ANALYSIS OF FACTORS FOR LAST MILE RELIEF DISTRIBUTION PERFORMANCE IN INDIAN CONTEXT

PRIYANKA ROY

Doctor of Philosophy

ASTON UNIVERSITY

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Thesis Summary

A natural disaster repetitively occurs all over the world from the decades and in every instance, the relief operation planning is necessary for the affected population. One of the key factors of effective relief operation planning is logistics. The objective of emergency logistics is to organise and manage the competent movement of relief from the original point to the destination point to meet the urgent needs of the affected community. Last mile relief distribution (LMRD) is the ultimate phase of emergency logistics. It refers to the supply of relief items from local distribution centres to the disaster-affected community. There are many challenges like oversupply, resource limitations, lack of field operation planning, those increase the challenges during final relief distribution. This thesis has adopted a case study approach to address the gap in the literature of relief distribution. The practical factors, which affect the LMRD performance, mainly in Indian earthquake context, has identified in this thesis. Finally, the influence of those factors in the LMRD performance has been analysed in this research project.

The performance metrics are identified by the analysis of the interviews with the practitioners and also this thesis present a generic framework about the behavioural factors which affect the LMRD performance metrics. This thesis specifically based on Indian earthquake context, therefore the conducted interviews with the Indian government and with South Asian NGOs have identified coordination, as the major factor, which affects the final relief distribution in India.

An Agent-Based Model (ABM) is developed based on the Indian LMRD system to investigate the impact of coordination on effectiveness. Here effectiveness defined as the speed and accuracy with which aid is delivered to the affected people. The ABM was tested under various scenario analyses to investigate the effectiveness of coordination. This thesis used two case studies: Gujarat (2001) and Sikkim (2011) earthquakes to validate the theoretical results.

It is established from the model results, that there is a statistically significant impact on the performance of the model when coordination is incorporated as a factor for the multi-agent system. Also, the results show the inventory efficiency and cost effectiveness for integrating coordination for LMRD system in India. The developed approach exhibited the importance of the micro-level issues like coordination for the relief distribution decision making process.

Keywords: Last Mile Relief Distribution, Agent-Based Model, Behavioural Operations Research, Emergency logistics

DEDICATION

This thesis is dedicated to my parents, my son and my husband for being my inspiration and motivation in every step of this journey

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Contents

List of Abbreviations

ABM	Agent Based Modelling
ACMSIGSIM	Association for Computing Machinery Special Interest Group on Simulation and Modelling
AHP	Analytic Hierarchy Process
ARMV	Accident Relief Medical Vans
APMOD	Applied Mathematical Optimisation and Modelling
BOM	Behavioural Operation Management
CASA	Church's Authority for Social Action
CERF	Central Emergency Relief Fund
CSR	Corporate Social Responsibility
DDMA	District Disaster Management Authority
DES	Discrete Event Simulation
DOM	Disaster Operation Management
DRR	Disaster Risk Reduction
DSJ	Decision Sciences Journal
ERGO	Evacuation Responsiveness by Government Organisations
EUROMA	European Operations Management Association
EM-DAT	Emergency Event Database
FEMA	Federal Emergency Management Agency
GCS	Generic Case Study
GDP	Gross Domestic Product
GIS	Geographical Information System
IASC	Interagency Standing Committee
ICMR	International Conference on manufacturing research
ICS	Indian Case Study
ICRC	International Committee of the Red Cross
IDRN	Indian Disaster Resource Network
IFRC	International Federation of Red Cross
IMD	India Meteorological Department
INFORMS	Institute for Operations Research and the Management Sciences
ISCRAM	International Association for Information Systems for Crisis Response and Management

JOM	Journal of Operations Management
LMRD	Last mile relief distribution
LMV	Last Mile Vehicle
LP	Linear Programming
MS	Management Science
MSOM	Manufacturing and service operations management
MOES	Ministry of Earth Science
MILP	Mixed Integer Linear Programming
NATCOR	National Taught Course in Operational Research
NDMA	National Disaster Management Authority
NDRF	National Disaster Response Force
NEC	National Executive Committee
NGO	Non-Governmental Organisation
NIDM	National Institute of Disaster Management
NSS	National Service Scheme
NYKS	Nehru Yuva Kendra Sangathan
OR	Operations Research
OCHA	Office for the Co-ordination of Humanitarian Affairs
OSOCC	On-Site Operations Cooperation Centre
POM	Productions and operations management
RMC	Research Methods Course
QRMT	Quick Reaction Medical Team
SAARC	South Asian Association for Regional Co-operation
SD	System Dynamics
SDMA	State Disaster Management Authority
SDMC	SAARC Disaster Management Centre
SEC	State Executive Committee
SUMA	SUMA is a software of Humanitarian Supply Management System
USA	United States of America
UN	United Nation
UNDP	United Nations Development Programme
UNDMT	United Nation Disaster Management Team
UNHCR	United Nations High Commission for Refugees
UNJLC	United Nations Joint Logistics Centre

USAID	United States Agency for International Development
USGS	United States Geological survey
VRP	Vehicle Routing Problem
WFP	World Food Programme
WHO	World Health Organisation

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Chapter 1: Introduction

1.1 Introduction

The natural disaster is occurring frequently in the whole world. A recent UN report says that in last two decades there are more than 600,000 people killed and left behind trillions of dollars in damages because of natural disasters (UN, 2015). Roughly 335 natural calamities, recorded each year between 2005 and 2014 (UN, 2015). Some of the natural disasters are uncertain and unpredictable for example earthquake. Acting against that uncertainty is difficult and preparedness against uncertainty is costly. There are some devastated disaster incidents, such as the earthquake in Nepal (2015), Japan (2011) and India (2001), floods in Australia (2001) and Pakistan (2010) causes a significant amount of life losses, property damages and economic losses.

1.1.1 Disaster

High impact disasters have captured international attention both in the media (which has impact on quick response to gather information about the property damages, life losses, and the economic losses of the disaster) and in the disaster management research community (these communities will develop tools for better preparedness and response to manage the affected community during disasters). Disasters create a huge impact when they happen near or inside a large population. The result is a significant amount of life losses and economic losses. A natural hazard is not termed as a disaster if it takes place in a remote area that is not inhabited by human beings (Alexander, 1997). The WHO defines disaster as "events that occur when significant numbers of people are exposed to extreme events to which they are vulnerable, with resulting injury and loss of life, often combined with damage to property and livelihoods" (Wisner and Adams, 2002, p 10). Disasters are defined as "a disruption that physically affects a system as a whole and threatens its priorities and goals" (Van Wassenhove, 2006, p 476). There are two categories of disasters: natural disaster and manmade disaster, which are clarified in the following Table 1.1.

Table 1.1 Explaining disasters (Source: Wassenhove (2006))

	Natural	**Manmade**
Sudden-onset	Earthquake Hurricane Tornadoes	Terrorist attack Coup d'état Chemical leak
Slow-onset	Famine Drought Poverty	Political crisis Refugee crisis

Disaster has a significant impact not only the affected country's economy but also the worldwide economy. Only on 2015 natural and manmade disasters created USD 37 billion economic loss and 198 natural disasters, which is the maximum number in one year (Swiss, 2016).

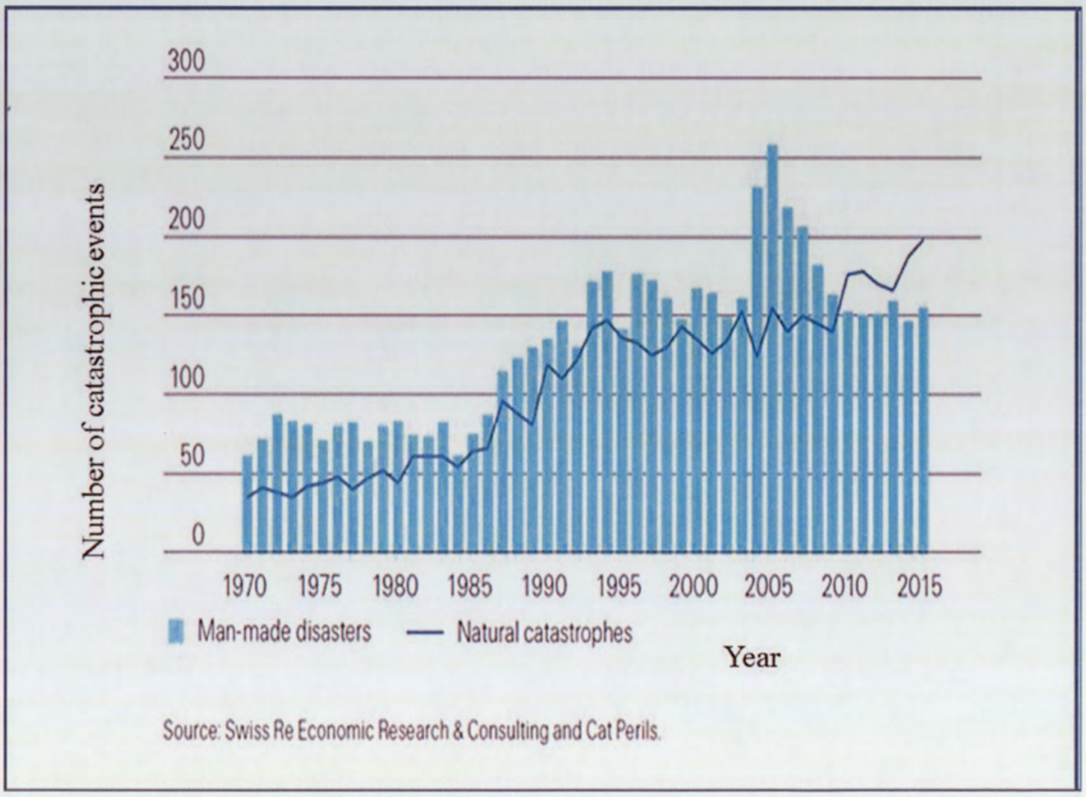

Figure 1.1: Number of catastrophic events 1970 – 2015 across the world (Source: (Swiss, 2016))

Thailand was affected by huge flood during October 2011 and more than 3.4 million people were bearing the consequences of the disaster (IFRC, 2011). This flood caused considerable damage to the world hard drive production facilities and resulted in a doubling of retail prices for the hard drive. Last few examples show that how the economy is affected by disasters. There is an emergency situation integrated within the affected community after a disaster strikes. An emergency situation is a state where standard processes are postponed and extraordinary events are engaged in order to prevent a disaster (WHO, 2002).

1.1.2 Difference between disasters and emergency

The terms "disaster" and "emergency" are often used interchangeably. The definition of emergency is "an exceptional event that exceeds the capacity of normal resources and organisation to cope with it" (Alexander, 2002, p 1). Minor incidents like local accidents; local fires, sudden medical emergencies etc. could be managed by the policeman, fireman and emergency medical personnel in a systematic and well-planned course of action. Most emergencies can be successfully managed without outside assistance. On the other hand, the impact of the disaster is so high, that it can only be managed with the full participation of the national government and perhaps also international aid (Alexander, 2002). It can be concluded that disasters are emergencies but not all emergencies are a disaster. A systematic and well-planned course of action is necessary to cope up with disaster.

1.1.3 Disaster Management

Disaster management describes the range of activities related to both the preparation for and response to cope up with disaster events. The objectives of disaster management are (Alexander, 2002):

- to mitigate the severances and effects of a disaster;
- total prevention, control and planning to respond the whole emergency situation;
- decrease the risk of life and managing the actual and potential disaster response in an organised manner;
- to reduce the damage to property, ensuring public safety during the disaster and caring for the beneficiaries (disaster affected people).

