MULTI-RISK: AN APPROACH FOR DISASTER RISK MANAGEMENT

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Abstract: *Natural disaster risk assessment is a critical part of a risk management system. Single risk assessment which addresses different natural hazards and their associated risks separately is a popular one used in risk management in Viet Nam. Single risk assessment deals with only one source of disaster ignoring all the possible risk interactions. A multi-risk approach therefore has currently been developed and tested by a number of scholars. This paper introduces a multi-hazard and multi-risk assessment methodology adopted from literature review, which combines single risk assessment and a three-level risk assessment. Multi-risk approaches takes into account the interactions and relations among hazards and among vulnerabilities. It can bring benefits but also challenges to both end-users and scientists.*

Keywords: *multi-risk, multi-hazard, disaster risk reduction.*

1. Introduction

Located in the tropical monsoon area, Viet Nam is one of the most disaster-prone countries in the world. Due to its geographic location and topography such as a long coastline, Viet Nam suffers from multi natural disasters including typhoons, tropical cyclones, tropical storms, floods, droughts, saline water intrusions, landslides and earth quakes. In recent years, in the course of a changing climate, natural disasters in Viet Nam have been increased significantly in terms of magnitude, frequency and volatility. Between 1990 and 2016, natural disasters claimed almost 12,000 lives and caused GDP losses of 1 to 1.5% per year [7, 8]. Therefore, natural disaster risk management including prevention and mitigation require appropriate approaches and methodologies to address these issues.

Single risk approaches deal with only one source of disaster and its relevant vulnerability of exposed elements. Single risk analysis allows to determine the individual risk arising from one particular hazard and process occurring in a specific geographic area during a given period of time, while it does not provide an integrated assessment of multiple risks triggered by different forces or the cascade effect of natural hazards [4]. However, natural disasters are usually closely linked to each other and cannot fully understand separately. For example: (i) A typhoon causes heavy rain, which triggers floods that can led to secondary landslide and debris flow [2]; (ii) An earthquake may result in a tsunami; (iii) High wind speeds during a tropical typhoon can cause a storm surge etc.

Consequently, multi-risk management should develop a more integrated approach. This is a new concept in risk management for Viet Nam. This paper will present a multi-risk approach that has been currently discussed internationally.

2. Multi-hazard and multi-risk concept

2.1. Multi-hazard concept

The Sendai Framework for Disaster Risk Reduction 2015-2030 highlighted that "Disaster risk reduction requires a multi-hazard approach". However, there is currently no clear definition of multi-hazard provided by the United Nations office for Disaster Risk Reduction (UNISDR). It is suggested that multi-hazard is an approach considering more than one hazard in a given place and the interrelations between these hazards, including their simultaneous or

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cumulative occurrence and their potential interactions [2]. The multi-hazard concept is related to the analysis of different relevant hazards, triggering and cascade effects threatening the same exposed elements with or without temporal concurrence. A multi-hazard risk assessment determines the probability whether or not different hazards, as a result of the same triggering event, occur at the same time or shortly following each other without chronological coincidence [2].

2.2. Multi-risk concept

Multi-risk concept addresses both a multi-hazard which may consider all the hazards and multi-vulnerability perspectives [3]. The multi-risk concept refers to a complex variety of risk combinations (i.e. various combinations of hazards and vulnerabilities). A multi-risk approach entails a multi hazard and a multi-vulnerability perspective. As mentioned in the above section, the multi-hazard concept may refer to: (i) the fact that different sources of hazard might threaten the same exposed elements (with or without temporal coincidence); or (ii) one hazardous event can trigger other hazardous events (cascade effects). On the other hand, the multi-vulnerability perspective may refer to: (i) a variety of exposed sensitive targets (e.g. population, infrastructure, cultural heritage, etc.) with possible different vulnerability degree against the various hazards; or (ii) time-dependent vulnerabilities, in which the vulnerability of a specific class of exposed elements may change with time as consequence of different factors (as, for example, the occurrence of other hazardous events, etc.) [1]. Multi-risk assessment is to determine the whole risk from several hazards, taking into account possible hazards and vulnerability interactions. In other words, to understand the multi-risk concept the most two important pillars must be taken into account are multi-hazard and multi-vulnerability in the target area (e.g. administrative unit, case study) [4].

