OPERATIONS RERSEARCH-AN EFFECTIVE TOOL FOR STRATEGIC DISASTER MANAGEMENT PLANNING: THEORITICAL STUDY

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ABSTRACT
Disasters are the unfortunate events which needs special attention and efficient decision making to handle. Operations research is the field of scientific study that deals with effective decisions making and its management. Disasters are defined as the occurrence of a sudden or major misfortune, which disrupts the basic fabric, and normal functioning of a society. These events results from natural processes or other geological processes that have disastrous consequences on human well-being. Disasters are the events whose consequences exceed the capability of public protection and its systems to provide necessary responses in a timely manner. Operations research principles and techniques can be applied in public protection as Public protection is of utmost importance. Operations research that address various Disasters are important tools for planning effective responses to these disasters. Main objective of this paper is to address various disasters and to analyse the operations research tools that can help in effectively manage and response to disasters that disturb the normal functioning of the public. This paper also highlights the operations research approaches that can be used for public protection. Decisions about procurement transport, stockpiling, and maintenance of needed supplies are essential in the emergency management. Major issues at all levels of disaster response decision making, including long-range strategic planning, tactical response planning, and real-time operational planning and support are still unresolved. Therefore operations research can provide useful techniques for effective decision making and management in terms of disasters.

Key-Words: Operations Research, Emergency Management, Decision Making, Natural disasters, quantitative methods etc.

INTRODUCTION

Disasters are the ultimate test of time. In 2011, Centre for Research on the Epidemiology of Disasters (CRED), has recorded 332 disasters from natural hazards in 101 countries, that caused more than 30 770 deaths, and affecting over 244 million people (CRED, 2012). Disasters are severe events that are characterised by a sudden onset and affect a large fraction of the population in the area they appear. They can be natural such as earthquakes, tsunamis, floods, tornadoes, hurricanes and pandemics, or anthropogenic or man-made such as industrial accidents, traffic accidents, terrorist attacks. Specific feature of disasters is to be unpredictable and have a substantial adverse impact on health and property. Therefore, the development of methodologies for the evaluation of the public protection as well as decision making process for management of disasters is of major importance and has drawn the attention of several scientific disciplines especially operations research, the science of decision management.

Operation research (OR) is a scientific area where methods coming, predominantly, from mathematics, computer sciences and economics are employed in decision making processes. The tools developed by OR are used to assess the consequences of alternative decisions of long or short term nature such as strategic planning or operational decisions. Therefore, OR can be seen as the science of resource allocation in an optimal way. In association with disaster management and the

impact on public protection OR can contribute in the evaluation of operational strategies and actions associated with large scale natural disasters. OR can help in providing guidance on the optimal choice of these strategies and the actions that needs to be taken into consideration.

Within the framework of public protection, operations research is the study of the employment and optimal use of various approaches and decision making techniques for effective management of disasters. In the context of disaster management OR can provide solutions that can be crucial for optimal humanitarian assistance deployment such as supply chains, resource allocation etc. OR can help to provide tools and methods which can be used in disaster epidemiology in the management of emergency public protection programmes. The ultimate goal is to achieve better managed plans & programmes scientifically analyse techniques that can contribute to information sharing and effective decision making.

In this paper operations research approaches are reviewed that have been used at large scale disasters and its management with respect to public protection. Also this paper describes the benefits from the use of operation research tools to the humanitarian assistance arena based on selected examples.

METHODOLOGY ADOPTED FOR SEARCH AND SELECTION OF DATA

The disaster database comprising a period of more than 12 years published from 1st January 2000 to 31st May 2012 was performed for studies. Keeping in view the goal of the work, the search was restricted to certain operations research techniques as mathematical programming and modelling, probability and statistics, simulation, decision theory, optimisation. My focus of work was on natural disasters at large scale like earthquakes, tsunamis, floods, tornadoes, hurricanes etc. Using the terms emergency/disaster response or preparedness for natural disasters 161 articles were screened. 76 potentially relevant articles were retrieved for full text review.

OPERATIONS RESEARCH APPROACHES USED IN NATURAL DISASTER MANAGEMENT.

Large number of methods has been used in disaster management e.g. mathematical programming, heuristic methods, probability theory and statistics, and simulations. In order to analyse situation, data and improve performance of the supply chain, quantitative methods were used in humanitarian logistics. Altay and Green (2006) did a literature survey on the operations research work that has already been done in the disaster operations area. Based on that review, mathematical programming, and heuristic methods were used most often and Probability theory, simulations and inferential statistics were used second most frequently. In specific cases Decision theory and queuing theory were also used. An analysis of the use of operations research models in transportation of relief goods was presented in an article by De la Torre et al. (2011).