These are several essential activities, which are carried out at different points of time depending on the needs. These activities are deployed for the individual stage to minimise the risk of occurrence and the impact of the disaster, along with the provision of suitable care for vulnerable communities. According to Drabek and Hoetmer (1991), disaster management planning consists four phases: mitigation, preparedness, response and recovery. These four phases have a definite discrete objective, which connects the practical activities for a successful comprehensive emergency management planning. These four phases are related schematically to reduce the impact of disaster, as it can be seen in Figure 1.2

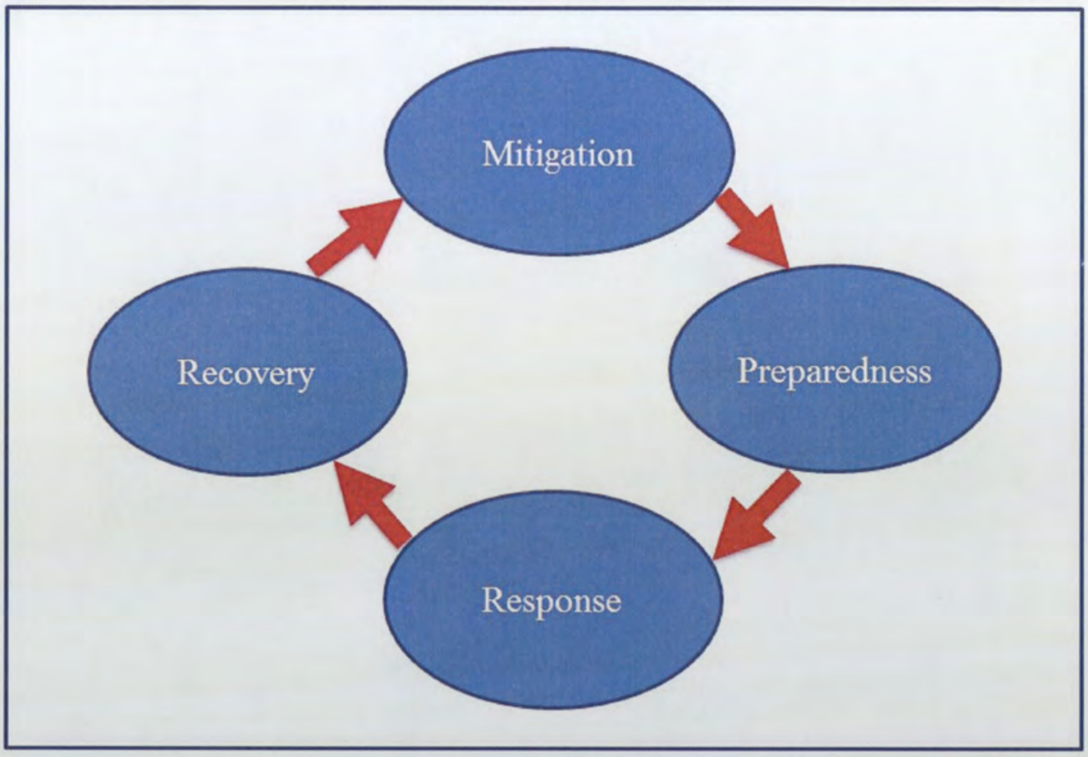

Figure 1.2: Phases of disaster (Source: (Drabek and Hoetmer, 1991))

Mitigation involves the activities for the accomplishment of avoiding or reducing the disaster occurrence risk. There are some activities for mitigation like hazard identification and mapping, design and construction application, land use planning, financial incentives, insurance and structural controls to reduce risks during a disaster (Haddow et al., 2011). Mitigation is normally addressed by the governmental authorities using engineering techniques to build dams, dykes, protective walls, among others (e.g. Lopez-Pelaez and Pigeon, 2011, Uddin and Ang, 2009, Yi et al., 2012) and it is the most studied among the four phases (Altay and Green, 2006).

Preparedness phase comprises actions such as designing emergency plans, conducting training to the volunteers, evacuation of a vulnerable population for security measure, shelter planning and organisational exercise. Primarily preparedness includes the planning for the individual or collective efforts to reduce the impact of disasters. Preparedness is the phase that involves the activities intended to help communities respond to any possible disaster (Caunhye et al., 2012). This phase is concerned with preparing the community to respond when a disaster occurs. There is an overlap between preparedness and response, but quite a lot of research on this phase is related to facility location (e.g.(Balcik and Beamon, 2008, Chanta and Sangsawang, 2012, Chen et al., 2013, Zhu et al., 2012) and stock pre-positioning (Campbell and Jones, 2011, Duran et al., 2011, Rawls and Turnquist, 2010, Rawls and Turnquist, 2011, Rawls and Turnquist, 2012, Van Wyk et al., 2011) .

Response phase is performed in the moments before, during and after the disaster strikes. The major activities related to this phase are to search and rescue the affected people (e.g. Chang et al., 2007, Chen and Miller-Hooks, 2012, Lakshmi Narayanan and Ibe, 2012, Wang and Wang, 2008, Zheng et al., 2013), evacuation (Ng et al., 2010, Scheer et al., 2012, Kimms and Maassen, 2012, Alçada-Almeida et al., 2009), managing the resource planning (Ozbay and Ozguven, 2007, Beamon and Kotleba, 2006, Davis et al., 2013, Jaller et al., 2008) and distributing immediate relief to the affected population (Banomyong and Sopadang, 2010, Döyen et al., 2012, Liberatore et al., 2014, Nolz et al., 2011, Suzuki, 2012) . The intended outcome of this phase is to save human life by providing food, water, medicine, shelters and other necessary resources.

The *Recovery* phase is the last phase of disaster management. The performed activities are repairing damage, restoring service and reconstructing facilities after a disaster has struck. Finally, the purpose of this phase is to integrate the essential activities for the normal condition of the affected community. Recovery "involves the actions taken in the long term after the immediate impact of the disaster has passed to stabilise the community and to restore some semblance of normalcy" (Altay and Green, 2006, p 480). Even though the recovery phase is the less studied phase in academic research (Altay and Green, 2006), there are some articles related to life sciences and economics to reduce the spread of diseases (e.g. Jordan et al., 2011, Santos et al., 2009, Westhoff et al., 2008), allocate displaced people (e.g. Nikolopoulos and Tzanetis, 2003), facility assessment (Chang and Nojima, 2001, Cret et al., 1993, Song et al., 1996), cope with the psychological effects of disaster (Ehring et al., 2011, Peek, 2008, Stellman et al., 2008) and reconstruction of infrastructure (e.g. Kim and Dshalalow, 2002, Liberatore et al., 2014).

The above four phases are related to each other and creating a cycle repeating itself to reduce the impact of the disaster, which is shown in Figure 1.2.

A brief overview of general facts about the disasters and significance of final relief distribution operation and explanation will be discussed in the scope of this thesis.

1.1 Research background

Experiences over time enhance the efforts to improve the disaster management activities currently performed because "over the last thirty years, mankind has been facing disasters on an unprecedented scale: an annual average of over one-quarter of a million people worldwide have been affected by natural disasters, with an absolute magnitude ranging between 68 million, and more than 620 million inhabitants" (Savoiu, 2011, p 11). Catastrophic flood, hurricane, earthquake, tsunami, famine and drought these events are representing scenarios where there is a significant amount of life and economic losses are noticed. Especially the economic losses for last 30 years have progressively increased between 1970 and 2016, which is explained in Figure 1.3 (the data was extracted from EMDAT database on 28/09/2016).

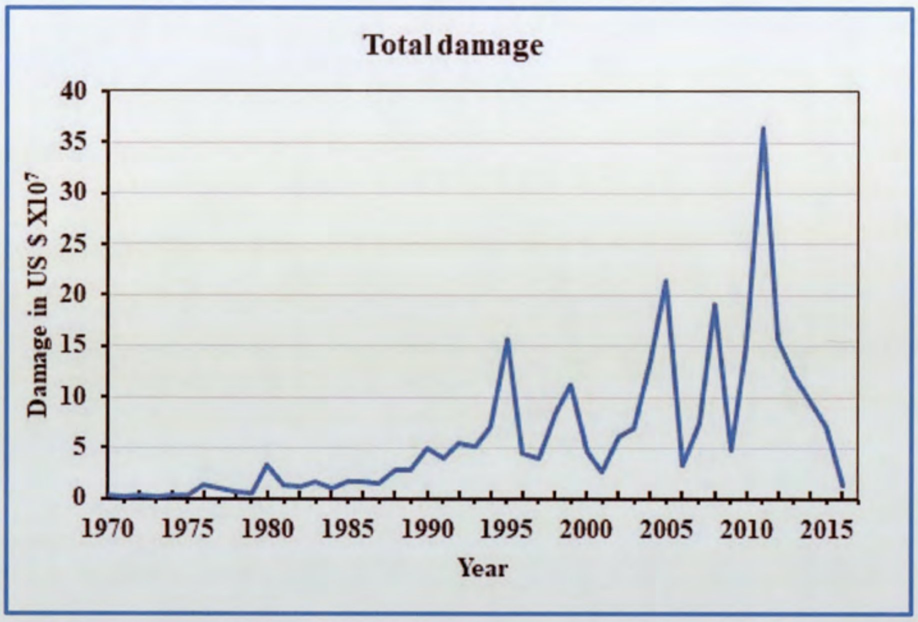

Figure 1.3: Economic losses from natural disaster (1970-till date) (Source (EMDAT, 2016))

Among the natural disaster there are some sudden onset disasters like earthquakes for which it is hard to predict the exact time of occurrence and as a consequence priority of preparedness for an earthquake is lower than other natural disasters (Shaw et al., 2004). According to Ferris (2010) "on the global level, between 2000 and 2009, 2 billion people were affected by disasters; 44% of those were affected by floods, 30% by drought and only 4% by earthquakes. However, since 2000 60% of those killed in disasters died in earthquakes" (Ferris, 2010, p 4). According to Wyss (2001) "earthquakes, the rupture of faults, obey the physics of failure processes. For failure to come about, elastic energy must be accumulated to a level at which friction is overcome. The current generation of seismologists figured out where the energy is coming from: movements of elastic plates at the surface of the Earth participate in cooling the planet by convection" (Wyss, 2001, p 217). The effects of the earthquake are shaking and ground rupture, landslides and avalanches, soil liquefaction, fires, tsunami, floods and much more (USGS, 1946, USGS, 1906, Ohnaka, 2013). The major cause of earthquake and tsunami is the movement of a tectonic plate of the Earth (Ohnaka, 2013).

Every disaster has specific challenges. "In most of the countries, an earthquake occurs once in several years, which may vary from 10 to 50 or even 100 years. Thus, obviously, the priority of earthquake is lower than other more frequent disasters like floods, cyclones and draughts" (Shaw et al., 2004, p 39). There are several issues, which differentiate an earthquake from other natural disasters and identify the significance of research in an earthquake, showed in Table 1.2.

Table 1.2: The difference between earthquake and other natural disaster (Developed by the researcher)

Challenges	**Earthquake**	**Another natural disaster**
Forecasting system	There is no forecasting system till now about the exact prediction of an earthquake. The occurrence of earthquake is very sudden and unpredictable.	There is sophisticated weather forecasting system exists, so it is easy to predict other natural disaster like flood, storm, typhoon, cyclone etc.
Accessibility of the affected area	Earthquake response could be a long process for a number of reasons like road blockage, building collapse and so on. Damage to the affected area creates access problem for relief worker.	Other natural disasters like flood, storm etc. are predictable, so the relief workers can start the evacuation process before the disaster.
Delay in relief operation	During an earthquake, most of the fatalities caused mainly due to the building collapse, road and ground movement damages. It is always captivating a long time to clean the debris.	In other natural disasters, the relief worker can continue the relief operation immediately after the disaster.
Trauma	The sudden and unpredicted occurrence of earthquake creates trauma to the survivals.	Every disaster creates trauma. But the predictability of other natural disaster can reduce the trauma to the survivals.
Aftershock of disaster	After a large-scale earthquake, there are several small scale earthquake occurred, which is called aftershocks. This creates a serious trauma for the survivors and the relief workers.	In other natural disaster, there are no such aftershocks.

Several disasters occur worldwide every year, whether in developed or in developing countries. The difference lies in the amount of resources available to deal with them and the number of vulnerable people. Thus sometimes two disasters with similar characteristics occurring in a developing and a developed country can have significantly different death tolls, and generally with higher impact on the developing country (Julca, 2012). "The social and economic cost of natural disasters due to climate is in a process of continuous expansion throughout the world. The trend is largely attributable to increase vulnerability in less developed countries, especially in the poor nations, where the population remains, in most cases, more vulnerable to extreme climate events that occur later, after the people experienced a first severe disaster" (Savoiu, 2011, p 13).

