European Journal of Operational Research 251 (2016) 1029–1042

Contents lists available at ScienceDirect

European Journal of Operational Research

journal homepage: www.elsevier.com/locate/ejor

Interfaces with Other Disciplines

Agent-based computational modelling of social risk responses

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ARTICLE INFO

Article history:
Received 8 September 2014
Accepted 16 December 2015
Available online 23 December 2015

Keywords:
OR in societal problem analysis
Multiagent systems
Risk management

ABSTRACT

A characteristic aspect of risks in a complex, modern society is the nature and degree of the public response – sometimes significantly at variance with objective assessments of risk. A large part of the risk management task involves anticipating, explaining and reacting to this response. One of the main approaches we have for analysing the emergent public response, the social amplification of risk framework, has been the subject of little modelling. The purpose of this paper is to explore how social risk amplification can be represented and simulated. The importance of heterogeneity among risk perceivers, and the role of their social networks in shaping risk perceptions, makes it natural to take an agent-based approach. We look in particular at how to model some central aspects of many risk events: the way actors come to observe other actors more than external events in forming their risk perceptions; the way in which behaviour both follows risk perception and shapes it; and the way risk communications are fashioned in the light of responses to previous communications. We show how such aspects can be represented by availability cascades, but also how this creates further problems of how to represent the contrasting effects of informational and reputational elements, and the differentiation of private and public risk beliefs. Simulation of the resulting model shows how certain qualitative aspects of risk response time series found empirically – such as endogenously-produced peaks in risk concern – can be explained by this model.

1. Introduction

Managing the major risks experienced by a complex society – the risks of epidemic disease, climate change, food and drug contamination, the catastrophic failure of hazardous installations and so on – almost invariably involves managing public anxiety or public complacency as well as containing physical threat (Leiss, 2001). Not only are public perceptions pivotal in shaping public behaviour, and therefore exposure to the threat, but characteristically produce further risks. A recent analysis of the Fukushima nuclear power accident argued that:

> 'There was a rushed evacuation response to the accident … this evacuation actually led to more premature deaths, by a factor of at least ten, than it gave protection from radiation … The reaction was driven to a large extent by the public's sense of the scale of the hazard, which was not close to the reality of the risk … The studies of many previous accidents have come to a similar conclusion. Even for an accident as significant as Chernobyl it can be shown that the vast majority of the public health impacts are caused by mental stress relating to the fear of the event, rather than the effects caused by the amount of ionising radiation released...' (Cahart, 2013).

Thus public risk perceptions have often mattered more than objective assessments of risk, as seen in such celebrated cases as Love Canal, Alar and TWA 800 in the US (Kuran & Sunstein, 1999) and the Sudan 1 and Hatfield scandals in the UK (Busby & Alcock, 2008). It has become essential for organisational decision making to be founded on an understanding of societal risk responses, and for decision makers to theorise, however loosely, about how such responses arise.

The formation of these responses has a number of defining features. Most if not all of the public, and many managers, have no first-hand technical knowledge of the risk and rely on other social actors – including the media – of whom they are often sceptical if not cynical (Petts & Niemeyer, 2004). These actors in turn generally have a clear appreciation of this cynicism and anticipate it in the way they act and communicate (Busby & Duckett, 2012). The responses of a wide range of actors, including risk managers and the general public, typically influence the character of the threat and the risk bearers' exposure to it (Busby & Onggo, 2012). Responses are shaped by the way in which such groups inter-communicate within their social networks (Scherer & Cho, 2003). And the responses become events in their own right, to which social actors further respond (Kasperson et al., 1988).

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http://dx.doi.org/10.1016/j.ejor.2015.12.034
0377-2217/

Credible models of social risk responses need to incorporate such features. They need to endogenise observation, representing the way in which actors, despite their heterogeneity, often base their own responses in part on how they see peers or neighbours responding, not on direct experience or knowledge of the risk. They need to endogenise behaviour, representing the way actors adapt their behaviour to changing observations of a risk, thus changing their exposure and the risk itself, and thereby also changing subsequent perceptions of this risk. And they need to endogenise risk communication, representing the way actors base their risk perceptions on the communications of others whose apparent biases they correct for, but who in turn can anticipate such corrections in formulating their communications. Yet, as Rahmandad and Sterman (2008) point out, we typically model disease outbreaks as though contact rates were fixed, ignoring the way people change their behaviour as prevalence grows. And, as Busby and Onggo (2013) argue, we have typically ignored the way in which actors communicating about risk anticipate each other's biases, and even anticipate the anticipation of each other's biases. The aims of this paper are to explore how an agent based model can incorporate these characteristics, to explore what we can say about model validity, and to explore what quantities need to be known in order to parameterise such a model.

