Spatially Enabled Risk Management: Models, Cases, Validation

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Abstract

Risk has a spatial nature. All events that result from risks have a link to a specific location or a factor in space. Understanding where on earth these risks are present allows for these risks to be mitigated, avoided, or managed. In order to manage the risks however accurate and timely spatial information about land and property is first needed. Historically, land administration systems have held this information, however, in recent years these systems have been superseded by other infrastructures that have the capability to capture and store information spatially. While these new systems offer the advantages of spatially enabled information, the authoritative information held within land administration systems is necessary for risk management. Land administration systems need to adapt to remain relevant in the 21st century, and coordination between these land administration systems and the new infrastructures is required to increase the ability of stakeholders to manage this information for risk management purposes. A framework targeted at this issue has been developed which proposes a spatially enabled approach for managing risks for governments, industry, citizens and wider society that takes into account the current information infrastructures (including land administration systems), the stakeholders, and the relevant risks that affect land and property. This framework results in the aggregation and dissemination of consistent information about risk to land and property to all stakeholders. So far the proposed framework has not been tested; however the recent floods in Queensland present an opportunity to apply the framework in the post event environment to determine whether the framework is appropriate within the Australian context.

KEYWORDS: Risk, Land administration, Risk Management
1. Introduction

In the last year there have been many natural disasters across the globe. These include large scale events that have caused devastation, disruption, and many deaths, as well as small scale events that create catastrophe and disorder at the local level. Examples of these events include the earthquakes that occurred in Christchurch, New Zealand, the worst of which struck in February 2011 killing 181 people (Bradley and Cubrinkovski, 2011); the 5th largest earthquake on earth in the last 50 years which hit Japan in March 2011 and the tsunami which came after it killing almost 16000 people and leaving a damage bill of US$235 billion (Tappin, 2011); the floods in the states of Queensland and Victoria, Australia in 2011 which resulted in 38 fatalities and a damage bill of A$32 billion; Hurricane Irene in the United States in August 2011 which resulted in 56 fatalities and US$10.1 billion in damage (Ingelsby, 2011; Orlove, 2011; Walsh, 2011); and other events such as droughts, volcanic eruptions, extreme weather, and landslides that affected a number of countries throughout the last year (Woodbridge, 2011).

In order to manage these disasters spatial information including land and property and risk information was utilized during these events. The ability to understand quickly who lives where, what parcels are located in the disaster area and what the zoning of the area is, is critical in risk management and disaster management. Land information, which is considered essential base data required for any risk management system for use in all phases of risk management, and in a broader sense disaster management needs to be easily accessible during these activities.

Currently, in Australia issues arise when implementing risk management and disaster management processes because of the current land information arrangements. The current sharing and aggregation of information inhibits access across organizations and government departments. Accurate and timely information about land and property is required for effective risk management and is critical for all stages of disaster management. An infrastructure to facilitate the coordination, sharing, aggregation and dissemination of consistent information on risk for risk management and disaster management is required.

This paper explores the information sharing issues related to infrastructures containing land, property and risk information which can be used for risk management. The aim is to assess a framework that enables risks on property and the information related to them to be analyzed. The framework can be used to understand failures and strengths of existing information infrastructures. The framework which will be analyzed consists of four main elements: the risk management stakeholders, the information infrastructures, the risk objects, and the risks. The first section of this paper discusses land administration and risk management and how these two processes are inherently related. The relationship and connection between risk management and disaster management is then discussed. The results of the research are then outlined detailing
the application of the framework to a case study, followed by discussion of the framework and conclusions.

2. Method and Approach

In order to develop the framework a number of steps were taken. First, a case study of the Australian context was undertaken. This involved investigation into stakeholders and information infrastructures (specifically land administration systems) currently active in Australia. This enabled a better understanding to be gained of the current land information environment and the provision of information for risk management. Based on this information the framework was developed featuring four key elements - risks, risk objects, information infrastructures, and risk management stakeholders. This framework was then applied to an active risk information environment to determine whether the situation of the land and property information and risk information is revealed through the application of the framework. This then lead to a discussion of the effectiveness and suitability of the framework for this function, and the benefits of this use. The application and assessment of the framework is discussed in this paper.