A relationship between multi-hazard and multi-risk could be demonstrated in the Figure 1 below:

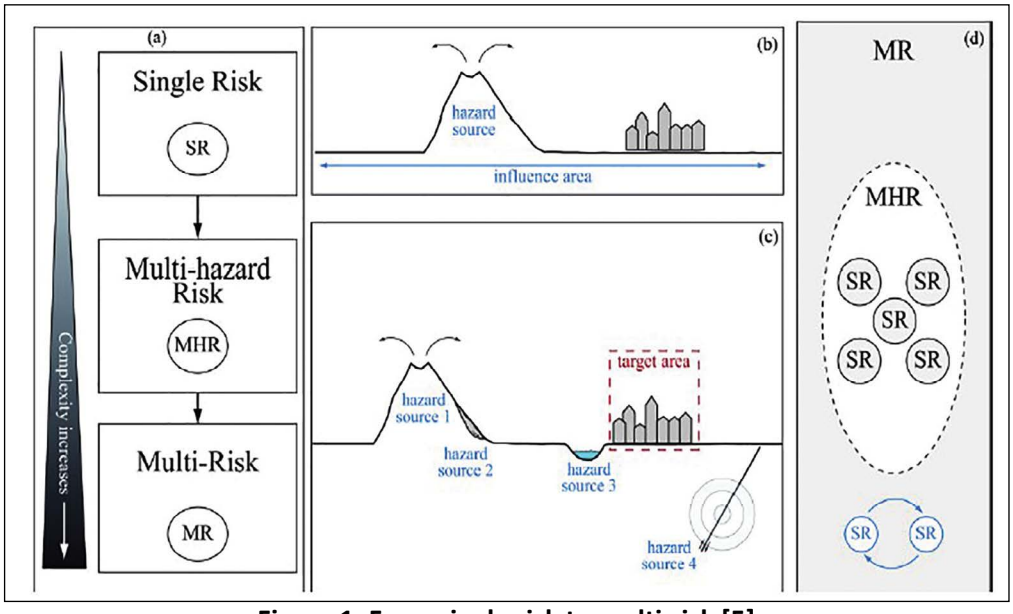


Figure 1. From single risk to multi-risk [5]

A single risk assessment considers only one source of hazard that could effect on a target area, multi-hazard risk assessment considers all interaction of risks caused by multi hazards and address all possible impacts on a target area.

3. Multi-risk assessment methodology

Multi-risk assessment methodology strongly depends on the purpose and scale of the study and the availability of the information and data. It may vary from a simple one such as using a

simple risk indexes for example potential losses and mortality to a very comprehensive one such as multi-risk models [4]. A new quantitative methodology for multi-risk assessment which is adopted from literature review is demonstrated in Figure 2 and will be introduced in this section.

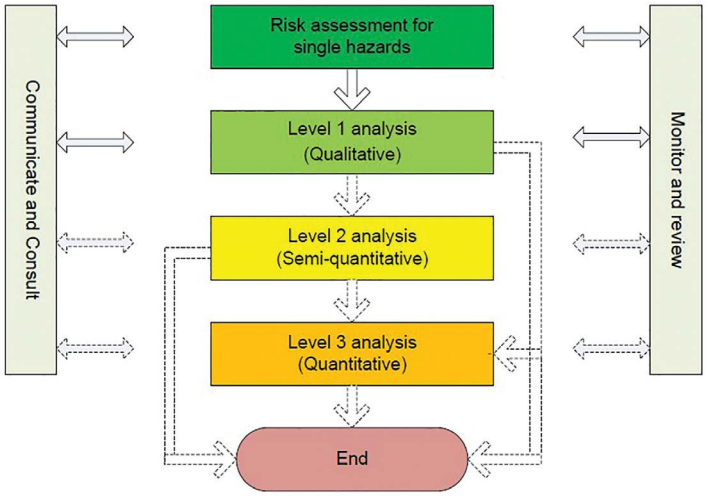


Figure 2. Multi-risk assessment framework [10]

The multi-risk assessment consists of following steps: (i) Risk assessment for single hazards; (ii) Level 1: Qualitative multi-risk analysis; (iii) Level 2: Semi-quantitative multi-risk analysis; and (iv) Level 3: Quantitative multi-risk analysis.