Our main theoretical foundation for doing this is the 'social amplification of risk framework' (Kasperson et al., 1988). The development of this framework followed earlier lines of work on individual risk perception (broadly starting with Fischhoff, Slovic, Lichtenstein, Read, & Combs, 1978), and on cultural risk selection (broadly starting with Douglas & Wildavsky, 1982). It has probably been the only mainstream attempt to try to synthesise this prior work, to deal with social emergence and to capture the importance of social communication in explaining risk behaviour (Renn, 1991). Much empirical work on risk responses in various domains, ranging from nuclear waste to terrorism, has been done under the heading of social risk amplification. But, as we attempt to show in the next section, the social amplification of risk remains largely un-modelled and under-specified. This means that various empirical findings that have emerged over the last 25 years remain ambiguous, and the implications for decision makers unclear.

There are several observations in the literature that motivate the use of agent models in particular. First, in the social risk amplification framework, risk has been seen as first and foremost a matter of social communication (Luhmann, 1993; Renn, 1991). The essence of the social amplification framework is that some risk event is experienced by a very small number of social actors, and communication about the risk then spreads through a system of heterogeneous actors seen as 'amplification stations' (Kasperson et al., 1988). Second, empirical work – notably Scherer and Cho's (2003) article and more recently Muter, Gore, and Riley (2013) in the risk literature, but also work such as that of Kohler, Behrman, and Watkins (2007) in the demography literature – has shown how important social interactions are in the development of risk perceptions. An individual's risk beliefs tend to be strongly correlated to those of others with close social connections, and individuals' reports tend to acknowledge how those others have influenced them. Third, non-linearities are central to how risk amplification arises. Some of the few prior attempts at modelling risk amplification (Burns & Slovic, 2007; Busby & Onggo, 2012) have shown how complex are the feedback loops between the perceptions, behaviours and communications among the different actors in a risk issue, making analytical modelling infeasible. Fourth, the actors respond heterogeneously. Much of the later work on individual risk perception (for example Langford et al., 1999; Marris, Langford, Saunderson, & O'Riordan, 1997) has stressed individual differences. And individual risk sensitivity (Sjöberg, 2000) has been an important explanatory variable for differences in individual risk perception. All of these strongly point to agent-based modelling as the appropriate medium for modelling social risk amplification.

In this article we first review the literature on social risk amplification in an attempt to draw out the main theoretical and empirical contributions that have arisen since it was first proposed. We then describe the construction of a model, justifying its content by reference to the literature. We base this model on Kuran and Sunstein's (1999) account of availability cascades, and show how we can model central aspects of such cascades – particularly the ideas that individuals have both espoused and expressed risk beliefs, that they have both informational and reputational reasons for responding to beliefs common in a social discourse, and that there are availability 'entrepreneurs' who knowingly exploit the possibility of such cascades. We present typical results of simulating the model, and we discuss issues of model validity by reference to empirical work on time series of risk perceptions and concerns in the literature. We conclude with a discussion of the study's implications and limitations.

2. Literature review

The social amplification of risk framework (SARF) was first proposed by Kasperson et al. (1988) as a way of explaining the often apparently mistaken responses of populations to risks in modern society. The original framework was intended to show 'that risk events interact with psychological, social, and cultural processes in ways that can heighten or attenuate public perceptions of risk and related risk behaviours'. And it stressed the 'ripple' effects through which risk perceptions led people to behave in ways that created secondary impacts beyond the harmful effects of the original risk. Generally, it has been applied to study excessively high rather than excessively low risk perceptions, although the need for symmetry has long been recognised (Rip, 1988).

It has been used in a wide variety of contexts, including wildfire risk (Brenkert-Smith, Dickinson, Champ, & Flores, 2013), the siting of potentially hazardous installations (Binder, Scheufele, Brossard, & Gunther, 2011), environmental risk from tunneling (Chung, 2011), disease outbreaks (Busby & Duckett, 2012; Lewis & Tyshenko, 2009; Raude, Fischler, Lukasiewicz, Setbon, & Flahault, 2004), genetically modified foods (Frewer, Miles, & Marsh, 2002), the dismantling of hazardous installations (Bakir, 2005), chemical accidents (de Souza Porto & de Freitas, 1996), climate change (Renn, 2011), nuclear weapons facility accidents (Metz, 1996), inoculation risks (Petts & Niemeyer, 2004) and general levels of violence in society (Hill, 2001). In such situations, the framework has provided a way of describing how discrepancies between the risk beliefs of different groups, and between experts and lay communities especially, can arise.

The methods used in such studies have been wide-ranging. Some are qualitative, analyzing rich verbal accounts among the public from interviews (for example Masuda & Garvin, 2006) and discussion groups (Busby & Duckett, 2012; Petts & Niemeyer, 2004), or analysing media content (Bakir, 2005). These have revealed how the worldview of individuals affects their tendency to amplify risk, and how particular actors use the media to convey their view of the risk and influence opinion. Quantitative studies have occasionally used economic measures of risk responses, such as property values and business activity (Metz, 1996), and there has been some content analysis of the news media (Lewis & Tyshenko, 2009). But most quantitative work has been based on public surveys (for example Binder et al., 2011, Frewer et al., 2002; Brenkert-Smith et al., 2013). These are generally directed at the public, but some involve surveying the specific groups involved in a particular risk issue, such as physicians dealing with a potential disease outbreak (Raude et al., 2004). Surveys have generally been analysed by regressing risk perceptions, and sometimes