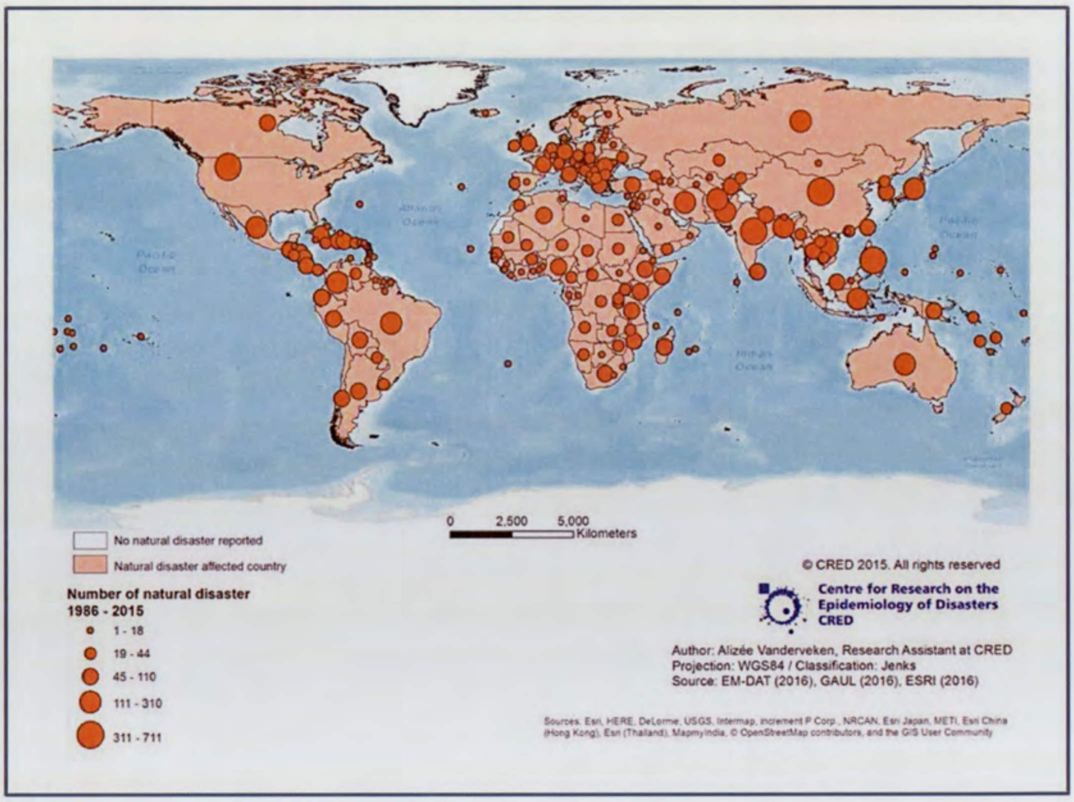

Figure 1.4: Number of natural disaster by country (1986-2015) (Source EM-DAT 2016)

The above Figure 1.4 demonstrates that from 1986 till 2015 (the data was extracted from EM-DAT database on 13/03/2017) the numbers of natural disasters happened worldwide but most frequently affected regions are the developing countries.

Figure 1.4 also illuminates that the Indian subcontinent is the world's most disaster-prone areas. India's geo-climate conditions and high-degree of socioeconomic vulnerability make this nation one of the most vulnerable in the whole world. It suffers severely from natural disasters every year. Poverty and risks to disasters are intimately related and mutually reinforcing. The poor and vulnerable community of the society is worst affected in the case of disasters. Poverty also forces the poor community to migrate and live in vulnerable locations such as unsafe lands or unsafe shelters. As a result during and after disasters, this poor community suffers enormously. Almost 85% of the area is at risk because of the multiple hazards in India (SAARC, 2015). There is an urgent need for systematic and well-planned disaster management paradigm in Indian perspective. This research is intended to study the LMRD performance in India. Therefore, it is necessary to have an understanding of the country profile. The following section provides background information relating to the geo-climate context, the socio-economic context of the study, the significance of the topic and scope of this research. The following section starts with a brief overview of general facts about the country and then followed with the significance of disaster management, relief distribution operation and finally earthquake response operation in India.

1.3 Disaster Management in India

1.3.1 Country Profile India

India is a developing country with world's largest democracy and second most populous country. It consists of 28 states and 7 union territories. It is a 7th largest country in the world, with a total area of 32,87,263 square kilometres (India.gov.in, 2015). India has total 1.311 billion population in 2015 (World-Bank, 2016). Indian economy has been rising with a minimum 7.6% growth rate of GDP in last decade as shown in Figure 1.5 (World-Bank, 2016). The total nominal GDP of India in 2015 is calculated at $2.095 trillion by the World Bank (2016) that is making it one of the major economic player in the world. On the other hand, 69% percentage of the population in 2010, were earning less than $2.00 a day (World Bank, 2012).

Figure 1.5: GDP growth of India (Source: (World-Bank, 2016))

1.3.2 Disasters in India-an overview

India has a surprising variety of climate regions, ranging from tropical in the south to temperate and alpine in the Himalayan north. This country's climate is strongly influenced by the Himalayas and the Thar deserts. The unique geographical and geological situations make this nation one of the worst disaster-prone countries in the world. There are five distinct regions of the country i.e. Himalayan region, the alluvial plains, the desert, the hilly part of the peninsula and the coastal zone have their own specific problems. The Himalayan region is prone to earthquake, flood and landslides. The coastal zone is vulnerable to cyclones and storms, while the desert part of the country is affected by droughts (SAARC, 2015). India's geoclimate conditions and high degree of socioeconomic vulnerability make it one of the most disaster-prone nations in the world. According to a recent study among 35 states in the country, 27 of them are disaster prone (India.gov.in, 2015). In India almost 58.6% of the landmass is prone to the earthquake of moderate to very high intensity, 12% is flood prone, about 8% is cyclone prone, 2% is landslide prone and a long coastline is exposed to tsunamis and storms (India.gov.in, 2015). Drought is (the slow onset disaster) as much as 68% of India's land area. If the other disasters such as chemical and terrorist attacks are added, every square inch of India is vulnerable and need immediate attention and sustained effort (Bhandari, 2006). According to NIDM, there are various disasters categorised into five major subgroups, which is clarified in the following Table 1.3 (home-affairs, 2011).

Table 1.3: List of various disasters (Source: (home-affairs, 2011))

Major subgroups	Disasters	Some examples of Indian disaster
Water and climate-related disasters	• Floods and drainage management • Cyclones • Tornadoes and hurricanes • Hailstorm • Cloudburst • Heatwave and cold wave • Snow avalanches • Droughts • Sea erosion • Thunder and lighting • Tsunami	Flood (Bihar flood July 2016, Assam flood 2016) Cyclone (Cyclone storm named Roanu east coast of India May 2016) Tornado (South India Tornado 31st March 2009) Tsunami (2004 Indian Ocean tsunami)
Geologically related disasters	• Landslides and mudflows • Earthquakes • Dam failures/ Dam bursts	Earthquake (2015 Nepal earthquake, 2011 Sikkim earthquake) Landslides (Kedarnath landslide Uttarakhand 16th June 2013, Malin landslide Maharashtra 30th July 2014)
Chemical, industrial and nuclear-related disasters	• Chemical and industrial disasters • Nuclear disasters	Chemical and industrial disaster (Bhopal disaster 2nd December 1984)

Table 1.3 Continued....

Major subgroups	Disasters	Some examples of Indian disaster
Accident related disasters	• Forest fires • Urban fires • Mine flooding • Oil spills • Major building collapse • Serial bomb blasts • Festival related disasters • Electrical disasters and fires • Air, road and rail accidents • Boat Capsizing • Village fire	Serial bomb blast (2006 Mumbai train bombing) Major building collapse (Delhi building collapse 15th November 2010)
Biologically related disasters	• Biological disasters and epidemics • Pest attacks • Cattle epidemics • Food poisoning	Epidemics (Swine flu outbreak 2015) Food poisoning (School midday meal food poisoning at Bihar on 16th July 2013)

NIDM under the disaster management act, 2005 is responsible for developing the mechanism for preparing a database for different kind of disasters. According to NIDM, there is a lack of a central statistical database, which is a major constraint for risk evaluation and compilation of disaster history in this country. Though the scientific data on major disasters are available for this country, the information deficiency on vulnerabilities is disseminated in multiple sources. Therefore the reliable data sources are not accessible uniformly for the entire nation.

In India 175 major disasters occurred in last ten years. As a result, 23127 people died, approximately 45 million people were affected and a significant amount of property loss and other infrastructure affected in last ten years (EMDAT, 2016) (the data was extracted from EM-DAT database on 13/03/2017).

India needs a systematic framework, to cope up with these high impact disasters, which will be able to save lives and prevent major economic losses.

1.3.4 Institutional framework

The institutional arrangement for disaster management in India can be outlined from the British administration period to current period of the twenty-first century. During the British administration period there are some devastating disasters like famines of 1900, 1905, 1907, 1943 and the Bihar-Nepal earthquake of 1937 occurs. The Scarcity Relief Division was established during British administration (Bhandari, 2006). The policy was primarily relief-oriented at that time, for example, all the activities included designing the relief codes and adjusting food for affected community. Recently the orientation of disaster management changed from a primarily relief centric approach to a holistic approach which includes mitigation, preparedness, response and recovery.

In the 1990s a permanent and institutionalised disaster management setup was established under the Ministry of Agriculture (home-affairs, 2011). After 1990s there were some devastating disasters like Latur earthquake (1993), Malpa landslide (1994), Orissa super cyclone (1999) and Bhuj earthquake (2001) compel the Secretary of Ministry of Agriculture to constitute a high-powered committee, which is guiding for a systematic and holistic approach concerning about disasters (home-affairs, 2011). Figure 1.6 explains the hierarchical structure of the national disaster management in India, which functions in four levels: centre, state, district and local. There are various relevant ministries, governmental departments and administrative bodies involved in the national disaster management structure; therefore it is a multi-stakeholder setup (home-affairs, 2011). The prime minister of the government of India is the main decision maker and there are ministries of various departments assisting in the decision-making process in India. Academic institutions, scientific organisations, technical institutions, professional bodies, corporate sectors and NGOs are the relevant communities who continuously incorporate their intelligence for better improvement of disaster management activities in India.

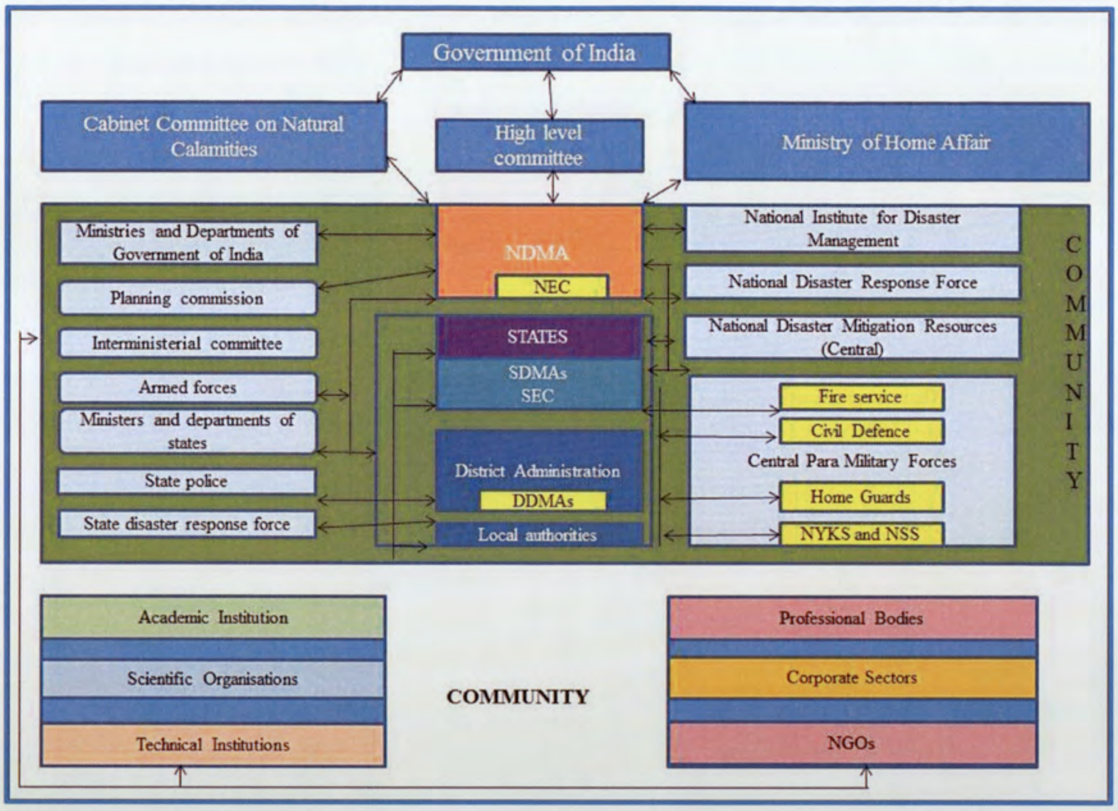

Figure 1.6: National Disaster Management Structure (Source:(home-affairs, 2011))

1.3.5 Operative Manual for disaster management

The policies, plans and guidelines for disaster management are essential for the effective response planning. The national authority under the disaster management act approves the national plan. The national plan followed by the state plan and the state plan followed by the district plan. National mitigation plan, national response plan and national capacity building plan are three primary measures for national disaster management planning.

There is a national disaster mitigation fund, which is applied completely for the mitigation purposes. There are two types of mitigation activities: structural and non-structural activities (home-affairs, 2011). The structural activities are dealing with physical construction, which includes engineering measures and hazard-resistant protective infrastructures (home-affairs, 2011). The non-structural activities indicate to the policies, awareness, public commitment, knowledge development, sharing mechanisms including operational guidelines and the type of information which can reduce high impact risks (home-affairs, 2011).

The Preparedness and Response activities are the key measures of the response planning. Table 1.4 provides some of the guidelines for the preparedness and response measures by the state and district level.

