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Invited Review

Review of recent developments in OR/MS research in disaster operations management

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ABSTRACT

Potential consequences of disasters involve overwhelming economic losses, large affected populations and serious environmental damages. Given these devastating effects, there is an increasing interest in developing measures in order to diminish the possible impact of disasters, which gave rise to the field of disaster operations management (DOM). In this paper we review recent OR/MS research in DOM. Our work is a continuation of a previous review from Altay and Green (2006). Our purpose is to evaluate how OR/MS research in DOM has evolved in the last years and to what extent the gaps identified by Altay and Green (2006) have been covered. Our findings show no drastic changes or developments in the field of OR/MS in DOM since the publication of Altay and Green (2006). Additionally to our comparative analysis, we present an original evaluation about the most common assumptions in recent OR/MS literature in DOM. Based on our findings we provide future research directions in order to make improvements in the areas where lack of research is detected.

1. Introduction

According to records from the International Federation of Red Cross and Red Crescent Societies (IFRC), 7184 disasters took place between 2000 and 2009. Some of the most memorable of these events include the World Trade Center attacks in 2001, the tsunami in Indonesia in 2004, hurricane Katrina in 2005, and the Haiti earthquake in 2010. The IFRC estimates 986,691 millions of dollars in economic damage from these events, 1,105,352 casualties, and 2,550,272,267 of affected people (IFRC, 2010). Moreover, the insurance firm Munich Re reported that in 2010 natural disaster caused more than 295,000 deaths and more than $130 billion in economic damage (Our Amazing Planet, 2010). These overwhelming statistics show the need of developing strategies in order to reduce the impact of disasters for humankind.

Disaster operations, as defined by Altay and Green (2006), represent the set of activities performed before, during and after a disaster in order to diminish its impact. Many of these activities are intrinsically related to traditional OR/MS applications. For instance, location of shelters in preparation for evacuations may be addressed as a special case of location analysis; evacuation itself may be better analyzed through the application of transportation techniques; statistics and probabilistic models may be applied to deal with uncertainties related to disaster locations and demands; and in general, diverse OR/MS techniques may be applied to the different stages of disaster operations management (DOM) in order to provide a scientific approach in the process of decision making.

DOM has become a highly active field in OR/MS. The amount of papers in DOM published in OR/MS main stream journals during 1990s was more than twice of the amount published during the previous decade (Altay and Green, 2006). Such popularity of DOM in OR/MS has not decreased in subsequent years. On the contrary, a great amount of research has been published after the occurrence of the World Trade Center attack in 2001 and the 2004 tsunami in the Indian Ocean (Natarajarathinam et al., 2009). As evidence of the popularity of OR/MS in DOM, it is noted that the INFORMS 2010 conference held 16 tracks—accounting for a total of 61 presentations—related to DOM. The significance of this number of tracks dedicated to DM is evident when one compares it to tracks devoted o traditional research areas. As an example, 19 tracks were dedicated to quality related issues, which is a much more traditional field in OR/MS. Another sign of continued activity are the two special issues produced by the journal Socio-Economic Planning Sciences on Disaster Planning and Logistics. Both of these special issues appeared in 2012.

In this paper, we present a literature survey of recent OR/MS research in DOM. Our study covers the timeframe 2005–2010 and comprises of 155 papers. The inspiration for our work came from Altay and Green (2006) who offered a survey of OR/MS papers applied to DOM, published between 1980 and 2004. Their study pro-

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vides a general picture of the state of the art of OR/MS research in DOM. In their paper, the authors offer a detailed descriptive analysis of the papers in their survey, based on a classification scheme. Altay and Green (2006) revealed several important gaps in the observed literature and suggested valuable future research directions. We started the effort towards this paper six years since the period covered by Altay and Green (2006). We believe that the popularity of OR/MS in DOM in recent years warrants the need to evaluate if the tendencies identified by Altay and Green (2006) still persist, and even more relevant, to what extent the gaps identified by them has been addressed in the recent literature. The key question here is: are OR/MS researchers developing studies to cope identified gaps in DOM? Or on the contrary, are they ignoring such gaps when defining their research subjects?

Furthermore, we identify new gaps, tendencies, challenges and opportunities that are relevant for OR/MS, in order to derive thoughts about the most appropriate future research directions. We believe that by having a clearer and unified picture of the past and present of OR/MS research in DOM, as well as of its most crucial needs, OR researchers will be able to conduct related future research in a more effective way. This is especially relevant for a field like DOM due to the magnitude and nature of implications due to disasters.

Our analysis is performed by classifying papers following the classification scheme proposed by Altay and Green (2006), which is based on six dimensions: authors' affiliation, disaster type, solution methodology, operational stage, research contribution, and a final dimension based on a previous classification framework designed by Denizel et al. (2003). In addition to performing this six dimensional classification, we present an analysis about the most common assumptions in the field. To our knowledge, such an analysis of assumptions has not been performed before.