3. Overview of Current Theory

As outlined in the introduction, the aim of this paper is to assess a framework that enables risks on property and the information related to those risks to be analyzed. The framework introduced was developed to understand the information infrastructure environment of each situation. The outcome of the framework then determines whether spatial enablement of the information is possible. The framework will be assessed by applying each element of the framework to a risk management environment. The elements within the framework all originate from different areas of theory. An understanding of risk and land administration, the relationship between risk management and disaster management, spatial enablement and the risk framework itself is required to interpret the results. A short overview of each component is now given, highlighting the information relevant for understanding and interpreting the framework and the results.

3.1 Risk and Land Administration

The relationship between risk and land administration is one of significance which is highlighted in the framework. The connection originates from the early requirements of society to have a process for managing the complex rights, restrictions, and responsibilities (RRR) related to land and it use. As information about risk has emerged, the management of this information has been incorporated into land administration systems alongside RRR information. Since this integration however, new risks related to issues such as social, economic, and environmental risks inherent to the 21st century have emerged. Land administration systems, largely based on 19th
century models have found difficulty in adapting. Unlike traditional rights, restrictions and responsibilities which are well defined, these new risks are capable of remaining largely unknown, or unrecorded. As a result, often these 21st century risks are not taken into account, leading to inaccessibility to risk information by stakeholders.

Only recently has the importance of understanding and identifying these risks received attention. The recent disasters around the world have demonstrated a need for this issue to be addressed. Timely and accurate land, property, and risk information is needed for effective risk management, and land administration systems have the capability to provide this. The ability to understand the location and the nature of risk can determine the land and property which is threatened. Once this is identified, the information can be used to implement risk management treatments. A new role for land administration systems needs to be defined and articulated to enable collection and dissemination of risk information. The framework presented aims to demonstrate this. The processes of risk management help determine the information required: an understanding of risk management practices is first needed.

3.2 Risk Management and Disaster Management

The requirement of land, property and risk information for effective risk management and disaster management is well established. Risk management and disaster management are both processes developed to manage events related to land, and therefore require land, property and risk information in their decision making processes. Risk management is focused on understanding the risk and taking action to identify, analyze, evaluate, treat, monitor and review the risk in order to prevent the risk from becoming an event (Standards Australia, 2009). Disaster management, while similar, has a focus on the mitigation, preparedness, response, and recovery aspects of an event caused by risk. The requirement by both for risk information forms the relationship. Based on the information available risk management implements one of four options to treat the risk: avoidance of the risk, reduction of the risk, transference of the risk, or retention of the risk. This process is reflected in the framework. If the risk treatment fails or is ineffective and a large scale event occurs as a result, then disaster management processes are initiated (Figure 1).
If the risk management practices are effectively implemented though, then a risk event may never occur. The access to relevant risk information can substantially increase the effectiveness of risk management processes; particularly the risk treatment which relies on relevant information available to guide selection of the most appropriate treatment. The framework will demonstrate this: the ability for this critical information to be disseminated to the stakeholders is dependent on the coordination and sharing of the infrastructure environment. If the treatment of the risk is effective, which is determined by the information available for decision making, then the likelihood of a large scale disaster is reduced. Furthermore, if the risk information is available for disaster management in the earlier phases of mitigation and preparedness then valuable preparation and response can be commenced. The availability of this information is therefore critical. Reliable, accurate and timely information is required for these decisions to be made. An understanding of the information environment facilitated by the framework is first needed. Once the environment has been assessed solutions such as spatial enablement can be proposed to solve problems of information accessibility.

3.3 Spatial Enablement of Risk

Spatial enablement of information in recent years has been shown to solve problems associated with access, sharing and dissemination of information. The term ‘spatial enablement’ is used to represent the management of information in a spatial way, or the utilization of the spatial or geospatial components of the information (Rajabifard, 2010). The geospatial components of information indicate ‘where’ the information relates to, which is a powerful tool when seeking to understand the relationship between different datasets or data types. In applying this to risk, spatially enabling risk would result in the organization of all information relevant to risk in a spatial way to allow risk to be viewed from a perspective of ‘where’. For risk management
stakeholders, the ability to apply risks to a specific location or place would allow for a better understanding of the risk, and more effective risk management to result. The advantage to this type of perspective is often demonstrated by the risk management stakeholder business group. Insurance companies, as a business related risk management stakeholder are often most interested in the location of individual properties to determine the risks that affect that parcel of land and the property on that parcel. Using flood as an example, spatial enablement of risk information can be used to determine the risk of flood and subsidence. Using the geospatial nature of the information flood risk can be calculated using an intersection of property location, digital map information containing river location, and other available information such as meteorological information for the area (Hart and Dolbear, 2007). Applications of this type can bring great advantages to stakeholders in the risk management and disaster management field. This is because information such as this underpins informed decision making and community resilience. In order to implement spatial enablement. However, the nature and relationships between the infrastructures containing the information must first be understood.