Table 1.4: Checklist for preparedness by state/district authority (Source:(home-affairs, 2011))

State level	**District level**
• Vulnerability assessment; • Dissemination of warning; • Emergency response activities; • Rapid damage assessment • Maintenance of essential services; • Stocking of essential commodities; • Medicines; • Drinking water; • Shelter/camps; • Coordination;	• Pre-contract; • Evacuation plan; • Activating control rooms; • Search and rescue team; • Communication; • Identification of nodal officer; • Status of state disaster response force; • Preparedness tool;

There are some circumstances where disaster happens with or without any early warning signals. There is a trigger mechanism, which activates the disaster response system automatically after receiving early warning signals. The central and state government are jointly in charge of the relief, rehabilitation, preparedness, mitigation and response measures (home-affairs, 2011). The central government is providing logistic and financial support for severe natural disasters. The logistic support contains deployment of aircraft and boats, the specialist team of armed forces, central paramilitary forces and personnel of national disaster response force, arrangements for relief materials including medical stores, restoration of critical infrastructure facilities including communication network (home-affairs, 2011). District Magistrate (DM) (head of the district administration) closely monitors the disaster situation for the strategic involvement for better disaster management planning. Proper liaison with the affected state or affected district with the central government is essential for improved strategic planning. The central government always provide financial, physical, logistical and manual support after a disaster. The state government need to understand the measures like the gravity of natural calamity, the scale of the relief operation, the requirement of central help, the requirement of international help etc. (home-affairs, 2011). State relief commissioner is the supervisor for the state level relief operation and controls the whole state level relief operation with the help of collectors or deputy commissioners. They are the main representatives to coordinate relief operation at the district level. The district administration is the focal point for the field level operations. All governmental contingency plan is implemented by this authority. District Magistrate (head of the district administration) is doing the needs assessment for the measurement of the impact of the disaster, necessity of relief material, loss of lives, damages of infrastructures etc. A district is subdivided into subdivisions termed as Tehsils or Talukas (home-affairs, 2011). Subdivision officer is the head of the Tehsil and during a disaster situation, the sub-district committee is concentrating on the liaison with the affected Talukas and the district agencies. There are other agencies, for example, national disaster response force, state disaster response force which are commencing with specialist professionals for specific duties. Decontamination of the area and personnel, removal of debris, search and rescue of victims, extrication of victims dead or alive, first medical response to victims, extend moral support for victims, assistance to civil authorities in distribution of relief materials, coordination with other agencies, capacity building, providing assistance to foreign countries, these are the activities carried out by the NDRF (home-affairs, 2011).

The key measure of national capacity building plan is recovery, reconstruction and the damage rehabilitation. The destruction caused by floods, earthquakes, tsunamis, storms, and cyclones is much larger scale than other disaster and recovery after those disasters pose big challenges (home-affairs, 2011). Disaster risk reduction in recovery, coordination, assessment, decentralising planning, sustainability in the recovery process, gender sensibility, infrastructure reconstructions, evaluation are the important measures for the improvement of living conditions of the affected communities (home-affairs, 2011).

Every disaster is different. Consequently, different disaster has a different contingency plan, code of conducts and mandates. This study is concentrating on earthquake relief operation. The following paragraph is concentrating on the earthquake response planning.

1.3.6 Operative Manual for earthquake control

About 59% land in India could face moderate to severe earthquakes (Daya Kaul and Ayaz, 2009). There are several devastating earthquakes from 1990 till 2015, for example, the Uttarkashi earthquake of 1991, the Latur earthquake of 1993, the Jabalpur earthquake of 1997, the Chamoli earthquake of 1999, the Bhuj earthquake of 2001, the Indian Ocean earthquake and tsunami 2004, the Kashmir earthquake of 2005, the Andaman Island earthquake 2009, the Sikkim earthquake 2011, the Kashmir earthquake 2013, and last but not the least the Nepal earthquake 2015 happen in India (India.gov.in, 2015). These earthquakes caused enormous damage to property, infrastructures, economic loss and live losses. Result analysis showed that all these earthquakes caused most of the fatalities mainly due to the building collapse as most of the construction in India are not earthquake resistant. Statistical report shows that 12% of the country's landmass is vulnerable for flooding while one third is at risk of earthquake on the sea floor (home-affairs, 2011). This loss every year could create a big economic problem for a developing country like India. Figure 1.7 demonstrates that there are five seismic zones according to the maximum intensity of earthquakes expected in India (home-affairs, 2007). Zone 5 is the most earthquake prone area.

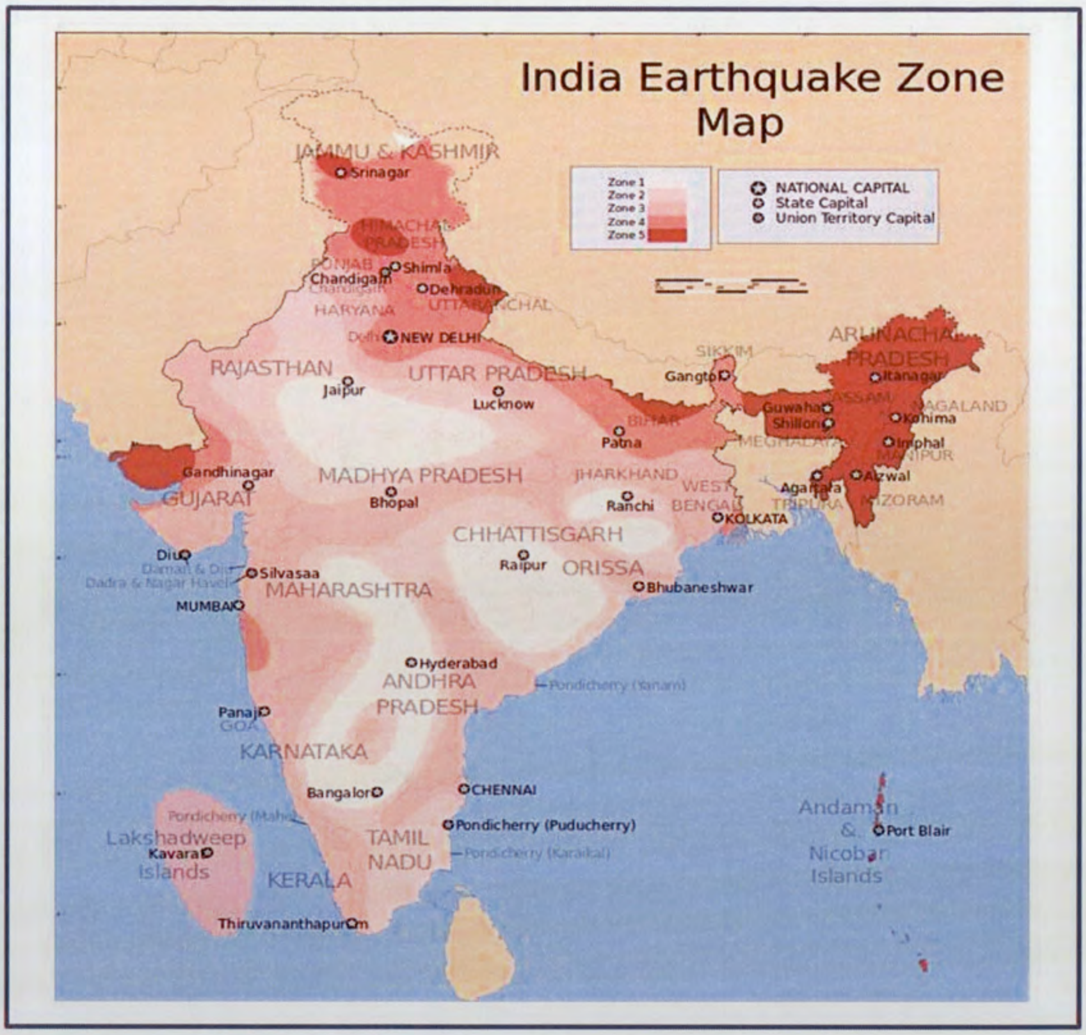

Figure 1.7: Seismic zone map of India (Source: (home-affairs, 2007))

The MOES, the nodal ministries establish the measures for earthquake management. The measures for earthquake mitigations are capacity building, public awareness, national building code, earthquake resistant construction of new structures, and timeline for implementation of the mitigation planning (home-affairs, 2007). The effectiveness of Indian earthquake disaster management planning depends on six pillar framework (home-affairs, 2007). Figure 1.8 explains the framework of earthquake disaster management planning. This framework considers six pillars as the significant activities and considering those activities before, during and after the earthquake. This six pillars (Figure 1.8) are connected to each other sequentially. The first two pillars are mainly concentrated on the mitigation stage where the government is planning to prioritise the importance of earthquake resistant constructions and reconstruct the existing structure according to the earthquake-resistant construction policy. The 3rd, 4th and 5th pillar are majorly concerned about the preparedness phase where the communities are informed about the earthquake policies, awareness by proper training, education, documentation and continuous research and development.

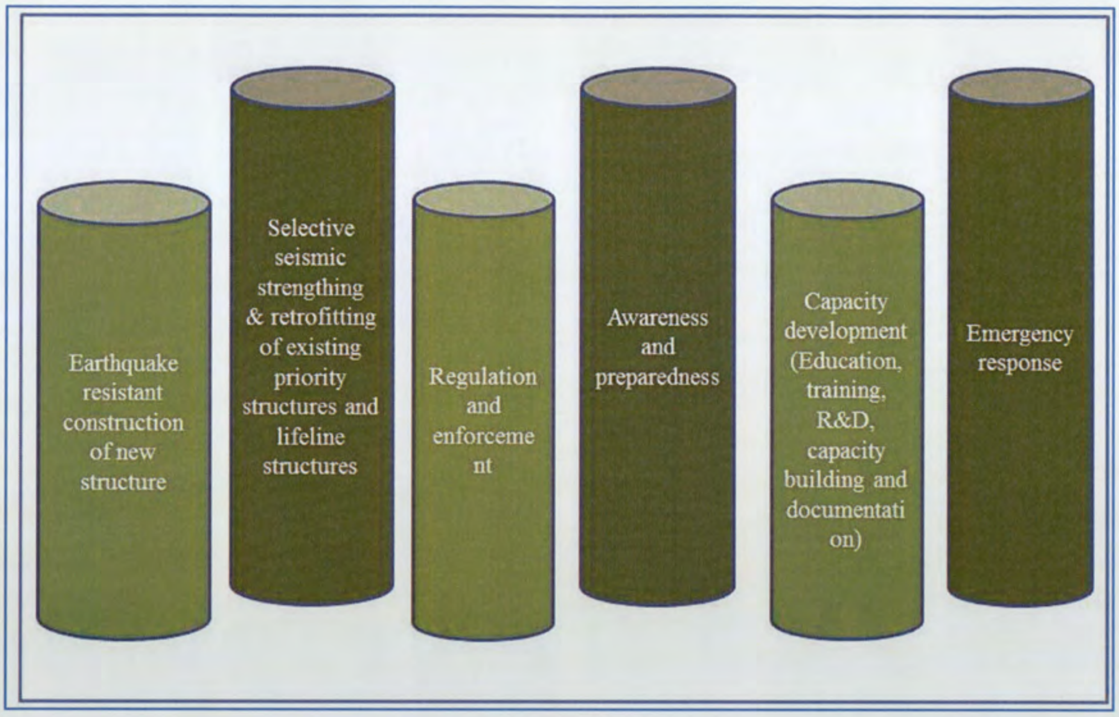

Figure 1.8: The six pillars for earthquake management in India (Source: (home-affairs, 2007))

In this study, the researcher is considering about relief distribution operation, which is a major part of the response operation. The next paragraph will explain about the earthquake response operation.

1.3.7 Operative Manual for earthquake response

This section explains about the final pillar of Figure 1.8. The devastation of an earthquake depends on the magnitude of the earthquake. The scale of response, the identification of corresponding role players and mobilisation of relief materials all depends on the severity of the earthquake. All involved agencies (government, local, national and international relief organisations) have their own disaster management planning including the activities like rapid deployment of people, supplies of relief materials, logistics, etc. The affected community is always the first responder after a disaster. According to a study, there is over 80% of search and rescue from collapsed building is carried out by the local community (home-affairs, 2007). Therefore, basic training and education in the earthquake preparedness and response operation among the community are essential. After the earthquake, the central and state government immediately send the special heavy earthmoving equipment to clear debris and to carry out search and rescue operation. The IDRN, which is a web-based resource for emergency equipment and response personnel is providing the information about the availability of equipment (home-affairs, 2007).

Trained community level teams (local response force, local community members) are providing assistance for planning and setting up emergency shelters, distributing relief, identifying missing people, addressing needs of education, healthcare, water supply, sanitation, food etc. to the affected community (home-affairs, 2007). These local community members are the key coordinating agents between the affected community and government. The local administration and district administration have information about the population density in that affected area. Only the local community member has the information about the most vulnerable people, who need special support after an earthquake. Therefore, in the earthquake perspective involvement of local community member always enhance the disaster management operation.