OPERATIONS RESEARCH APPROACHES RELATED TO NATURAL DISASTERS-A PUBLIC PROTECTION PERSPECTIVE

Varying approaches and models are being adopted for decision making about responses to disasters. These models address a variety of decision makers like first responders, hospital officials, planners, public protection officials etc, locals, and use a range of modelling methodologies. Regarding natural disasters the modelling approaches have been rather limited. Decisions about procurement transport, stockpiling, and maintenance of needed supplies, mass vaccination, and treatment are essential in case of disaster management.

NATURAL DISASTERS

Natural disasters can be classified in four major categories.

1. Meteorological Disasters: Storms, hurricanes, cyclones, tornadoes, typhoons, heat waves
2. Hydrological Disasters: Floods, avalanches
3. Climatological Disasters: Droughts, wildfires
4. Geophysical Disasters: Earthquakes, tsunamis, landslides, volcanic eruptions

Meteorological disasters

a) Heat waves

Heat waves belong to one of the major public protection threats since they can affect an enormous number of people. Typical example is the heat wave of the year 2003 in Europe that caused an estimated 70 000 additional deaths in 12 European countries (Robine et al., 2008). According to IPCC, 2012 Projections based on mathematical modelling approaches indicated that heat waves are going to occur more often). Early warning mechanisms are introduced through heat-health action plans introduced by many countries as a consequence of the 2003 heat wave in Europe. They include monitoring of meteorological forecasts and public protection activities to reduce or prevent heat related illness and death.

b) Storms and hurricanes

The health effects of storms and hurricanes include injuries, and mental health issues as well as stress of critical infrastructure facilities such as hospitals, schools, fire services, emergency rooms. Storm and hurricane forecasting tools can contribute to preparedness and save lives.

Hydrological disasters

Floods

Floods can lead to disastrous conditions with consequences for public protection, and damages to personal property. Loss of life and destruction of critical public infrastructure with substantial economic losses is usually the result. With respect to public protection increasing cases of drowning and injuries are expected after flood incidences. Mental health effects associated with emergency situations during flood incidences have been documented in the literature (IASC, 2007). There is increasing risk of water- and vector-borne infectious diseases. Disruption of health systems, facilities and services when they are needed most and another consequence is the damage of essential infrastructure such as food and water supplies. The Intergovernmental Panel on Climate Change (IPCC) published a report on disasters with projections of the increase in the number of people exposed to floods. They calculated that all over the Globe there will be an increase in the number of people exposed to floods. One area of employment of quantitative methods in flood management is the management of microbial contaminations. In large-scale floods in urban environments pathogens can be brought into homes and buildings and contaminate water and food supplies with substantial public protection risks. The risk of microbial contamination under different environmental conditions can be assessed with mathematical modelling approaches as well as epidemiological approaches (Taylor, et al. 2011, Cann et al., 2012).

Geophysical disasters

a) Landslides

Landslides have been least investigated as far as geophysical disasters are concerned. In a study by Das et al. (2011) the authors assessed the vulnerability of elements at risk to landslides such as buildings, persons inside buildings, and traffic, with a stochastic approach. By defining vulnerability as a stochastic consequence of a landslide that quantifies the potential loss in space, time and hence expressed as a probability, they consider a set of objects vulnerable to landslide, e.g., buildings, persons, vehicles at risk. Their vulnerability depends on the location and time with respect to landslide. Statistical approaches such as logistic regression were used to assess vulnerability of static elements such as buildings whereas Poisson modelling was used to assess vulnerability of dynamic elements such as persons in a building or vehicles on the road. They concluded that vulnerability of elements at risk to landslide varies greatly in space and time. This variation was attributed to the dynamic nature of the elements at risk.

