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An information diffusion technique to assess integrated hazard risks

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ABSTRACT

An integrated risk is a scene in the future associated with some adverse incident caused by multiple hazards. An integrated probability risk is the expected value of disaster. Due to the difficulty of assessing an integrated probability risk with a small sample, weighting methods and copulas are employed to avoid this obstacle. To resolve the problem, in this paper, we develop the information diffusion technique to construct a joint probability distribution and a vulnerability surface. Then, an integrated risk can be directly assessed by using a small sample. A case of an integrated risk caused by flood and earthquake is given to show how the suggested technique is used to assess the integrated risk of annual property loss.

1. Introduction

Over the past twenty years, risk analysts have developed several new approaches for risk assessment. One of them is holistic approach that addresses the integration of multi-disciplines (Munns et al., 2003; Sekizawa and Tanabe, 2005) and the integrated databases (Fedra, 1998). It provides a systematic overview of the sources of risks or hazards. Then, a new terminology, integrated risk assessment, appears before there is no accordantly accepted definition about risk. When some models with several parameters are understood as capable of assessing integrated risks, the corresponding databases are maned as integrated risk information systems (McCready and Williams, 2013; Zhang et al., 2014).

The new terminology makes risk communication more difficult include (Huang, 2009):

- What does the result from integrated risk assessment mean compared to one from non-holistic approach? Is the integration more accuracy? or more near real risk?
- How to choose the right dimension for integrated risk assessment? Is the higher the dimension the better?

In the latest United Nations' framework for disaster risk reduction 2015–2030 (UNISDR, 2015), international financial institutions, such as the World Bank and regional development banks, are proposed to consider the priorities for providing financial support and loans for integrated disaster risk reduction. The goal of the framework is to prevent new and reduce existing disaster risk through the implementation of integrated and inclusive economic, structural, legal, social, health, cultural, educational, environmental, technological, political and institutional measures that prevent and reduce hazard exposure and vulnerability to disaster, increase preparedness for response and recovery, and thus strengthen resilience. In the framework, *integrated risk assessment* has been developed to be *integrated disaster risk reduction*. In a sense, the bureaucrats are more interested in how to get more resources to reduce disaster risk, rather than to know what is integrated risk caused by multiple hazards.

One of the reasons why many frameworks emphasize "integrated risk management" but underrate "integrated risk assessment" is that people still do not find a scientific approach to assess an integrated risk.

Considering a risk as a scene in the future associated with some adverse incident (Huang and Ruan, 2008) and classifying risks into four categories: pseudo risk, probability risk, fuzzy risk, and uncertain risk, in this paper, we define integrated risk and integrated probability risk. Aiming at the drawbacks of the weighting methods and the copulas for integrated risk assessment, we develop an information diffusion technique to assess integrated hazard risks. Then, a case is given to show how we use the suggested technique to assess the integrated risk of

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annual property loss.

2. Definition of integrated probability risk

For the meaning of risk, natural scientists, engineers, psychologists, sociologists, financial scholars can have a variety of different interpretations.

The formal science mainly explain risk based on probabilistic thinking and statistical calculations in digital forms. There are about 77% risk concepts defined by probability or possibility in scientific literatures. The risk in the media, such as newspapers and television, is more flexible and focused on perception and expression. Public risk is perceived by analogy with the environment of catastrophic events. To the public, risk is a result of psychological cognition. Different cultural backgrounds lead to different interpretations to risk, and different groups have their own ideal picture for risk response.

Even in the fields of scientific and technical applications, there might be no commonly accepted definition of risk. For example, based on concepts of systems theory and probability, Massimo (2014) defined risk as the probability of an adverse effect, related with all the possible anomalous states that produce damages of magnitude. With respect to the five criteria for a professional risk assessment context, Terje and Seth (2015) defined terrorism risk as the combination of the future occurrence of a threat-attack-consequence scenario and associated uncertainties, similar to that in recent years many suggestions have been put forward on how to define risk based on uncertainties instead of probabilities.