The NDRF has specially trained team, who are equipped for the collapsed structure search and rescue operation. The NDRF team also provide communication equipment for establishing relief distribution operation. The police force maintains the law and order by assisting in search and rescue and in the transportation network. The homeguards are the part of the police force, who are supporting the district agency for the protection of assets in evacuation areas, management of relief camps, managing the security of the aid distribution centre. Indian armed force act promptly to provide support for the earthquake response operation. Immediate and efficient emergency medical response is supplied by quick reaction medical team (QRMT), mobile field hospitals, accident relief medical vans (ARMV) and heli-ambulances after the earthquake (home-affairs, 2007). The whole response activities are undertaken at the local level through a suitably devised incident command system, which is interconnected with the local administration through the emergency operation centre (home-affairs, 2007). These whole response activities are accessible by the state administration as well as the central administration. The state government also involves corporate sector as a CSR. The corporate sector can provide the service of hospitals, power and telecommunication, relief supplies, search and rescue equipment, earthmoving equipment, transportation and logistics after an earthquake (home-affairs, 2007).

1.3.8 Other Agencies involved

The NGOs are the other involved agencies for disaster management operation. These agencies participate in disaster preparedness, mitigation and response for the development of effective disaster management through a well-organised management system with the government at a different level. CASA, SEEDS, BAPS Swaminarayan sanastha, Bharat Sebashram Sangha etc. these are the local NGOs in India. There are some other international organisations, for example, UN, Red Cross, Oxfam, CARE, SAARC Disaster management centre (SDMC), Asian

Disaster Reduction Centre, Asian disaster preparedness centre, United States agency for international development (USAID) etc. (home-affairs, 2011). These agencies follow the legal institutional framework of national government of India for the development of disaster management in India. Indian government does not pursue assistance during the relief and response phases, but it appreciates sharing of expertise and also technical assistance based on international development (home-affairs, 2011).

1.3.9 Summary

The enormous population and the multiple natural disasters always expose to challenge for disaster management planning in India. The disaster management planning has to be a multi-disciplinary and proactive approach for the safe and sustainable nation. As community members are the first responders to any disasters, therefore, there is a necessity to capacity development (training, proper education, proper campaign, knowledge about health and safety issues, social responsibility etc.) among the community members (home-affairs, 2011). During 2005 Indian Ocean Tsunami, during 2001 Bhuj earthquake relief operation, there are some incidents happened such as duplication of delivery of relief materials to the same site, mismatch of relief materials to the needs etc. (home-affairs, 2011). These incidents indicate that still there is a gap in the preparedness and response phase, which need to be addressed by the proper engagement of multiple stakeholders and suitable planning of the relief distribution operation. There are some recent initiatives taken by the government of India for example introduction of disaster management in schools, professional courses, training facilities for disaster management, mass awareness about natural hazards, promoting social and gender equalities in disaster risk reduction by planning and focusing on the needs of the vulnerable section of the society. But still there are some sectors, which need additional consideration for example: mitigation plans, strengthening the preparedness phase, capacity building plan, response plan (national, state and district level response plan), CSR, developing a centralised database, emergency operations centres and last but not the least communication and connection for the final relief distribution.

1.4 Need for this research

In an emergency situation, the objective is to rapidly and efficiently provide relief to the disaster affected population in the form of food, water, medicine and shelter. Aid is available to the beneficiaries after disaster strikes, by the action of relief organisations. This supply chain process must be rapid and efficient. Before, during and after a disaster the necessity is to secure and move the required materials (food, water, medicine, shelter etc.) to the affected area in the most efficient and operative way. An effective logistics system is also very important to continue a well-organised supply chain process (Chopra and Meindl, 2007). Logistics is responsible for the movements and storage of materials as they move through the supply chain (Chopra and Meindl, 2007). Consequently, logistics management concerns demand forecasting, inventory management, material handling, warehousing, order processing and distribution management throughout the entire supply chain process (Chopra and Meindl, 2007). Recent estimates would suggest that as much as 80% of the expenditure of aid agencies is on logistics (Christopher and Tatham, 2014). Consequently, humanitarian logistic management needs to be more efficient and effective. The Fritz Institute provided a common definition for logistics in humanitarian sector: “The process of planning, implementing and controlling the efficient, cost-effective flow and storage of goods and materials as well as related information, from point of origin to point of consumption for the purpose of meeting the end beneficiary’s requirements” (Thomas and Kopczak, 2005, p 2). Humanitarian logistics are characterised by large-scale activities to meet huge quantities of demand, the uncertainty of funds, as well as unusual constraints in large-scale emergencies.

The overarching aim of humanitarian sectors is to save lives and provide the basic needs to the affected people. The objective of the disaster relief operation is always linked to how quickly and conveniently the resource reaches to the affected people. This operation is enormously complicated and very costly because of the difficulty of forecasting for the actual time of disasters and the actual demand after a disaster. Additionally, each organisation is working according to their organisational code of conduct and mandates, therefore each organisation are working distinctly. In the relief operation, the active agencies need to communicate and collaborate with the affected country’s government and the other national and international active agencies to understand the situation and for improved relief distribution planning. The general aim of relief operation is to reduce the casualties and help the disaster affected community with the relief items (food, water, medicine and so on). The LMRD is the ultimate stage of relief operation and final connector of the humanitarian sector with the affected people. LMRD is the supply of the relief items from the local distribution centres to the disaster affected people (Balcik et al., 2008). After a large-scale disaster, not only the affected country’s government is involved but there are significant numbers of other stakeholders also involved (for example national, international, regional NGOs, Civil organisations, International aids, Private sector etc.). There is a need for joint guidelines to manage the unusual constraints and uncertain demand during LMRD.

Previous research for LMRD demonstrates the routeing decisions problem, fleet management and efficient vehicle supply chain affecting the LMRD operation (Balcik et al., 2008, Martinez et al., 2011, Battini et al., 2014). Furthermore, efforts have been conducted for strategic and tactical decisions taking into account the main criteria for example cost, time reliability, equity

(Tzeng et al., 2007, Vitoriano et al., 2011, Sheu, 2007b). In the operational perspective the short-term relief distribution planning, identification of the most affected area, reduce the oversupply and unmet demand, sharing and collaborating with the active agencies in the field need more attention from the researchers and practitioners to improve. The researcher is discussing with the complexity by integrating a higher level of details in the LMRD with other activities but it is necessary to identify the exact factors, which affect the LMRD planning. It is in the light of these findings that this research is investigating the factors for LMRD for operational decision level, which will be emerging from the detailed discussions with the practitioners.

Most of the previous research about LMRD is generic. Every single disaster has different challenges, issues and different disaster management planning. So, it is necessary to concentrate on a specific disaster. This research focused on the earthquake.

This research is planning to use multi-methods approach to achieve these goals. Multi-method refers to the use of two or more methods sequentially. The advantage of multi-method is to incorporate the benefit of each method and provide more sophisticated and comprehensive tools to improve the operational perspective in the relief distribution operation. It is essential to understand the practical challenges of final relief distribution. Consequently, the practitioner's input will be necessary for the identification of the factors, which will affect the final relief distribution performance. Finally, analysis and justification of the factors are necessary for the significant impact in the LMRD performance.

1.5 Aim and Objectives

The aim of this research is to demonstrate how different factors affect the LMRD performance. The general objectives that derive from the above discussion are:

1. Identify the theoretical and practical factors which affect the LMRD performance;
2. Classify, verify and validate those factors;
3. Identify the major factors for Indian LMRD, particularly focused on earthquakes;
4. Evaluate the impact of these major factors on Indian LMRD system performance.

1.6 Scope of the thesis

The scope of this research is restricted to identify the importance of factors for LMRD performance at the operational level. This research also demonstrates and analyse the major factor, which has a significant impact on Indian LMRD performance. The intent is to focus on Indian perspective and specifically from the earthquake disaster. A number of earthquake cases are presented for the validation of the performance of LMRD.

1.7 Thesis structure

The purpose of this section is to outline the structure of the thesis. The structure of the thesis is constructed by highlighting the important issues on each chapter and connecting the chapters for a strong construction of the thesis. Figure 1.9 maps the structure of the thesis. It also shows the input to the different stages of research and also the outputs (in terms of presented and published work) of each phase.

Chapter 1 is about the motivation, research background, aim, objectives and structure of the thesis. The intention of this chapter is to introduce the topic and provide a brief explanation of the necessity of this research.

Chapter 2 will illuminate the analysis of the literature about emergency logistics, relief distribution and LMRD. This chapter is starting with a comprehensive analysis of current literature for relief distribution; operational techniques used for the relief distribution and derive the necessity of managing LMRD efficiently. Finally, the limitations of current knowledge are identified and research questions are formulated.

Chapter 3 deals with methodology and the methodological paths that were made to achieve the objective of this research. The chapter includes the choices of major philosophical paradigm. This chapter continued with a research strategy, design, methods and techniques (data collection and data analysis techniques) for the different stages of this research.

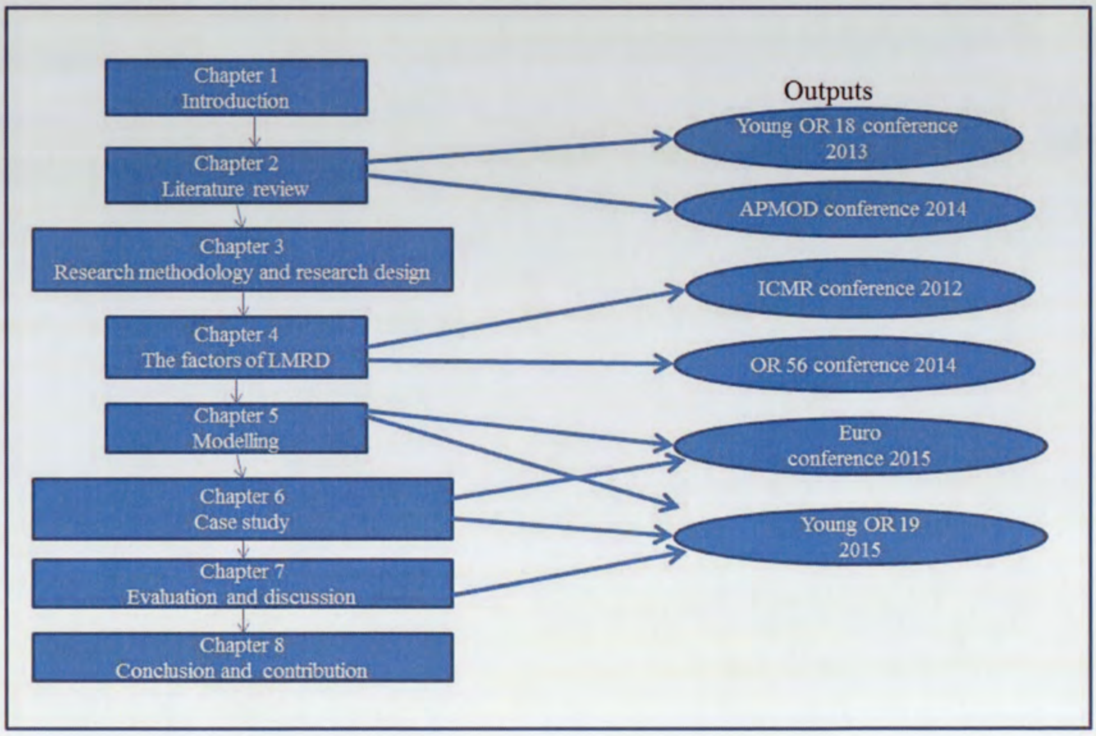

Figure 1.9: Thesis structures and outputs (Developed by the researcher)

Chapter 4 will present the practical liable issues, which affect the LMRD and also justify those factors as behavioural factors. Lastly, compare those behavioural factors with current final relief distribution literature for the validation of those factors.

The goal of Chapter 5 is to integrate the major factors (which are identified in chapter 4) for LMRD model in Indian perspective and analyse the performance of the LMRD model with and without those factors. This chapter begins with explaining about modelling approach and why ABM simulation approach is the correct choice. This chapter continues with presentation of the modelling aspect of this research using ABM simulation and illuminates the main analysis of the current framework

Chapter 6 presents two case studies for the validation of the theoretical results. The two case studies are about two earthquakes in India: Gujarat (2001) and Sikkim (2011) earthquake. This chapter is discussed about the affected regions, the chosen cities for the selected case studies, data collection for the analysis.

Chapter 7 is about the comparison and evaluation of the case studies results with actual field situation. This chapter is continuing the discussion about the adjustments between the actual field situation and the case studies result.

Chapter 8 considers the discussions and lesson learned from the work and describes the theoretical and practical contribution of this research. This chapter also presents the conclusions and summaries of this research and also provide the future research perspective for relief distribution. A practitioner's guideline for Indian LMRD is presented in this chapter, emerged from the analysis.

