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Integrating spatial planning and flood risk management: A new conceptual framework for the spatially integrated policy infrastructure

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ABSTRACT

Flooding is a widely occurring natural hazard that noticeably damages property, people, and the environment. In the context of climate change, the integration of spatial planning with flood-risk management has gained prominence as an approach to mitigating the risks of flooding. The absence of easy access to integrated and high-quality information, and the technologies and tools to use information are among the factors that impede this integration. Limited research has been conducted to develop a framework and to investigate the role of information and technologies in this integration. This study draws primarily on the European experiences and literature and identifies three dimensions of the integration of spatial planning with flood-risk management: territorial, policy, and institutional. To facilitate integration and in accord with these three dimensions, a Spatially Integrated Policy Infrastructure (SIPI) is conceptualised that encompasses data and information, decision support and analysis tools, and access tools and protocols. This study presents the connections between SIPI elements and integration dimensions, which is important for a better understanding of roles of geographic information and technologies in integration. The conceptual framework of SIPI will govern further development and evaluation of SIPI.

1. Introduction and problem description

Flooding is a common natural hazard that noticeably damages properties, human lives, and the environment. Flooding contributed to about 39.26% of worldwide natural disasters and caused USD 397.3 billion worth damage between 2000 and 2014 (EM-DAT, 2015). Flooding can be caused by excessive or concentrated precipitation, rapid or heavy snowmelt, storm surge, or embankment failure (White, 2010). In addition, other disaster events or circumstances may trigger flooding under specific conditions, such as earthquake-triggered landslides (Xu, Fan, Huang, & Westen, 2009) or tsunamis (Jankaew et al., 2008). When they consider climate change, scientists predict an intensified global water circulation with respect to magnitude and frequency of extreme precipitation events (Dankers & Feyen, 2008), which would manifest as a global increase in the frequency and severity of floods and drought (Hirabayashi, Kanae, Emori, Oki, & Kimoto, 2008) and increases in uncertainty regarding coastal flooding from rising sea levels (Nicholls, 2004).

At the same time that the risk of devastating floods grows, the demands for development continue and in some regions even increase. Population growth, particularly in urban areas, is increasing the likelihood of the overuse of land in flood-prone areas (Larsen, 2009). For example, in England, about 5.2 million properties, accounting for about one-sixth of all properties, are located in areas at risk of flooding (Department of Environment Food and Rural Affairs & Environmental Agency, 2011). Adamson and Cussen (2003) pointed out that, in Ireland, the growing population and continual development in flood-prone areas are likely to raise the flood risk. These two areas are typical of the growing pressure that continual development is exerting on spatial planning and flood-risk management.

Actions that address flood risk in areas under continual development include: (1) strengthening existing or constructing new protective structures, such as embankments (Neuvel & Van Den Brink, 2009); (2) increasing natural retention and storage capacities, such as the "Room for the River" projects in Netherlands (Butler & Pidgeon, 2011); (3) expanding insurance for flood damage and improving flood resilience (Dawson et al., 2011); and (4) upgrading forecasting, early warning, and preparedness systems (Al-Sabhan, Mulligan, & Blackburn, 2003; Pathak & Eastaff, 2014). These measures tend to be implemented in isolation from each other and occasionally encounter local opposition such as in the case of increasing natural retention and storage capacities in the Netherlands (Neuvel & Van Der Knaap, 2010). Integration of different measures and cooperation among various types of interventions are required to ensure their effectiveness (Veraart et al., 2010; Wilson, 2006). The term *integration* is defined as

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an act or process to combine, unite, bring together, or incorporate parts into a whole so that they work together (Hornby, 2010).

This study proposes that geographic information (GI) and geographic technologies (GT) can support such integration specifically of spatial planning and flood-risk management by capitalizing on their utility in various planning and management activities, including land-use administration (Shariff, Hamzah, Mahmud, Yusof, & Ali, 2011), coastal risk management (Jeanson, Dolique, & Anthony, 2014; Zanuttigh et al., 2014), cultural heritages (McKeague, Corns, & Shaw, 2012), and organizations (Dessers et al., 2012). Also, GI is a useful tool to assess flood risks and mapping (Porter & Demeritt, 2012), prepare for flood disasters (Chang, Tseng, & Chen, 2007), evaluate development scenarios (Macharis & Crompvoets, 2014), and combine urban flood management with urban planning (Price & Vojinovic, 2008). A testament to the utility of GT and shared databases is the creation of spatial information infrastructures in more than 100 countries (De Man, 2007; Masser, 2005) and their application across various disciplines, such as economics, demographics, geo-history, sociology, and e-governance (Sridharan, 2015; Van Manen, Scholten, & Van De Velde, 2009). Similarly, accessible, appropriate, and comprehensive GI and GT support vital communication, cooperation, and coordination necessary to the integration of spatial planning with flood-risk management (Roche, Sureau, & Caron, 2003; Roose & Kull, 2012).

The first objective of this study is to identify the requirements for integrating spatial planning with flood-risk management and to conceptualise and identify the dimensions of 'integration', primarily in the European, and particularly in the Irish, context and framework. Then, the study aims to develop, as its second objective, a conceptual framework of an infrastructure, termed Spatially Integrated Policy Infrastructure (SIPI), which allows for sharing GI and decision support and analysis tools between spatial planning and flood-risk management.