b) Earthquakes

Response of service providers to large-scale disasters such as earthquakes with respect to casualty treatment includes logistics issues such as the movement of casualties from the stricken area to hospitals. Fawcett at al. (2000) present a simulation model wherein various operations like numbers of locations of casualties rescued alive, the scale of pre-hospital care, the post-earthquake hospital capacity and the transport system were taken into consideration. The model predicts the number of casualties that die during that movement and waiting time before treatment. Thus the mathematical model can be used for planning and training. It is well documented that mortality rates increase with proximity to the epicentre of an earthquake and with increasing earthquake magnitude. Seismic intensity has been identified as the primary cause of mortality and injury during earthquakes, mediated by building damage (Aleskerov et al. 2005). Studies about the role of socio-demographic factors on earthquake vulnerability are rare (Badal et al. 2005). In a combined concept using a house hold survey and observational damage assessment, social and environmental determinants for injury and displacement were investigated by Milch et al. (20120) and statistical modelling approaches were used to explore to what extend seismic intensity, distance to rapture, living conditions and educational attainment affect displacement and injury rates (Milch et al. 2010). The results showed that about 55% of the variability in displacement rates could be explained by the above factors. Living conditions were a strong predictor of injury and displacement, indicating a strong association between risk and socio-economic factors.

c) Tsunamis

From the public protection point of view, there has been poor documentation of the health consequences of tsunamis. In order to describe the distribution of mortality among internally displaced persons during two and a half months after the Indian Ocean tsunami 2004 Nishikiori et al. (2006) conducted a cross-sectional household survey with retrospective cohort analysis of mortality in affected areas. Their findings confirm the plausible notion that most casualties occurred on the day of the tsunami and up to three days after. Starting one week after the disaster and for the two and a half months of the duration of the study no deaths were reported. In a second report and using the same epidemiological approach Nishikiori et al. (2006a) tried to identify the risk factors of the mortality during the same tsunami and therefore the vulnerable population groups. The distribution of mortality in 13 evacuation camps for internally displaced persons and associated risk factors were analysed using logistic regression modelling and generalized estimating equations methods. There was a higher mortality among females and children and elderly compared with adults. Other factors such as being indoors at the time of the tsunami, the house distraction level, and fishing as an occupation were all statistically significant associated with increased mortality.

DISCUSSION

Disasters are always strongly associated with substantial casualties that demand for effective and efficient public protection responses. Quantitative methods including disaster response modelling have become integral part of decision making processes in disaster management. They can help in answering questions such as how should the logistical systems for response to various types of public protection disasters be organised? What is the most efficient and effective way to rapidly dispense services, medications or aid to large numbers of individuals? Despite progress in recent years there have been major unresolved issues at all levels of disaster response decision making that include long-range strategic planning, tactical planning and response, and real-time operational planning & support.

Disaster response models should be designed to address real-world disaster response problems and should be made available for use by those planners who can understand how to use these models

and interpret the results. By this way a judicious balance can be maintained between computational complexity and usability. New public protection disaster response modelling approaches should evaluate relevant disaster response outcomes that go beyond those considered in traditional cost-effectiveness analysis and explore critical uncertainties. There are major unresolved issues at all levels of decision making process including long-range strategic planning, tactical response planning, and real-time operational planning and support. Operations research can provide useful techniques for decision management at all these levels. Finally, they should be presented in sufficient detail that their results can be interpreted in a reasonable way. Most of the time planners customise the approaches and models according to their own needs but these approaches need to be used for on-going decision making by these planners. Major emphasis should be given to the design and reporting of such models keeping in views that most of the planners lack necessary expertise. Developing a Modelling response to disasters is highly heterogeneous in terms of methodologies, outcomes evaluated, and quality of presentation. Operations research and other methodologies are essential in effectively disaster preparedness planning and response. These techniques and approaches can help better in terms of protecting public from adverse effects of natural disasters and to have an efficient preparedness planning and response.

CONCLUSIONS

Disaster response quantitative methods such as operations research addressing public protection are important tools for planning effective responses to disasters. Several modelling methods have been applied to analyse public protection and disaster response decisions. These include statistical analyses, Markov models, epidemiological models, supply chain management models, facility location models, and routing and network flow techniques.

The models and approach adopted for public protection differs from other models as they are designed to support on-going planning scenarios. These range from long-term strategic decisions to immediate operational decisions.

Impact of disasters on public and their protections systems have been modelled more intensively since decisions about procurement, transport, stockpiling, and maintenance of needed supplies, prophylaxis, aid and treatment are essential in case of disasters and their effective management.

Operations research methods used in disaster management can help the decision makers involved in public protection on the important issues like magnitude of the event, operational response capabilities, supply chain capacity, and robustness etc. operation research techniques can help to measure effectiveness of decisions and guide the decision making process.

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