Chapter 2 Literature Review

2.1 Introduction

A literature review is an important step in a research project. This is an essential step to understand the context of the research project, the study of literature is to identify the existing body of established research about the current project and defining how the work connects to others. A literature review is a methodical, organised and reproducible process for classifying, assessing and creating the present body of finalised and documented work shaped by the investigators, academics and practitioners (Fink, 2013). Ridley (2012) describes and highlights the objectives of the literature review, which are explained as follows:

- the literature review identifies the background of the research;
- it relates the specific research topic with the current context of the specific topic. For example, it connects the specific research by referring to existing debates, issues and questions in the particular area;
- it contains evaluation and analysis of relevant theories and concepts which underpin the specific research;
- it clarifies the use of relevant terminology and provides definitions to that terminology in the context of the specific research;
- it justifies and analyses the relevant work in the specific field and identify the gap, where the specific research will be fitting in the field;
- finally, literature review highlights the relevant evidence for the practical challenges or issues, where the specific research project is to address and demonstrate the significance of the specific research.

The literature review of this research will perform the above objectives for the development of the research within a theoretical framework. The literature review must include all the relevant subjects which are related to the research topic. The search and analysis process of relevant literature has to concentrate on the research project as well. Finally, a literature review has to be completed and intensive.

2.1.1 Scope of the literature

The previous chapter explicates that this research project is about emergency logistics particularly in the last stage of relief distribution. The study of literature in this research project is focussing on two broad domain areas: emergency logistics and relief distribution. These two areas are overlapping with each other (e.g. relief distribution is a subset of emergency logistics). Figure 2.1 demonstrates the focused areas of literate review.

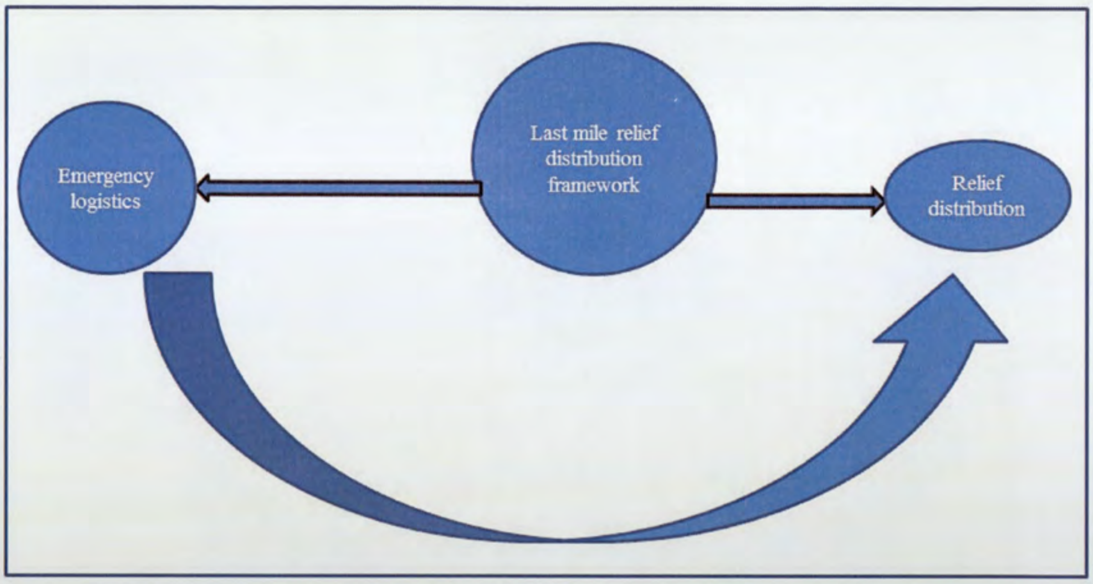

Figure 2.1: Scope of literature review (Developed by the researcher)

The following paragraph will clarify the scope and structure of the literature review.

Emergency logistics: This area concentrates on the definition of emergency logistics, differences between emergency logistics and commercial logistics, emergency logistical activities during pre and post disaster, major challenges in emergency logistics and finally tools and techniques used for emergency logistics literature.

Relief distribution: This area is a subset of emergency logistics. The major factors which affect the relief distribution and the tools and techniques used for relief distribution are discussed in this area of study. Finally, this part of literature will introduce LMRD and explain the importance of that in the disaster response operation.

The above two areas are the most relevant areas to identify the context of this research after defining the aims and objectives of this research in Chapter 1. The searches were carried out using the following resources from the electronic library service of Aston University: Science Direct, Elsevier Science, Jstor, EBSCO, Pubmed (NLM), and Web of Science. The searches were also continued using web search engine (Google, Google Scholar) and other resources. A number of preliminary searches are undertaken to clarify the best possible set of keywords. Emergency logistics, relief distribution, humanitarian supply chain, LMRD etc. are some of the examples of search strings. Thorough searches are carried out with the identified keywords, which showed in Appendix 1 from 1990 till 2013. A literature review always is an ongoing process. The author combines the search keywords with AND, OR, NOT for more accurate results. Also, some other keywords are included, for example, decision support system, simulation, optimisation and combined them with the above keywords. A more refined set of keywords is then used for each data set. The references from the relevant papers are also analysed for the complete context of the research. A thorough literature analysis is conducted by identifying types of disasters, the aim of the paper, the methodology used for individual papers, the proposed model, the validation technique, the country profile and finally the results. A sample of few literature analysis procedures are provided in Appendix 2. Finally, 30 papers are analysed and integrated into the literature review. The tenure of those 30 papers are from 2014 till 2015.

2.2 Background

Large-scale disasters represent major concerns for all over the world's emergency executives due to the potential devastation. In recent years, a large number of natural disasters happened, including the 2004 tsunami in South Asia, the 2005 earthquake in South Asia, the 2010 earthquake in Haiti, the 2010 floods in Pakistan, the 2011 earthquake in Japan and 2015 earthquake in Nepal. According to the international disaster database EM-DAT, there are on average 388 annual natural disasters frequently observed between 2003 to 2012 (Guha-Sapir et al., 2014). The annual average of 106,654 people died and 215.5 million people affected by the disasters between 2003 and 2012 (Guha-Sapir et al., 2014).

After disaster strikes, a large number of agencies for example affected country's government, local, national and international NGOs, civil organisations, international aids from other countries, donors and private organisations are involved in providing relief and resources. The objectives of those organisations are to provide humanitarian assistance in the form of food, water, medicine, shelter to the affected community. These humanitarian relief responders are extensively developed during first and second world war (Thérien and Lloyd, 2000) and included multilateral agencies such as UNHCR, WFP and ICRC. These NGOs are aiming to decrease the risk of life, property and economic losses and minimising the impact of disasters by proper disaster management planning.

The four phases (mitigation, preparedness, response and recovery) of disaster management are demonstrated in the previous chapter. According to Altay and Green (2006) the classification of four phases in disaster management "is based on the comprehensive emergency management concept introduced in the 1978 report of the National Governors' Association Emergency Preparedness Project" (Altay and Green, 2006, p 480). There is a significant amount of research carried out in individual phases, for example, 44% research conducted in mitigation, followed by 21.1% in preparedness, 23.9% in response and finally 11% research conducted in the recovery phase (Altay and Green, 2006). On the other hand, the more recent research showed that there is 23.9% research conducted in mitigation, 28.4% in preparedness, 33.5% in response and finally 3.2% work done in recovery phases (Galindo and Batta, 2013). In that same research, the authors also identify that there is 11% research directed about the multiple stages work.

In disaster management, every phase (mitigation, preparedness, response and recovery) has different challenges, needs and decisions to make. Rapid proactive decisions and activities are essential to perform properly during disasters. The most challenging efforts during a disaster are to rescue the affected people, take them to a safe place and provide them with resources. Response phase, where the above activities are pursued, engages with unpredictability, quickness of events, unavailability of resources, uncertainty about the situation, less time to decide and high pressure. The response phase is the primary studied phase within comprehensive disaster management but still, there is room for improvement for the sophisticated and integrated approach (Galindo and Batta, 2013). Based on the objective of the proposed research, this research is focusing on the response phase. Every emergency is unique therefore response plan needs to be customised according to the emergency situation. The active responders also need to take actions and create new procedures for the better emergency response (Kennedy et al, 2008). Mobilisation and organisation of resources, providing shelters to the affected people, risk assessment, prioritise the goals, distribution of relief materials are the main activities in this response phase. The stakeholders (donors, beneficiaries and media) have to learn how quickly and efficiently the relief organisations are able to respond to cope with these disasters (Davidson, 2006). Aid is available to the beneficiaries after disaster strikes, by the action of relief organisations. This supply chain process must be very rapid and efficient.

2.3 Emergency logistics

Supply chain management tends to manage the supply process from production to customers sequentially. Logistics is one of the most significant factors in the supply chain process. Logistics is responsible for the movement and storage of materials as they move through the supply chain (Chopra and Meindl, 2007). Subsequently, logistics management is to manage the movement and storage of the materials (including demand forecasting, inventory management, material handling, warehousing, order processing, managing distribution etc.) during the whole supply chain process.

There are some substantial differences between commercial supply chain management and humanitarian supply chain management (Beamon, 2004, Van Wassenhove, 2006, Ertem et al., 2010). For example, the primary objective of the commercial supply chain is to maximise profit on the other hand in the humanitarian supply chain the objective is to save lives and help beneficiaries (Ertem et al., 2010). The lead-time in the commercial context is mostly predetermined but in the humanitarian context, the lead-time is approximately zero as demand (relief) is urgent and uncertain (Ertem et al., 2010). According to Van Wassenhove (2006) "the ultimate effective humanitarian supply chain management has to be able to respond to multiple interventions, often on a global scale, as quickly as possible and within a short time frame" (Van Wassenhove, 2006, p 480). The working definition of the humanitarian supply chain is provided for this research project from the above discussion and the definition is as follows. The humanitarian supply chain is to manage the integration of the zero lead time, unpredictable demand pattern, dynamic network structure, less technology usage, high employee turnover and finally extensive stakeholders involvement to fulfil the objective of save lives and help the affected people (beneficiaries) by providing the relief (food water medicines, vehicle, people, shelters, hygiene kits and others) with respect to quality, time and place.

The logistics process for a successful disaster relief operation has to be operative and well-organised, as they account for 80% of expenditure in emergency relief operations (Van Wassenhove, 2006). Emergency logistics is more demanding than normal commercial logistics because of the uncertainty and characteristics of the situation. In the emergency logistics umbrella there are two activities: one is continuous aid work (which is targeting a slow onset situation) and another is an emergency relief (sudden onset situation) (Jahre et al., 2007).

This research will concentrate on emergency relief which is aiming to mostly sudden onset situation during disasters. The following paragraph explains the practicality of emergency logistical challenges.

On January 12th, 2010, an earthquake of magnitude 7.0 on the Richter scale struck Haiti's capital Port-au-Prince and its surrounding area. This earthquake had distress effects. An estimated 230,000 people were killed, with many lefts injured and homeless (Eberhard et al., 2010). Material loss was reported to be more than 100% of Haiti's national income. By May 2010, over 1,000 international organisations had provided humanitarian assistance in Haiti (Bilham, 2010). The overall early response from January to April 2010 in quickly mobilised aid, setting up cluster coordination and mobilising important resources in the form of money, military (civil servant) and staff (responder). But several logistical factors delayed the response and left a large series of uncovered geographic or sector-based gap. In many areas, tarpaulins were already in the bad condition and the evaluation team witnessed of many situations where people were no longer protected from the rain (Bilham, 2010). Furthermore, at the time of the evaluation only 400 transitional shelters built which was very less compared to the requirement (Bilham, 2010). The rural areas were abandoned from the relief operation at the early response time, due to lack of food security and insufficient coverage. The affected population were largely excluded from the design and implementation of the response operation due to affected road network and deployable logistical system. These above reasons are the logistical issues which delayed the Haiti earthquake response operation.

The previous example showed that the role of logistics need to develop a connection between preparedness and response, between relief procurement and relief distribution and between head office and the ground stuff. Emergency logistics concept started during the 1970s (Caunhye et al., 2012) but it has been growing enormously because of the impact of recent disasters and instances of poor relief operations. There are some basic differences between emergency logistics and commercial logistics.

The performance measure in commercial logistics is to maximise the profit and minimise the cost but in the emergency logistics, the main measure is the ability to fulfil the needs of the disaster affected community within minimum time (Balcik and Beamon, 2008). The demand in commercial logistics is predictable in terms of location, type, timing and amount but in the emergency logistics, the demand is random and unpredictable (Balcik and Beamon, 2008). Finally, the continuous effective information system is the key of successful commercial logistics but during a disaster situation, the lack of information is another challenge for emergency logistics (Sheu, 2007a). Other issues like lack of resources (Balcik and Beamon, 2008), death and suffering during disaster (Balcik and Beamon, 2008), independent donors and individually driven interests (Apte, 2010, Whybark et al., 2010, Glenn Richey Jr et al., 2009), unstable priorities over time (Van Wassenhove, 2006, Whybark et al., 2010, Apte, 2010), changing operational need (Whybark et al., 2010), self-initiated responders (Wachtendorf and Kendra, 2004, Whybark et al., 2010, Nilsson et al., 2010, Drabek and McEntire, 2003) and the large number of involved stakeholders (Whybark et al., 2010) are other challenges which make emergency logistics more challenging and different from commercial logistics. Emergency logistics is a procedure of development, handling and controlling the effective flows of relief, information, and services (Whybark et al., 2010) from the starting points to the end points to meet the crucial needs of the affected population under emergency circumstances (Sheu, 2007a). Briefly, emergency logistics is the process and the system, which supply the resources (food, medicine, shelters, water etc.) to the disaster affected vulnerable population and mobilise the affected population to the safe and secure places.