2. Flood-risk management and spatial planning

2.1. Flood mitigation measures in flood-prone areas

In the field of flood governance, the recognition of 'flood-risk management' is increasing and replacing traditional methods of 'flood defence', 'flood protection', or, more recently, 'flood management' (Butler & Pidgeon, 2011; Galloway, 2008; Sayers, Hall, & Meadowcroft, 2002). The flood-risk management approach emphasises the importance of controlling the hazard and lessening social vulnerability to its effects, whereas the traditional methods merely seek to control the hazard (Galloway, 2008). Flood-risk management, therefore, deals with the outcomes, which are the combinations of the probabilities of an event occurring and the impacts associated with that event. Sayers et al. (2002) defined risk-based flood management as a whole-system approach that assesses and compares the structural and non-structural ways to pursue the optimal ameliorating effects.

Structural measures to mitigate flood hazards often imply the construction and maintenance of levees, dams, mobile elements such as sand bags and mobile flood walls, removing obstacles from flood plains, restricting construction, and controlling the design of the physical spaces in flood-prone areas (Kryžanowski, Brilly, Rusjan, & Schnabl, 2014; Neuvel & Van Den Brink, 2009). The new flood-risk management approach adapts the principles supporting structural measures from diverting water away from our area to making room for water. Examples of the new structural measures are two programmes: Make Space for Water in the UK (Butler & Pidgeon, 2011) and Room for the River in the Netherlands (Neuvel & Van Den Brink, 2009).

Non-structural measures apply knowledge, practices, agreements, and/or policies to mitigate flood hazards. For example, Dawson et al. (2011) summarized the three non-structural measures of land-use (spatial) planning, insurance, and improvements to resistance to the effects of flooding. Neuvel and Van den Brink (2009) argued that spatial planning is a promising instrument to reduce flood impacts. In another example, Butler and Pidgeon (2011) proposed that a desirable approach is to deliver governmental flood mitigation objectives with non-coercive guidance of citizen and organizational conduct.

Another vein of research on non-structural measures recognizes Information and Communication Technologies (ICT) as tools that aid flood mitigation because they support the formulation of appropriate risk-mitigation approaches that combine structural with non-structural measures. For example, Decision Support Systems and Geographic Information Systems inform decision makers with reliable information, such as hazard forecasts. These systems are communication tools that involve an array of stakeholders as well as educational tools that raise public awareness (Price & Vojinovic, 2008).

Thus, flood-risk management strategies no longer primarily rely on structural measures and, instead, combine structural with non-structural measures. Evidence from practice suggests that a combined approach is the most effective way to combat flood risk because it takes advantage of the individual strengths of the two approaches (Hall, Sayers, Walkden, & Panzeri, 2006; Hayes, 2004). The advantage of structural measures is that they aim to provide a physical protection to flood-prone areas, although their weaknesses are significant economic and environmental costs (Hall et al., 2006) and occasional failures due to inadequate planning and construction (Sills, Vroman, Wahl, & Schwanz, 2008). However, non-structural measures are economically efficient and environmentally friendly, but their effectiveness is sensitive to socioeconomic context and governmental behaviours (Dawson et al., 2011).

2.2. Spatial planning: potential for flood-risk management

Planning is a rational and systematic process of guiding public and private actions and influencing the future by identifying and analysing alternatives and outcomes (Davidoff & Reiner, 1962; Steiner, Butler, & American Planning Association, 2012). Spatial planning is a type of planning concerned with arranging physical space and guiding future activities within it according to suitability and other accepted principles (Kidd, 2007; Larsson, 2006). Planners work on the spatial distribution of types of land use, such as transportation, residential, institutional, commercial, and industrial. Thus, spatial planning is usually referred to as land-use planning or urban/regional planning (Davidoff & Reiner, 1962).

In flood-prone areas, spatial planning is expected to contribute to flood mitigation (Howe & White, 2004; White & Richards, 2007) mainly because it can influence the incidence of flooding and its consequential damage by regulating the locations of activities, types of land use, scales of development, and designs of physical structures (Neuvel & Van Der Knaap, 2010; White & Richards, 2007). For example, the approach applied in Germany and the 'Making Room for the River' approach in the Netherlands emphasises regulating land use to prevent the incidence of flooding by preventing incursions on water-retaining areas of the flood plain (Krieger, 2013; Van Heezik, 2008). Conversely, the 'Making Space for Water' project in England emphasises the consequences side of the risk equation and the impossibility of complete flood prevention. The French spatial planning system is similar to the British model in its goals (i.e., exposure reduction rather than probability prevention), but it is relatively less effective (Beucher, 2009; Pottier, Penning-Rowsell, Tunstall, & Hubert, 2005).

Furthermore, other characteristics distinguish spatial planning in flood-risk management. For example, spatial planning can influence crucial factors at multiple spatial scales, from local-level plans to national or even international strategic plans (White & Richards, 2007; Wynn, 2005). Planning authorities are generally given more power than flood-risk agencies regarding land-use planning and development control in the flood-prone areas (White & Richards, 2007).

Although the potential of spatial planning in flood mitigation is recognised, several practical obstacles impede its integration into mitigation plans. In the UK context, Howe and White (2004) found