In the first step, single risk assessment will be carried out following the classical approach as demonstrated in Figure 3.

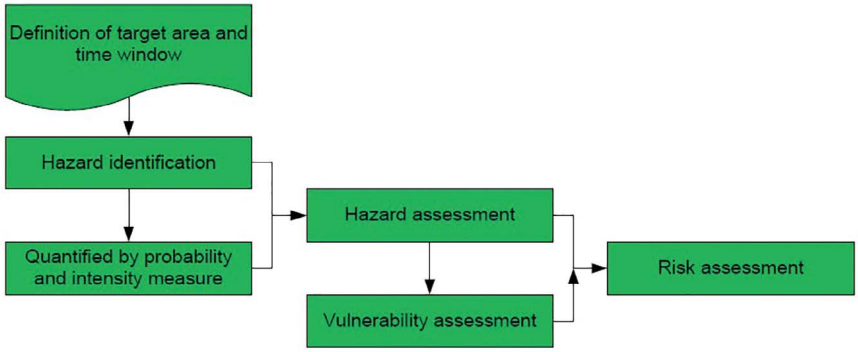


Figure 3. Multi-risk assessment framework [10, 13]

The single risk assessment comprises of the following stages:

- Definition of space/time assessment window (target area, time window) and the risk metric quantifying the expected losses (e.g., economic loss, fatalities, etc.). Depending on the purpose of the end-user, the space and time window is different. For example, if the purpose of using the multi-risk assessment results is to prioritize mitigation actions, a window will be a typical time frame that can facilitate the comparison e.g. one year; if the purpose is to take mitigation actions during an emergency, real-time forecast for each different risk scenario will be required, then the window may be days or weeks; if the purpose is for land-use planning, a longer time frame of typically decades or centuries will be possible [10, 11].

- Threat(s) identification (e.g., earthquake, volcano, landslide, meteorological events, etc.).

- Single hazard assessment (e.g., rate of occurrence, pathway, intensity measure, etc.).

- Assessment of the vulnerability of the elements at risk (receptors, e.g., people, buildings, environment, etc.); and

- Assessment of the consequences in terms of the chosen metric (e.g., loss of life, economic losses, environmental degradation, etc.).

In the level 1 analysis, a list of questions that help to decide whether or not to move to the level 2 analysis will be provided. Each question will be supplied with an exhaustive list of answers.

Depending on individual cases, the questions will provide multiple choice answers. In case that the level 1 results strongly suggest that a more detail analysis is required, we move to level 2. If cascading events are potentially a concern, we can directly move to level 3 analysis [10].

In the level 2, interactions between hazards and dynamic vulnerabilities are assessed by using a matrix approach as a semi-quantitative method.

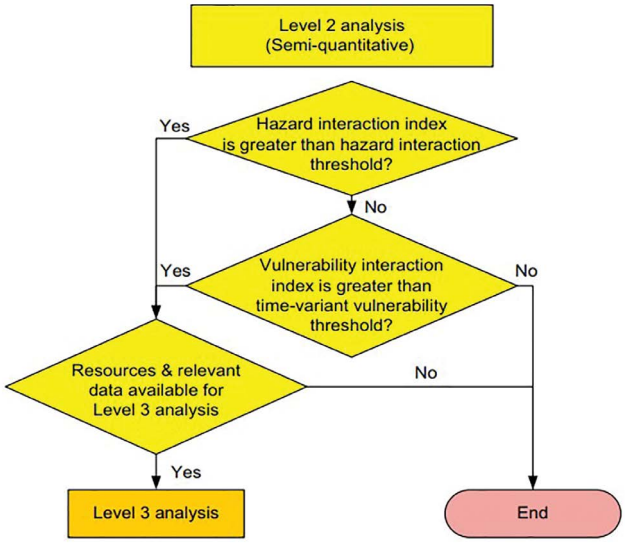


Figure 4. Level 2 multi-risk analysis framework [10, 13]

As illustrated in the Figure 4 above, in the level 2 we have to create the hazard interaction and vulnerability interaction indexes. In case that these indexes are greater than the correspondent thresholds and resources and required data are available, we will move to the level 3.

