312779703_Are_residential_property_values_adversely_affected_by_disclosure_of_flood_risk

Yeo, Stephen. (2003) Effects of disclosure of flood-liability on residential property values. *Australian Journal of Emergency Management, 18 (1): 35-44*. https://search.informit.org/doi/abs/10.3316/ielapa.377037580622842

Zhai G, Fukuzono T, and Ikeda S. (2003) Effect of Flooding on Megalopolitan Land Prices: A Case Study of the 2000 Tokai Flood in Japan. *Journal of Natural Disaster Science*, *25* (1): 23–36. https://jsnds.org/jnds/25_1_4.pdf

Zhang, Y., Hwang, S. N., and Lindell, M. K. (2010) Hazard Proximity or Risk Perception? Evaluating the Effects of Natural and Technological Hazards on Housing Values. *Environment and Behavior*, *42* (5), 597-624. https://doi.org/10.1177/0013916509334564