

Quantitative Natech Risk Assessment and Application to Disaster Evacuation Planning: Towards an Integrated methodology for Area-wide Analysis

○Haruki SUDA, Ana Maria CRUZ, Michinori HATAYAMA

1. Introduction

Natural disasters sometimes bring about secondary disasters such as chemical accidents. We call these joint natural and technological disasters Natechs. Natechs have occurred in the wake of a natural disaster often causing injuries and fatalities, environmental pollution and economic damage through supply chains. The accident at the Cosmo Oil Refinery in Chiba Pref. during the Great East Japan earthquake is one example of Natechs. However, specific disaster countermeasures for Natechs have not been formulated yet in Japan. Thus, the objectives of this research are as follows: a. To carry out a quantitative risk assessment (QRA) for Natechs in a case study area; b. To do evacuation analysis for Natechs in the case study area; and c. To develop an integrated methodology that covers both risk assessment and evacuation planning for Natechs.

2. Background

Several Natech qualitative and quantitative risk assessment methodologies have been proposed but mostly for individual facilities, and they do not consider wider impacts offsite.^[1, 2, 3] In this study we adapt a quantitative risk assessment (QRA) methodology and improve it to assess area-wide impacts to residents living near an industrial park in order to inform evacuation planning.

Japan has several regulations regarding disaster prevention, but evacuation planning for Natechs has not been formulated yet. This fact actually caused a confusion in evacuation from an LPG gas release

during the Great Hanshin earthquake. This is the motivation for doing evacuation analysis in this study.

3. Methodology

Some definitions should be explained here for the QRA of this research. The basic equation is:

$$IR_i^k = P_{\text{natech}}^k \times P_{\text{fatality } i}^k$$

IR_i^k is individual risk for humans in the area i from the storage tank k . P_{natech}^k is the probability of Natech occurring at the storage tank k , and $P_{\text{fatality } i}^k$ is the probability of fatality of an individual in the area i in the case of Natech occurring from the storage tank k .

TR_i^k is the total individual risk during a person's evacuation from the area i to the safer area against the Natech of storage tank k . TR_i^k is the summation of IR_i^k that the individual experiences during the evacuation. The algorithm of the methodology is shown in [Figure 1](#). For the analysis, data on the natural disaster, industrial plants, hazardous materials, and geography are necessary. We use RAPID-N, BREEZE Analyst, and ArcGIS in the numerical simulations and results mappings.

4. Results

This research investigated the effects of explosive and toxic scenarios in Kobe City, Higashinada Ward triggered by a Nankai trough earthquake. For the explosive scenario, we select a cylindrical, vertical storage tank, E, containing 15,214 tons of refrigerated LPG. We estimate both the overpressure and building collapse effects on risk. $IR_{i,\text{out}}^k$ is the

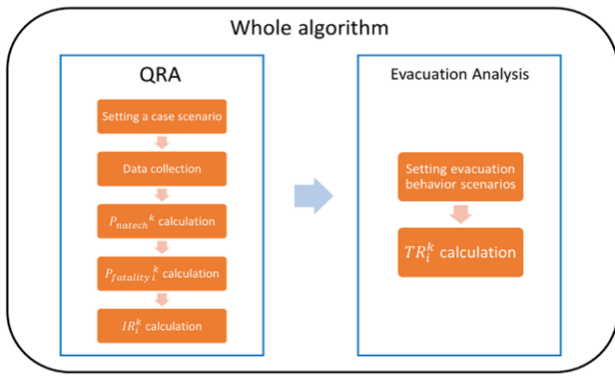


Figure 1. This research's algorithm

IR_i^k for a person who is outside when the explosive accident occurs. The main cause of death is direct overpressure. $IR_{i,in}^k$ is the IR_i^k for a person who is inside, fatality is due to building collapse.

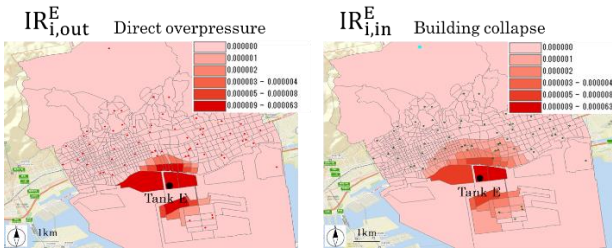


Figure 2. IR_i^k for explosive scenario

In explosive scenario, TR_i^k will be largely different when one evacuates to the nearest designated shelter or when one stays at home, because explosive accidents instantly attack the surrounding area. For numerical simulation, the case study area is classified into area α and area β as shown in Figure 3.

Calculation results showed that all TR_i^k in area β are higher when people stay at home, but TR_i^k in almost all area α are higher when people evacuate.

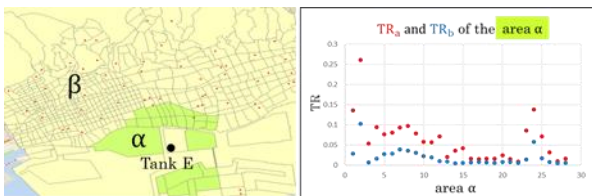


Figure 3. TR_i^k for explosive scenario

For the toxic scenario, the target storage tank is a cylindrical, vertical tank, T, containing 551,842 kg pressurized ammonia. We assume average wind speed and direction, SSW at 1.0 m/s. The IR_i^k calculation results are shown in Figure 4.

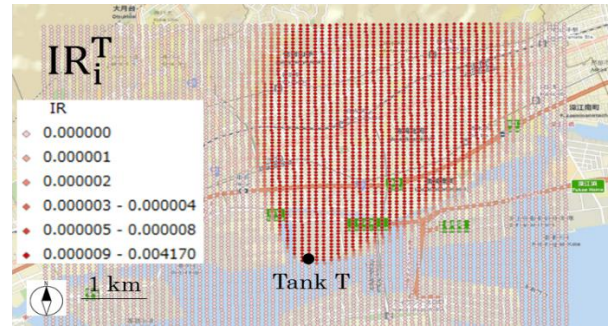


Figure 4. IR_i^k for toxic scenario

In the toxic scenario, all persons should evacuate because the toxic cloud dispersion can be predicted. Figure 5 shows the TR_i^k when people evacuate to the north and south, and when people evacuate in a perpendicular direction against the wind.

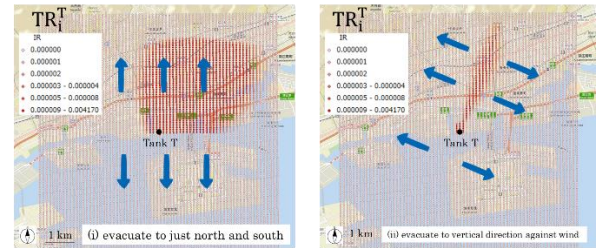


Figure 5. TR_i^k for toxic scenario

5. Conclusions

This research did a QRA and evacuation analysis for Natechs, however, the concurrent earthquake and tsunami conditions were not modeled in the evacuation analysis. As future work, this research should study potential domino effects, and the impacts on the concurrent earthquake and tsunami on the feasibility of the evacuation.

Reference

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- [3] Antonioni et al.: Quantitative assessment of risk due to NaTech scenarios caused by floods. *Reliability Eng. and System Safety*, 142, 334-345, 2015.