Issues like resource limitations, damaged routes, safety issues, vehicle shortage and damaged infrastructures make emergency logistics more challenging and complicated. Facility location, inventory management, evacuation planning, relief distribution and emergency services are the performed activities to reduce the life loss and property damage during an emergency situation (Naji-Azimi et al., 2012). Emergency logistics is characterised by large-scale activities to meet substantial quantities of demands, with the uncertainty of funds as well as unusual constraints. The emergency logistics literature is categorised according to the activities are performed before (preparedness) or after (response) the impact of a disaster (Caunhye et al., 2012). The following Figure 2.2 will clarify the logistical activities during the emergency situation. There is an overlap between preparedness and response phase, therefore the literature of this research briefly concentrates on preparedness phase and elaborately focused on response emergency logistics activities mainly relief distribution during an emergency situation.

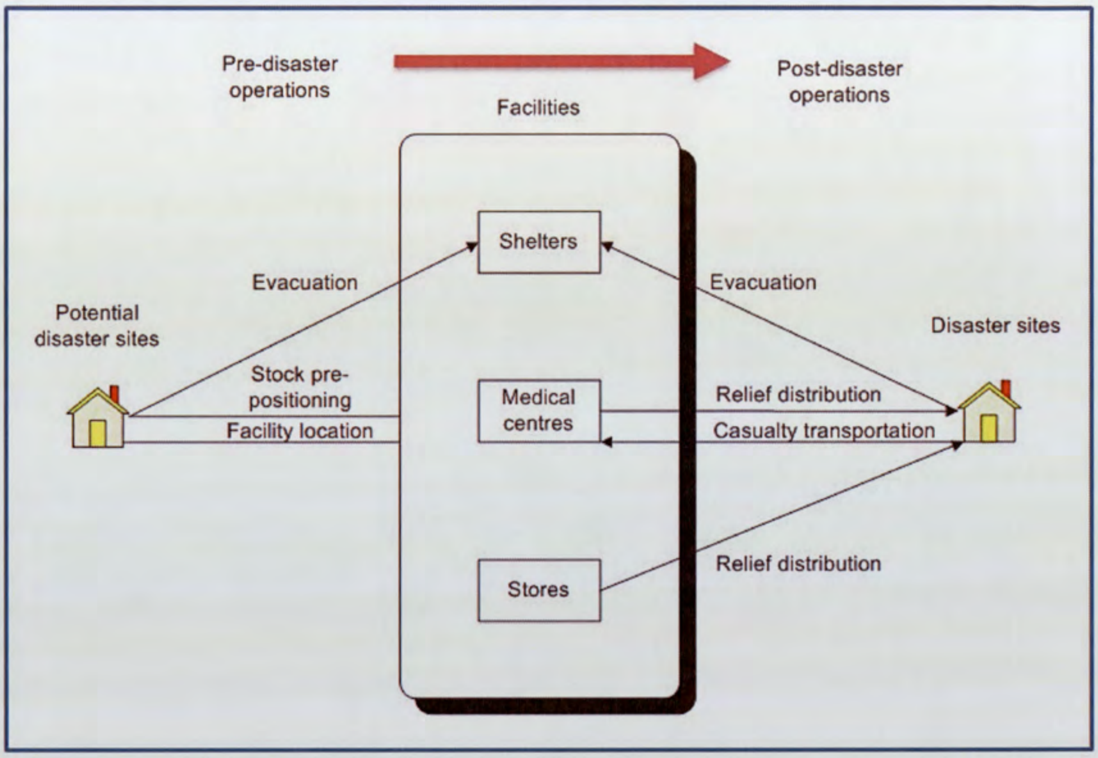

Figure 2.2: Logistical activities during disaster (Source: (Caunhye et al., 2012))

Emergency logistics is relatively new research area (Sheu, 2007a), but there is a continuously increasing body of research which is addressing the challenges like evacuation (Alçada-Almeida et al., 2009, Scheer et al., 2012), stock pre-positioning (Döyen et al., 2012, Campbell and Jones, 2011, Rawls and Turnquist, 2010, Rawls and Turnquist, 2012), facility location (Chen et al., 2013), (Balcik and Beamon, 2008, Chanta and Sangsawang, 2012, Chen et al., 2013, Döyen et al., 2012) casualty transportation (Barbaroso and gcaron, 2004, Martinez) relief distribution (Beresford and Bayasuf, 2008, Mete and Zabinsky, 2010, Sheu, 2007b, Tzeng et al., 2007) for the effective and efficient system.

It is necessary to identify the correct performance measures to perform the above activities. In commercial logistics, there are two dimensions to measure the performance: effectiveness and efficiency (Mentzer and Konrad, 1991). The effectiveness focuses on the logistical goal for example fulfilment on time or in-stock availability (Mentzer and Konrad, 1991). On the other hand, the efficiency is the ratio of resources utilised against the results achieved (Mentzer and Konrad, 1991). In the emergency logistics, availability and supply of the relief items on time will measure the effectiveness of the emergency logistics. Now in an emergency situation, the efficiency is the relevant measure to identify the success of the emergency logistics. The primary goal is to serve the affected community after a disaster with the available relief items. The decision maker needs to manage the efficiency of total emergency logistics process in the context of distance, cost and other to obtain improved quick response. The following Table 2.1 will analyse the individual performance efficiency in the context of emergency logistics, mainly in the response phase.

Table 2.1: The efficiency measures (Developed by the researcher)

Efficiency	**Description**	**Reference**
Cost efficiency/ Financial efficiency	In an emergency situation, the main aim is to save the affected people but minimising the cost always consider as a major factor for the effective emergency logistics process. Here cost efficiency measured in terms of total distance cost, total relief supply cost, penalty cost.	(Rath and Gutjahr, 2014, Liu et al., 2013, Bozorgi-Amiri et al., 2013, Döyen et al., 2012, Vitoriano et al., 2011, Horner and Widener, 2011, Balcik et al., 2008)
Distance efficiency	During emergency situation one of the challenges is to identify the closest distance for the relief transportation, as most of the road network and communication is interrupted because of the disaster. Therefore managing the correct route network, allocation of vehicles, mode of transport etc. are essential issues during a disaster. The aim of distance efficiency is how quickly the relief can reach to the different nodes (affected communities) by minimising the distance. Finally, the demand can be satisfied by minimum timeframe.	(Zhang et al., 2013, Nigam and Jethoo, 2013, Chen et al., 2013, Naji-Azimi et al., 2012, Widener and Horner, 2011, Nolz et al., 2011, Han et al., 2011, Tatham et al., 2010c, Maliszewski and Horner, 2010, Lee et al., 2009a, Jia et al., 2007a, Chang et al., 2007)

Table 2.1 Continued....

Efficiency	Description	Reference
Coverage efficiency	During a disaster situation, the coverage level is considered mainly for the facility decisions (e.g. shelters, distribution centres, medical units among others). The coverage efficiency will be successfully measured when the decision maker can maximise the demand satisfaction with the limited number of facilities, allocated vehicles, and resources.	(Berman et al., 2013, Doerner et al., 2009, Berman et al., 2009, Balcik and Beamon, 2008, Jia et al., 2007a, Jia et al., 2007b)
Service efficiency	In the emergency situation, the service is considered as to help the affected population with the necessary resources and keep the affected population safe. Therefore, the efficiency measure will be considered as maximising the fill rate of the relief items, maximising the demand satisfaction of the affected communities and finally minimise the unmet demand.	(Altay, 2012, Rath and Gutjahr, 2014, Chang et al., 2014, Najafi et al., 2013, Liu et al., 2013, Bozorgi-Amiri et al., 2013, Suzuki, 2012, Ortuño et al., 2011, Han et al., 2011, Mete and Zabinsky, 2010, Yi and Kumar, 2007, Tzeng et al., 2007, Özdamar et al., 2004)

2.3.1 Emergency logistics in preparedness phase

2.3.1.1 Facility Location

According to Galindo and Batta (2013), preparedness phase is the second most researched phase in disaster management. Perry (2007) conducted interviews with the 2004 Indian Ocean tsunami response logistics managers and analysed those findings with the recent academic and practical literature and developed the holistic inclusive planning model. In this phase, the decision maker needs to think about the facility location (i.e. shelters, distribution centres, medical units) to protect the affected population. There are three important components of facility management: the role of a facility, the capacity of a facility and the location of a facility. The role of a facility concerns its purpose (e.g. to be a warehouse and enable distribution). The capacity of a facility concerns its size and functionalities such as throughput (which is affected by the degree of automation). The location of a facility depends on what could be the best geographic location in order to fulfil its purpose (e.g. locating a warehouse in a port). Facility location is an important strategic decision which can significantly impact on disaster management planning. A limited amount of literature only considers facility location independently (Dalal et al., 2007, Jia et al., 2007a). Jia et al. (2007a) optimised the number and location of medical emergency facilities and use a generalisation of the covering, p-median and p-center, adopting the objective function according to the problem. Again a minimax optimisation approach is presented by Dalal et al. (2007) for determination of the location and capacity of shelters using distance as a performance measure.

Kongsomsaksakul et al. (2005) emphasised the necessity of the shelter location for evacuation and use a bi-level methodology for shelter location for the problem of evacuation as well using user equilibrium for the formulation. Shen et al. (2008) and Ng et al. (2010) also choose the same methodological approach for facility location. However, an optimisation approach is found to consider the importance of the location of warehouses for distribution (Balcik and Beamon, 2008). Not only optimisation approach Lee et al. (2009a) combine mathematical modelling, large-scale simulation and powerful optimisation engines and connected them into automatic graph drawing tools and presented a user-friendly interface RealOpt© to deliver a decision support system for facility location. This practical decision support system for emergency response allows public-health emergency coordinator determine locations for facility setup, the floor plan for facilities, perform disease-propagation analysis, identify the dynamic response strategies for casualties and identify the minimum medical resources for treating the casualties. Horner and Widener (2011) used Florida city in the USA as an example to examine the impact of simulated network failure during a hurricane. The authors use the pre-determined location for the relief distribution points by following the passage of a storm. The simulation results demonstrate that the uncertain interruption to the transportation network, produce a noticeable difference in the number and spatial configuration of relief facilities. The transportation network is becoming strong and able to support the relief service provision even at elevated levels of hypothesised interruption.

In the literature, the cost efficiency (El-Anwar et al., 2009, Zhao et al., 2012, Chen et al., 2013), the distance efficiency (Jianming et al. (2012), coverage level (Yushimito et al., 2012) are also considered during facility location setup.

2.3.1.2 Stock pre-positioning

In the preparedness phase, another important activity is stock-prepositioning for the effective and efficient relief supply process (Rawls and Turnquist, 2010). (Balcik and Beamon, 2008)identified and analysed the importance of stock pre-positioning during relief response operation. The authors proposed a maximal covering model, to determine the number and location of the distribution centres and the amount of relief supplies to be stocked in each distribution centres. These results provide important insinuations for the decision makers in the relief system. The essential factors during the inventory pre-positioning are number of facilities, facility points, capacity of facility, allocation, inventory type, inventory policy and transportation policy, which identified by Richardson et al. (2010). A conceptual framework about pre-positing relief items during emergency situation is presented by (Akkihal, 2006). Mixed integer linear programming (MILP) problem is proposed for the prepositioning of emergency relief items for the CARE international NGO (Duran et al., 2011). The upfront investment, like initial inventory stocking and warehouse set-up, average response time and operating costs are the factors which affect the prepositioning network. The model helped CARE to determine the desired configuration of the network and provided a roadmap for the achievement of that configuration as funds become available. CARE able to establish its first prepositioning facility in Dubai 2008, and second and third in Panama and Cambodia respectively on 2009 with the knowledge of this optimisation model. Thus, CARE has prepositioned more than one million sachets of water purification kits in each facility. Facility location with stock pre-positioning is extensively studied literature in the emergency logistics (Campbell and Jones, 2011, Döyen et al., 2012, Rawls and Turnquist, 2010, Chang et al., 2007, Ukkusuri and Yushimito, 2008). Mete and Zabinsky (2010) proposed a stochastic modelling to provide an optimal policy of warehouse selection and inventory levels for medical reliefs in the first stage and also about transportation decision in the second stage. The authors also compared between the developed stochastic model and the deterministic equivalent to demonstrate the better performance of the model.