As we know, there are different ways of interpreting the concepts of likelihood, probability, and chance. What types of interpretations are applicable for risk? Any risk assessment depends on what information we have. In fact, in many cases, we are not able to model a risk. Before we define "integrated probability risk", we want to reiterate that we are dealing with how a term -here "risk"- is conceptualized, not how it is modelled.

It is interesting to note that the word "risk" has consistently been used in our society to express a negative construct. The "risk" related to positive results would be called "venture". In such a sense, the core of all definitions of risk is the same: risk exists when loss is possible and its financial impact is significant. This linguistic definition captures a property of risk that eludes definition in terms of mathematical formulas (Starr and Whipple, 1980). But, what on earth is risk, anyway? Is it injury, loss, probability, or probability of loss? No, it is not. They are, at most, features of risk. In the Chinese synthetic thinking (Zhang, 2004), Huang and Ruan (2008) suggested the following definition that answers the question.

Definition 1. A risk is a scene in the future associated with some adverse incident.

Scene means something seen by a viewer, or felt by individuals or various societal groups. It is a view or prospect. The "scene" is very different from "scenario" that has been introduced to study risk. A scene is the instantaneous/particular state that opens the possibility of each instantaneous/particular distinction, whereas a "scenario" is a continuous/general state that opens the possibility of any distinction.

Adverse is contrary to one's interests or welfare. It is harmful or unfavorable. The loss of life or injury, property damage, social and economic disruption or environmental degradation are adverse incidents.

A scene must be described with a system consisting of time, a site, and objects. The association would be measured with a metric space. And, an incident would be scaled with a magnitude.

Obviously, any past scene is not risk. The risk analysis is for the future.

A risk's characteristic depends on our knowledge for the risk. For example, to the flight insurance company, flying constitutes a known statistical risk. Meanwhile, to the passenger purchasing insurance at the airport, flying constitutes a perceived risk.

According to our knowledge for risks, they should be classified into four categories: pseudo risk, probability risk, fuzzy risk, and uncertain risk:

*A pseudo risk*is the scene in the future associated with a specified adverse incident that we are able to accurately predict it by using system models and currently available data. This kind of risk is without any suspense, which is not a real risk. For example, when a nuclear bomb explodes in a city, the destroyed area can be accurately predicted. The nuclear bomb is a pseudo risk.

A probability risk is the scene in the future associated with a specified adverse incident that we are able to statistically predict it by using probability models and a lot of data. Such risk is with random uncertainty related to that the corresponding events occur or not occur. For example, there are powerful probability models and a lot of data to study traffic incidents. To accident insurance, the traffic incident risk is a probability risk.

A fuzzy risk is the scene in the future associated with some specified adverse incident that we are able to approximately infer it by using fuzzy logic and incomplete information. A fuzzy risk is with fuzzy uncertainty related to that the corresponding events have fuzzy boundaries or the information we have for prediction is incomplete. For example, using the existing models and currently available data, we neither accurately forecast nor statistically predict any strong earthquake. However, we have some experience about earthquake and incomplete information to approximately recognize seismic activity. It is possible to approximately infer earthquake disaster by using fuzzy logic and incomplete information. A earthquake risk is a fuzzy risk.

An uncertain risk is the scene in the future associated with some adverse incident that it is impossible to predict or infer it by using any existing approach. This risk is with uncertainty not only related to the occurrence, boundary and incompleteness, but also interpretation for cause and result. For example, the actual impact of global warming on humankind is unclear. Most risks derived from global warming are uncertain risks.

Following the path of Definition 1, we give the definition of integrated risk:

Definition 2. An integrated risk is a scene in the future associated with some adverse incident caused by multiple hazards.

Hazard is source of potential harm (ISO Guide, 2009). Any biological, chemical, or physical agent and human activity with the potential to cause some adverse incident is a hazard. Flood, earthquake and terrorism are hazards. The magnitude of a hazard is a measurement that characterizes the relative size of the hazard, rather than the amount of harm that might result. Hazard is associated with the intrinsic ability of an agent or situation to cause adverse incident to a target. This ability may even never materialize if, for example, the targets are not exposed to the hazards or made resilient against the hazardous effect.

Multiple hazards involve more than one type of hazard. For example, wind, wave and earthquake are multiple hazards, which result to adversely influence the structural integrity and service life of