In the level 3, interactions among hazards and dynamic vulnerability are assessed quantitatively using the Bayesian network.

A conceptual Bayesian network as shown in Figure 5 is suggested to use for determining the whole risk from several threats. The network takes into account possible hazards and vulnerability interactions that include: (i) hazards that independent but threatening the same elements at risk with or without chronological coincidence; and (ii) hazards that depend on another one or caused by the same triggering event or hazard. Besides, the network consists of two main sub-networks for: (i) multi-hazard and (ii) time-dependent vulnerability [10, 11, 13].

4. Multi-risk benefits

A multi-risk approach creates results that consider both quantitative assessment of the different risks and the effects of their possible interactions. Therefore, it is found that a multi-risk approach could bring benefits to improve land use planning, response capacity as well as evidence for the identification of priorities for natural disaster mitigation actions [14].

Land use planning will be improved if the multi-risk approach is applied for risk assessment in general and natural disasters in particular. Currently, in Viet Nam maps with the areas vulnerable to flash floods, typhoons, storm-

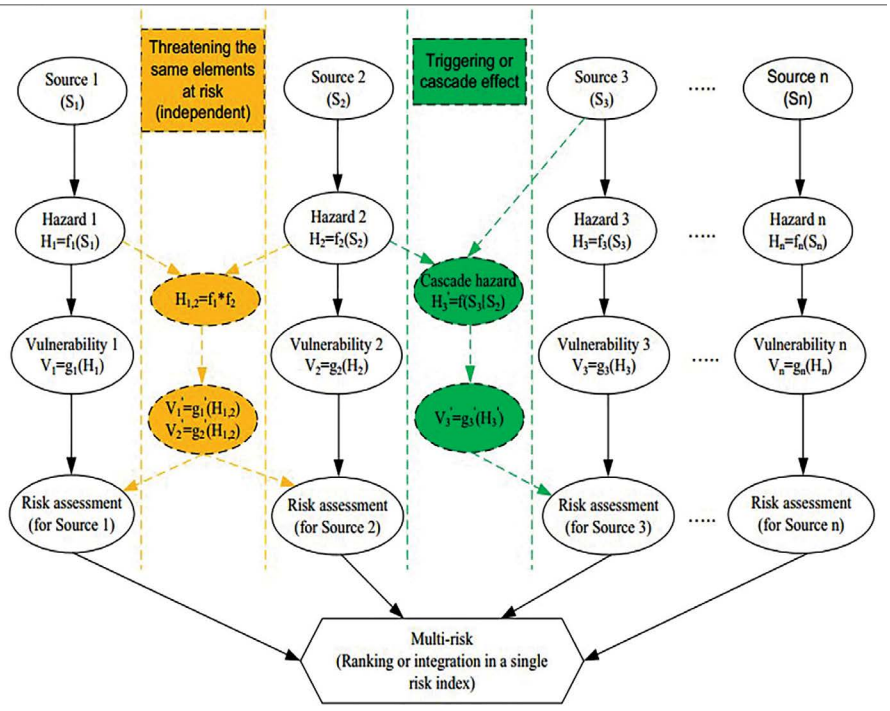


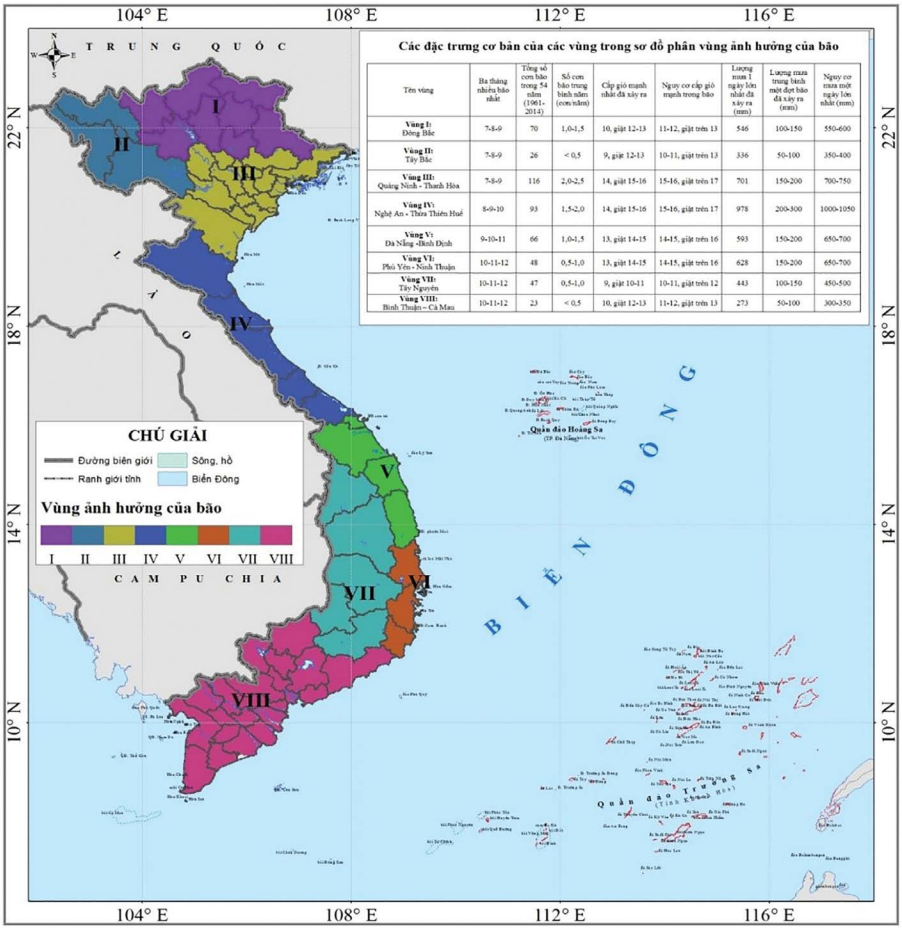
Figure 5. Bayesian network for quantitative multi-risk assessment [10, 13]

surges etc. are available but they are developed based on the single risk approach, focus on single disaster, neglecting other events occurring at the same time or shortly following. For example, the typhoon zoning as in Figure 6, which illustrates Viet Nam's exposure to tropical typhoons, heavy rain falls and strong winds [12].