3.4 Risk Framework (Australian Context)

The risk framework, shown below (Figure 2) was developed from preliminary research carried out in the Australian context. The framework was developed as a response to the recurring issue in Australia of no infrastructure existing to facilitate the coordination, sharing, aggregation, and dissemination of consistent information on risk. As a consequence, the ability of governments, industry, and citizens to manage risks to land and property has become limited. The case study involved a study into the arrangements of the current information infrastructures, particularly the land administration systems, as well an investigation into the risk management stakeholders. Research into problem cases identified as resulting from risks was also carried out. The results of this case study found that accurate and timely spatial information and land and property information is fundamental for effective risk management. Based on this, the risk framework (Figure 2) was developed. The framework gives an overarching view of the current arrangements of all stakeholders, information infrastructures and risks in Australia currently. Within the Australian context the problems associated with coordination, sharing, aggregation and dissemination of information, which are exacerbated by out of date land administration systems are highlighted in the framework. Further issues surrounding the presence of and relationships between stakeholders in the Australian context are also incorporated in the framework (Potts et al., 2011).

The framework consists of four different layers; each layer of the framework representing a different issue or element. The risks, risk objects, information infrastructures and stakeholders are all reflected in the framework by a different level. Explanation of each layer is detailed below.
- **Risks**
The risks affecting land and property that are present (within any context) are represented within the layer section of the framework. In this layer the information available describing the nature of each risk accompanies the risk. Examples of risks affecting land and property that can be applied to the framework are flooding, sea level rise, earthquake, fraud, storms, rights restrictions and responsibilities, asbestos, and pests. All of these risks, if they were to eventuate into a risk event would affect in some way land and property.

- **Risk object**
The risk object layer represents the recognition of a particular risk affecting land and property by the person who has a connection or relationship to that particular risk. If this relationship is realized then this is reflected in the framework by the presence of an envelope. If no relationship exists between the person and the risk then no risk object can be created. Similarly, if a relationship exists between a person and a risk, however no realization or recognition has occurred, then the risk object will not be created.

- **Information Infrastructures**
The information infrastructures layer represents all infrastructures that store information about land and property. This includes information about rights, restrictions, responsibilities and risks. This information is critical to all stakeholders, as decisions regarding the tenure, value, use, and development of land are made based on the information available. If the infrastructures holding this information are not
coordinated and restrict accessibility to this information, then the use of this information is reduced, potentially leading to poor decisions regarding the management of land.

- **Stakeholders**

The stakeholder layer in the framework represents all the parties which have an interest in the management of risks to land and property. Within this layer the stakeholders gather the information required to implement effective risk management. In order to obtain the information from the lower layers of the framework, robust infrastructure must exist. If this strong infrastructure exists then the information from all levels of the framework should be disseminated to all the relevant stakeholders, however if the infrastructures are not adequate or well structured, then the information may be prevented from reaching the stakeholders. Embedded within the risk management stakeholders layer is the risk treatment cycle. The cycle is represented by the rotation figure in the framework. The information about risk received from the lower layers is used to inform decisions regarding the treatment of risks. Within this layer the implementation of risk treatments is reflected by each different stakeholder transferring the risk (via an arrow) to other stakeholders. If the information required to make these risk management and risk treatment decisions is not available then the most appropriate decision may not be made by the stakeholders, which may result in problems related to risks in the future.

As each level of the framework interacts the current risk information environment is revealed. If the risk information cannot be disseminated from the bottom of the diagram to the risk management stakeholders then the framework will identify where the problems are occurring. Once the problems are diagnosed then action to resolve the issues can be set in motion. Figure 3 illustrates an operational model, and an effective environment.
Within this proposed framework (Figure 3) the information infrastructure layer reflects a coordinated environment, where arrangements have been established to allow for sharing of information. The information at the lower levels can be disseminated easily for all risk management stakeholders to access. In this framework the land administration system acts as the central infrastructure to all of the other information infrastructures. The ‘overarching’ infrastructure is depicted as a land administration system due to earlier discussions branding land administration as key to effective risk management, and as most suited to the role. Land administration systems already adequately manage the collection, recording and dissemination of information regarding land tenure, value, use, and development. Therefore, the incorporation of risk information is not outside the scope of their role.
If realized then a framework modelled from Figure 3 above would create within the Australian context a land administration system which could provide aggregated land, property and risk information from all jurisdictions. Access to this system would facilitate the implementation of effective risk management, disaster management, and a spatially enabled approach to risks for all stakeholders.