Since the year 2006, there have been some recent review papers in DOM; however, none of them can be considered as an update of the work given by Altay and Green (2006). Lettieri et al. (2009) developed a systematic review of disaster management that covers the period between 1980 and 2006, in which the authors define the state of the art of disaster management in general (and not particularly from the point of view of OR/MS). Wright et al. (2006) offer a survey on OR research in disaster management whose scope is dedicated to issues related to the Department of Homeland Security (DHS). There is not any specific statement in the paper about the period surveyed, but the references go from 1969 to 2005. Natarajarathinam et al. (2009) offer a literature review on papers published before 2008 about supply chain management (SCM) in times of crisis. The scope of Natarajarathinam et al. (2009) is not limited to crisis caused by the occurrence of disaster; it also includes financial and managerial crises. Finally, in Simpson and Hancock (2009), the authors cover the period 1965–2007 with the purpose of analyzing the evolution of OR in emergency management. This latter paper includes every type of emergencies, and not only those related to disasters. Comparing our work to the papers discussed above, we conclude that our main contribution is the evaluation of the evolution of OR/MS in DOM, by contrasting the reports from Altay and Green (2006) with our findings from the recent literature. The value of this contribution is that it measures recent progress of the field and highlight future needs.

The remainder of the paper is organized as follows: Section 2 discusses the search process and the boundaries for our survey. Section 3 presents an analysis of the papers in our collection based on the classification framework proposed in Altay and Green (2006). Section 4 offers future research directions and discusses the evolution of recent OR/MS research in DOM in the context of the gaps proposed in Altay and Green (2006). Section 5 presents our remarks and conclusions. The list of the references for all the papers gathered in our survey is available in the online complementary section for this paper.

2. Search methodology and scope of the study

In this section we discuss the search methodology and the boundaries of our survey. Our study focuses on published journal papers that exhibit the application of OR/MS in DOM. The databases used in our search are: *ISI's Web of Science, Business Source Complete, Compendex Engineering Village 2, Scirus, Emerald, Jstor, Scitation* and *Google Scholar.* The keyword *disaster* was searched in any place of the documents corresponding to journal articles published in English. Conferences proceedings, book chapters, books, working papers, and theses were not included in our study. We limited the period of our search to 2005–2010, which corresponds to the subsequent years to the period considered in Altay and Green (2006). The exploration was limited to engineering and business management topics. Some databases provided more tools to define the boundaries of our search, as in the case of *ISI's Web of Science* for which we were able to choose the topic of *disaster management* to perform the exploration.

The scope of our survey, as that of Altay and Green (2006) is OR/MS research in DOM. Therefore, the boundaries of our survey depend on the definitions of OR/MS and of DOM. In Altay and Green (2006) OR/MS is defined as a scientific approach to support decision making in complex systems. On the other hand, DOM is defined as the set of activities performed before, during and after a disaster in order to reduce its impact on the economy and human casualties, and returning the community to its normal functioning. Note that the definition of DOM requires us to establish the definition of disaster. According to the IFRC a disaster is "(...) a sudden, calamitous event that seriously disrupts the functioning of a community or society and causes human, material, and economic or environmental losses that exceed the community's or society's ability to cope using its own resources" (from http://www.ifrc.org/en/what-we-do/disaster-management/about-disasters/what-is-a-disaster/). We agree with this definition except for the use of the term "sudden" which can be understood as if only rapid-onset events can be classified as disasters, leaving aside known disasters such as epidemics, droughts and complex humanitarian emergencies. Instead we would prefer the term "shocking" to reflect the emotional component that disasters cause in society.

We complement the definition of disaster from the IFRC with thoughts from Altay and Green (2006) and with a definition offered by Salkowe and Chakraborty (2009). In Altay and Green (2006) the term "emergency response" is used to refer to catastrophic events, while excluding daily emergencies and situations that may be typically managed by a governmental agency through standard procedures. On the other hand, Salkowe and Chakraborty (2009) offer a definition of disaster from a governmental perspective, according to which a disaster declaration request occurs when the local or state government indicates that it has been overwhelmed by the effects of the disasters. Based on the definitions presented above, we define a disaster as "a shocking event that seriously disrupt the functioning of a community or society, by causing human, material, economic or environmental damage that cannot be handled by local agencies through standard procedures". This definition of disaster established the scope of our survey.

Having defined the boundaries of our survey, we proceeded to verify which of the papers identified fit into our scope. Our screening process can be divided into two levels: initially there were results that could be rapidly eliminated by inspecting the titles of the papers and their abstracts, since they provided clear evidence that such papers were not related to OR/MS and/or DOM. We used a second and final filter for inspecting papers that passed the first