The typhoon zoning is based on three criteria including: (i) Three consecutive peak months in the year; (ii) Annual frequency of storms; and (iii) Rain and strong wind caused by storms. Tropical storm and tropical depression data during 1961-2014 was used for the study. As a results, Viet Nam can be divided into 8 typhoon risk zones. The interaction at both hazard and vulnerability level were not taken into account in the study.

Another example is the natural hazard risks map of Viet Nam developed by the United Nations Office for the Coordination of Humanitarian Affairs. Areas exposed to earthquake and tropical storm are visualized based on the likelihoods of the specified intensities. Earthquake intensity zones indicate where there is a 20% probability that degrees of intensity shown on the map will be exceeded in 50 years; tropical storm intensity zones indicate where there is a 10% probability of a storm of this intensity striking in the next 10 years [6]. Possible risk of the landslides triggered by earthquake or heavy rains occurring with the tropical storm are not included in the map. Neglecting effects of interactions between hazards could lead to an underestimation of the risk. Therefore, a multi risk approach is highly desirable in land use planning. The adoption of a multi-risk approach could help to support the decisions on a restriction of buildings and other constructions as well as permitting or forbidding construction of new buildings, infrastructures, constructions and economic activities in the risky areas.

Response capacity would substantially benefit from applying a multi-risk approach. A development of multi-risk scenarios to facilitate a respond plan therefore is highly recommended. For instance, the interaction among typhoon, intense rainfall, flash flood and their consequences for infrastructures and the evacuation of injured people to hospitals