4. Results and Discussion – an Assessment of the Framework

Accurate and timely spatial information and land and property risk information is fundamental for effective risk management and disaster management as demonstrated above. In the context of risk management, the coordination, sharing, aggregation and dissemination of consistent information on risk is necessary. The ability of government, industry and citizens to manage risk to land and property is dependent on this information. The risk framework discussed above is now applied within the context of Australia and the Queensland floods disaster.

Analysis of the Queensland floods situation revealed the stakeholders involved and the information infrastructures used during this disaster. The different stakeholders involved and their role in the disaster as well as the information infrastructures involved are detailed. The arrangements and interactions that took place are discussed within the context of the overarching framework. The application of this context to the framework will provide some real data to input into the framework and validate whether the arrangement of the framework is reflective of the Australian environment. The details of the particular case are discussed below.

In December 2010 unprecedented summer rain following a decade of drought caused a series of floods in Australia, primarily in the state of Queensland. The floods that ensued soon forced the evacuation of thousands of people from towns and cities, including the state capital Brisbane. In a short timeframe at least 70 towns and over 200 000 people had been affected. The damage from the flood, initially estimated at A$1 billion, totalled A$30 billion by the time the water had subsided and the flood passed. As a result of these floods, three quarters of the state of Queensland was declared a disaster zone.
4.2 Application of the Framework to the Queensland Flood Disaster

From the investigation carried out into the use of spatial, land and property, and risk information in the Queensland flood event, the details regarding the risk stakeholders and information infrastructures were revealed. This information was then applied to the framework detailed above to produce Figure 5.
Figure 5. The risk management framework – applied to the Queensland Flood Disaster

As shown in the framework above a number of stakeholders and information infrastructures were identified. An overview of the stakeholder and the information infrastructures, and their role in the event is now given:

- **Risk management stakeholders**
  In the context of the Queensland disasters, three main groups of risk management stakeholders were identified: government, industry, and citizens. Citizens as a whole were the most affected by the disaster with a large number revealed to have implemented little or no risk management treatments for flooding. The involvement of industry was related primarily to insurance companies who had accepted the risk in the treatment form of transference from both governments and citizens. The government in this event were largely involved at both the commonwealth and state level with the coordination of many departments across the state and Australia. Each stakeholder and the role they had in the event are detailed below.

- **Information Infrastructures**
  In the Queensland flood event many information infrastructures were utilized. The major infrastructures and the information they provided are described below.
o Bureau of Meteorology (BOM): provided weather information and warnings based on potential rainfall, storms, cyclones, and other weather related phenomenon. This information is made available free to the public through their website, and was made available during the time of the disaster, in all phases.

o Department of Environment and Resource Management (DERM): stores all the land administration information for the state including surveying infrastructure data, cadastral data, and topographic information. Other information held by DERM includes aerial imagery of the flood extent, town before and after maps, catalogue and key maps, international charter products, basin inundation maps, disaster relief arrangement maps, GIS modelling and analysis, and radar satellite imagery.

o Queensland Reconstruction Authority: hosts a website active only for the short term. The website generated queries related to flood lines, eligibility for funding maps, aerial imagery and interactive before and after maps (supplied by DERM).

o Geoscience Australia: provided basic flood information, detailed reports on floods in Australia, flood capabilities, and research into floods in Australia.

o Brisbane City Council: provided through their website information on flooded suburbs, suburbs predicted to flood, flood level maps, flood flag maps, and flood wise property reports (which includes the data: January 2011 river flood levels; estimated flood levels; source of flooding including river, creek, defined overland flow or storm tide; minimum and maximum ground levels; and minimum habitable floor level for building and development) (Planning and Building, 2011).

What the framework above reflects is the stakeholder and information environment for the Queensland flood event. What is shown is that there are a number of infrastructures providing information to the majority of stakeholders. Due to the scale of the disaster much of the information was made available free to all stakeholders. It is important to note that within the framework above, the interactions, coordination and accessibilities of the infrastructures between each other is not reflected. Based on the results, the information which is made available to all stakeholders by the infrastructures (Bureau of Meteorology (BOM), Queensland Reconstruction Authority, and Geoscience Australia) would share the information to all other information infrastructures. For the other two infrastructures, which have limited accessibility for industry and citizens, it can be assumed that the limitations would be extended to all other non-government bodies, including the information infrastructures. The information with limited access within the infrastructures, shown in the framework as the Department of Environment and Resource Management (DERM) and the Brisbane...
City Council, is limited as a result of its content (certain land administration data – held by DERM), limited by its value (not freely available), or limited in it use.

A strength of the framework is that is depicts the relevant information in an easily understood way which can help facilitate further analysis of the environment. One way this could be used, based on the information shown in the framework (Figure 5), is to assess the development stages of the information infrastructure. Kok and van Loenen (2005) present an assessment framework which is able to determine maturity stages of spatial data infrastructures. The framework has a series of stages (stand alone/initiation, exchange/standardization, intermediary, and network) which reflect the maturity level and a series of aspects (vision, leadership, communication, self-organizing ability, and financial sustainability) which can be used to determine the maturity level. Application of the maturity framework to Figure 5 enables the maturity of the infrastructures within the environment describes to be established. This information can then be used to determine whether the operational model (Figure 3) and spatial enablement of the environment will be possible.

Due to the flexibility of the model, the application of the information specific to the event and specifically to the infrastructure environment is simplified. The framework, with its many possible applications has assisted in revealing the information sharing environment of the Queensland flood event. The role of each stakeholder and the access that is available to each stakeholder has been shown. Moreover, the available infrastructures and the information contained within each have been reflected in the framework. Based on this the framework can be considered effective for detailing the information environment. The benefits of the framework are that it reveals the interactions between each stakeholder and the information infrastructure. This quickly reflects whether coordination, sharing and dissemination of the information is occurring. From the above example as demonstrated by the framework, further coordination is required between infrastructures to enable dissemination of the information held in the infrastructures to stakeholders. Coordination from all of the above infrastructures (which includes the land administration system) incorporated with arrangements for sharing could allow for a spatially enabled approach to be implemented.

4.3 Moving Forward – a Spatially Enabled Approach

Spatially enabling information about risks to land and property is the future. Arranging information in this way enables citizens, governments, and industry to easily understand risks and how risks affect them. Permitting access to this information as a result leads to better risk management and better disaster management.

The arrangement of infrastructures in Queensland leads to a simplified ‘spatially enabled system’. However without integration between the infrastructures, spatial enablement will not be realized. Moreover, the resulting ‘system’ exists only as a post-disaster development, with data collected largely after the event. While this is useful
and sought after during the recovery phase, the real value of the system is never realized.

A system put in place at the discovery of a large risk affecting many interests, would allow for the population to gain access to this information at times of land purchase, development, deciding on insurance plans and would result in a more informed and prepared community. If citizens are able to understand ‘where’ risks exist, and the places the risk might affect, then the management of the risk can take place more effectively. Allowing access to this information enables stakeholders to make intelligent well-informed risk management and disaster management choices. Figure 6 below demonstrates this idea, where all risk information is spatially enabled, and accessible by stakeholders.

![Spatially enabled risk information](image)

**Figure 6.** Spatially enabled risk information

Based on this approach a stakeholder would be able to enter into the system a real address or parcel of interest and search for all risks that affect that parcel within the system. If the system was spatially enabled then more complex queries could also be incorporated into the search allowing for specific types of risk, or risks shown only for a certain period of time. If the idea is extended even further then the possibility of including crowd sourced data into the database and then restricting the search to only authoritative or crowd sourced would be possible also.

Firstly, however, the upfront problems within Australia of implementing an infrastructure that facilitates the coordination, sharing, aggregation, and dissemination of consistent land and property information (including risk) must be overcome.

### 5. Conclusions and Future Direction

Accurate and timely spatial information and land and property risk information is fundamental for effective risk management and disaster management. In the context
of a disaster the coordination, sharing, aggregation and dissemination of consistent information on risk is necessary. The ability of government, industry and citizens to manage risk to land and property is dependent on this information.

In the application of the developed model to reveal the spatial information environment of a post-disaster Queensland, the relevant stakeholders, information custodians and providers have been revealed and the accessibility of the information shown. What is required now is further investigation into the risk management stakeholders, and the identified information infrastructures to determine their capabilities and potential for spatial enablement.

In summary, the framework presented demonstrates the value of spatial enablement to government, industry and citizens, showing the possibilities for the future if administrative arrangement problems can be resolved to allow for coordination, sharing, aggregation and dissemination of consistent information on risk.

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