Các đặc trưng cơ bản của các vùng trong sơ đồ phân vùng ảnh hưởng của bão

Tên vùng	Ba tháng nhiều bão nhất	Tổng số cơn bão trong 54 năm (1961-2014)	Số cơn bão trung bình năm (cơn/năm)	Cấp gió mạnh nhất đã xảy ra	Nguy cơ cấp gió mạnh trong bão	Lượng mưa 1 ngày lớn nhất đã xảy ra (mm)	Lượng mưa trung bình một đợt bão đã xảy ra (mm)	Nguy cơ mưa một ngày lớn nhất (mm)
Vùng I: Đông Bắc	7-8-9	70	1,0-1,5	10, giật 12-13	11-12, giật trên 13	546	100-150	550-600
Vùng II: Tây Bắc	7-8-9	26	< 0,5	9, giật 12-13	10-11, giật trên 13	336	50-100	350-400
Vùng III: Quảng Ninh - Thanh Hóa	7-8-9	116	2,0-2,5	14, giật 15-16	15-16, giật trên 17	701	150-200	700-750
Vùng IV: Nghệ An - Thừa Thiên Huế	8-9-10	93	1,5-2,0	14, giật 15-16	15-16, giật trên 17	978	200-300	1000-1050
Vùng V: Đà Nẵng -Bình Định	9-10-11	66	1,0-1,5	13, giật 14-15	14-15, giật trên 16	593	150-200	650-700
Vùng VI: Phú Yên - Ninh Thuận	10-11-12	48	0,5-1,0	13, giật 14-15	14-15, giật trên 16	628	150-200	650-700
Vùng VII: Tây Nguyên	10-11-12	47	0,5-1,0	9, giật 10-11	10-11, giật trên 12	443	100-150	450-500
Vùng VIII: Bình Thuận - Cà Mau	10-11-12	23	< 0,5	10, giật 12-13	11-12, giật trên 13	273	50-100	300-350

Figure 6. Typhoon and typhoon risk zoning [9, 12]

or safety places will be addressed in multi-risk scenarios but not in a single disaster one [8]. In the Northern mountainous area in Viet Nam, intense rainfall triggered by a circulation of tropical storm then causing flash flood might cut off the main transportation infrastructure affecting the evacuation of the injured to hospitals. A respond plan adopting a multi-risk approach will provide more accurate time for evacuation of injured either considering or not considering the damage or interruption of transportation network and connectivity to the hospitals [4].

Prioritizing risk mitigation actions based on a single risk approach will neglect the hazards and vulnerability interactions. As a result, identification of priority risk reduction actions using a single risk approach may increase the vulnerability to other hazards. A multi-risk approach therefore is useful for decision makers in prioritizing the mitigation actions.

5. Challenges

Even the advantage of a multi-risk approach is evident, challenges for an effective implementation still remain and can be summarized as follows:

i. The challenge to compare risks caused by different hazards. Each type of risk has its own scale or unit of measurement for quantifying risk or damages, for example, loss ratio for floods and damage state for seismic [14].

ii. A limited understanding of the complex relations and interactions between hazards. This consequently can hamper a multi-risk assessment.

iii. Limited exchange between scientists

and end-users in terms of knowledge transfer particularly at local level [14].

iv. Different interests of end-users and researchers: Researchers are interested to improve knowledge and understanding of physical processes and models especially related to cascade effects; harmonizing terminology and databases; reduce uncertainty of assessments; integrate results of multi-risk assessments into existing emergency scenarios and conduct multi-vulnerability assessments [14]. Meanwhile end users would prioritize collecting evidence about lives and property saved; learning to use and integrate multi-risk assessment results in existing plans.

6. Conclusions

The multi-risk approach determines the whole risk from several relevant hazards, taking into account possible hazards and vulnerability relations and interactions. The new multi-hazard and multi-risk assessment method adopted from the literature was introduced, which consists of risk assessment for single hazards and a three level multi-risk assessment of qualitative, semi-quantitative and quantitative multi-risk analysis. Depending on the purpose and scale of the study and the available of required information and data, the application of the multi-risk assessment approach could be adjusted accordingly. It is found that a multi-risk approach could bring benefits to improve land use planning, response capacity as well as provide more evidences for the identification of priorities for natural disaster mitigation actions. However, this approach comprises challenges such as comparing the risks, limited understand of complex hazard relations and interactions, different views between end-users and researchers etc. Due to the fact that multi risk approaches will consider both hazards and vulnerability interactions, which is neglecting in the single risk approach, it is therefore highly recommended to introduce this approach to the disaster risk reduction community in Viet Nam.

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