In the above discussion, the main logistical activities are discussed (facility location, stock-prepositioning), and addressed independently or simultaneously with other problems. The adopted objective in the above area depends on the perspective of the stakeholder. In the preparedness phase sensitivity analysis is the most common approach for the evaluation of the method (Chang et al., 2007, Duran et al., 2011, Rawls and Turnquist, 2010, Döyen et al., 2012), which is catagorised in Table 2.3. Döyen et al. (2012) complemented the sensitivity analysis by using a comparison between the results through the proposed heuristic and commercial software. The comparison approach between results for evaluation of method is also used by Chang et al. (2007) and Mete and Zabinsky (2010). The above discussion is to set up the context of the proposed research. The purpose of the proposed research is mainly aiming to provide an integrated and holistic relief distribution system during the response phase by focusing on resource allocation and LMRD for the relief operation planning. Therefore, however facility location and stock pre-positioning are two important activities but these two logistical activities are lies outside the scope of the proposed research.

2.3.1.3 Evacuation

Evacuation is one of the activities which is performed in both phases preparedness and response. Evacuation is widely studied in the literature (Scheer et al., 2012, Nagarajan et al., 2010, Chen et al., 2007, Chiu and Zheng, 2007, Liu et al., 2007, Hamza-Lup et al., 2008, Lindell, 2008, Kimms and Maassen, 2011, Kimms and Maassen, 2012) and this lies outside the scope of the proposed research. Therefore this review will not include evacuation literature.

2.3.2 Emergency logistics in response phase

Response phase is one of the crucial stages in disaster management, as in this phase, every activity counts whether to save lives or to reduce economic losses. A state director of emergency management said: "I will never lose my job for failing to do mitigation, but I could lose my job if I mess up with response" (Haddow et al., 2011, p 647), which shows the importance of this phase. The aim of this phase is to save lives and prevent major economic losses and environmental problems. The response phase begins immediately after an event and ends when the situation has been stabilised. Altay and Green (2006) justified that response phase is the second researched phase in disaster management but recent research showed that response phase is the most researched phase in disaster management (Galindo and Batta, 2013), which shows that the challenges and uncertainty of this phase need additional research to manage the complexity.

2.3.2.1 Relief distribution

The purpose of relief distribution is to distribute the relief items in the form of food, water, medicine, sanitation, manpower to the disaster-affected community. This is a vital challenge for a response operation because of the uncertainty and the active agencies need to understand the importance of the situation and perform rapidly and efficiently. For example, Beamon and Balcik (2008) proposed a conceptual framework for relief supply chain performance measures by using practitioners interview. In the relief distribution literature, there are two types of proposed models, one is a static model, which provides the planning of distributing the relief for a single period of time (Barbaroso and gcaron, 2004, Arora et al., 2010). Dynamic models involves a preparation prospect divided into several periods.

Barbaroso and gcaron (2004) presented a scenario based two-stage stochastic programming model for transportation decision and validated for earthquake disaster. The objective of this multi-commodity and multi-model network formulation is to minimise the total cost. Another static cost effective model is proposed by Arora et al. (2010) to determine the allocation and redistribution of medical aids. The above model is focusing on the cost associated policy selection by considering the connection between the regions. Davis et al. (2013) proposed a static model to manage the uncertainty of supply and demand and the possibility of disaster into a two-stage scenario-based design. The primary phase is focused on pre-positing decision whereas the final stage is considering distribution by incorporating equity of service. Brown and Vassiliou (1993) established a real-time decision support system for the disaster. The aim of this decision support system is to provide decision in the context of relief resources distribution and assignment by using optimisation techniques, simulation techniques and the decision maker's judgement.

The dynamic models are aiming for single objective divided into several periods in relief distribution. Holguín-Veras et al. (2013) analysed the objective function by combining the logistical cost and social cost for the economic welfare during relief distribution operation. In this context, the author combines all the private logistical cost associate with the impact of the delivery actions on the population for the consideration of the social cost. The total social cost is equal to the summation of the deprivation costs at discrete time periods, plus the summation of the deprivation costs for all nodes outstanding at the end of the planning horizon. The objective of this model is to minimise the unmet demand. The authors use non-linear non-convex approach to compare with penalty based models and the results show that the inclusion of social cost can improve the quality of the solution. After a large-scale disaster, the economic transaction of the affected regions is destroyed as well as the normal business are also interrupted because of the limited credit. In that situation, it is essential to estimate the correct social cost by integrating all the private and external cost and obtain the economic benefit.

Sheu (2014) suggested a conceptual framework for a comprehensive analysis of the perception-attitude-resilience relationship of the survivors for response operation. The author used structural equation modelling on questioners for the validation perspective. The outcome is used to classify survivor-specific disaggregate attitudinal functions and proposed a service distribution model. The objective of this centralised dynamic model is to minimise the cost whereas maximising the collective resilience of the survivors. Sheu (2007b) also proposed a bi-objective model for the three days of rescue period using forecasting, clustering and dynamic relief supply for the relief distribution logistical operation. The aim of this bi-objective model is to maximise the fill rate and minimise the distribution cost and this model is solved by using the weighted-sum method. Sheu (2010) complemented the previous research by proposing multi-criteria optimisation for the identification of the relief demand urgency for the individual clusters to rank the associated demand for distribution. The complexity of managing relief

distribution with a single performance metrics is very difficult, therefore Sheu (2007a) started with more than one objective function to reduce the complexity of the relief distribution.
Huang et al. (2015) followed the multi-objective concept and integrated three objective functions: maximise the lifesaving efficacy (i.e. preference the affected people regarding the relief resources), minimise delay cost as a measure of human suffering and minimise the sum of squares of the distance between the demand fill rates and the ultimate demand rate. The proposed model is presented to be a convex quadratic network flow problem and solved by the weighted-sum method and an efficient variation inequality algorithm.
Liberatore et al. (2014) proposed a multi-objective model, which is aiming to maximise the total reached demand, minimise the maximum distance from every attribute from its ideal values, which is determined by reliability, security and demand satisfaction and minimise the sum of the attribute distance. A three-level lexicographic model is used for the solution approach. Ortuño et al. (2011) used the same lexicographic approach for prioritisation of the objective function to determine the amount of relief items to send and the used routes by a fleet heterogeneous vehicle. The primary objective is to assign the first priority of the model and then the following priorities are a combination of the cost to budget, travel time, maximum ransack probability and minimum reliability in links, equal distribution of relief items and urgency grade for a single node. Another lexicographic approach is proposed by Tirado et al. (2014) for the relief distribution. The authors analyse the delivery of aid as the first priority by minimising the difference between the planned aid to be distributed and the aid sent. The following priorities are time, cost and highest unsatisfied demand.
Vitoriano et al. (2015) described intelligent decision-making models for disaster management by introducing two multi-criteria decision-making model where one for the assessment of consequences and another for the final relief distribution. Vitoriano et al. (2011) focused to minimise the time of response, maximise the equity of the distribution, consider the security of the relief materials for relief distribution by proposing another multi-criteria optimisation model. The proposed model is validated by the case study of Haiti earthquake 2010. Widener and Horner (2011) proposed a hierarchical capacitated-median model for the efficient placement of facilities for distribution relief services for post-hurricane. The authors combine the optimisation model with GIS for the efficient allocation of distribution facilities and this model is solved by Cplex®. In the analysis perspective GIS only used to create a cost matrix based on distance. Another multi-objective, multi-vehicle and multi-period model is proposed by Lin et al. (2011) and solved by using weighted sum method by Cplex®. The objective of this model is to minimise penalties related to unsatisfied demand, travel time and the different demand satisfaction rate between nodes.

Lee et al. (2009b) presented a simulation model for the disaster response, where the main purpose is to model the supply chain of relief supplies, distribution operations at the point of distributions, dynamics of demand and progression of disasters. In this research, the authors introduced a modelling framework i-DRuM, which uses simulation and optimisation for effective analysis of disasters relief plans and operations. Monte Carlo simulation is used for the development of emergency logistics response model (Tatham et al., 2010a). The outcomes of this emergency response model depend on the simulated outputs, which help the decision makers to refine the decision making capability. But this model still needs to be validated in real life examples. Crooks and Wise (2013) proposed a prototype model by using ABM simulation with the help of crowdsourced geographic information and other sources of publicly available data to demonstrate that how people react during the aid distribution and rumours relating to aid availability. Some key success factors of the emergency relief chain in the cyclone Larry (March 2006) in Australia was identified and analysed by Oloruntoba (2010). The result is based on the document analysis and semi-structured discussions with disaster managers related to the cyclone relief management process and emergency relief chain undertaken by disaster management agencies.

The importance of managing inventories during relief distribution is another challenging effort (Clay Whybark, 2007). The author explains about the disaster relief, characteristics of disaster relief inventories and the importance of disaster relief inventories with the help of thorough review of practitioner's perspective and academic perspective of the literature. According to (Whybark et al., 2010), there is a limited research available in disaster inventories, but the significance of this subject is focused by (Van Wassenhove, 2006). A time-dependent stochastic model is proposed for the inventory planning and management plan during the post-disaster operation (Ozbay and Ozguven, 2007). The main objective of this research is to determine the minimum safety stock so that during disaster response operation the stocked goods can be supplied to the affected people without disruption, though there are few things need to add in this model like transportation cost, additional item cost etc. for the better performance of this model.

Transportation management is another substantial issue for relief distribution. During the relief distribution, the decision maker needs to identify how to deliver the relief items? Where to deliver? Which route should they use for the delivery? And finally how many allocated vehicle they can use for the delivery? It is necessary for the decision maker to consider all the above questions and also need to have a clear identification of transportation cost during the relief distribution operation. There are more than one activities are performed during relief distribution operation. Casualty transportation (how to transport the affected population to the shelters, medical centres etc.) and routing and scheduling (the selection of routes to supply the relief items and also the allocated number of vehicles for the supply of relief) are two significant activities for a successful relief distribution operation.

2.3.2.1.1 Casualty transportation and relief distribution

Casualty transportation is to transport the affected people to the medical centres and shelters during the relief distribution time (Caunhye et al., 2012). In most of the literature, casualty transportation and relief distribution are always considered together (Barbarosoğlu et al., 2002), Tatham et al. (2010a), (Yi and Özdamar, 2007, Yi and Kumar, 2007, Ozdamar and Yi, 2008). For example, AHP combined with MILP is used for helicopter mission planning during a disaster relief operation (Barbarosoğlu et al., 2002). The authors decomposed the hierarchical process of assigning helicopter into two subproblems, top level and primary level. The tactical decisions at the top level, like determination of the helicopters fleet composition by assigning helicopters from the air force base to the operation base, the assignments of pilots, the determination of a number of tours for the helicopter are calculated. The primary level operational decisions like routing and loading decisions, a rescue plan for each helicopter, the refuelling scheduling for each helicopter are addressed. During disaster relief operation the number of helicopters, the number of tours per helicopter, the detailed routing and delivery scheduling decisions are treated as hierarchically. In the second stage, the AHP is used to evaluate and select the best solutions to the decisions makers in order to specify their preference. Najafi et al. (2013) addressed the multi-objective, multi-period casualty transportation model by using stochastic modelling by incorporating humanitarian and cost issues for managing both disaster relief commodities and affected people during earthquake response. This paper considers the network structure as constant but after a large scale earthquake demands, travel time (due to damage of road network), capacity always uncertain. Therefore optimised network will present better performance of this model.

Gong and Batta (2007) proposed hierarchical cluster and routing procedure to minimise the total length of the schedule and minimisation of the weighted total flow time for casualty transportation and relief distribution by using probabilistic approach and simulation. Yi and Özdamar (2007) combined relief distribution and casualty transportation hierarchically and propose mixed integer multicommodity network flow model to minimise weighted sum of unsatisfied demand and wounded people waiting. The output of this model produced a detailed vehicle route and loading instruction scheduling, followed by the solution approach of a linear system of equations defined in a very restricted domain. Fiedrich et al. (2000) explain about allocating technical resources for minimising the number of fatalities after a major earthquake by presenting an optimisation model. In this paper, casualty transportation is only controlled without relief distribution.

2.3.2.1.2 Relief distribution, routing and scheduling

The purpose of relief distribution is to rapidly respond with emergency supplies to the disaster affected people. Some of the previous researchers combine vehicle routing and scheduling with relief distribution to overcome the challenges during relief distribution time.

The purpose of Rathi et al. (1992) is to assign a limited number of vehicles loading for multiple types of goods in given pairs of origins and destinations such that the induced multi-commodity flow problem is solved with minimal penalties caused by delivery inefficiency. Rathi et al. (1992) proposed a three-stage linear programming formulation, where the routes and the supply amount carried on each route are assumed to be known in each of the given origin-destination pairs.

As it is very difficult to solve the disaster logistics distribution problem, recently there is a trend to decomposing the main problem into mutually correlated subproblems and then solve that subproblem in the same decision scheme. For example Özdamar et al. (2004), incorporated the vehicle routing problem into the relief distribution process, in which vehicles are treated as commodities to simplify the comprehensive disaster logistics distribution problem into two multi-commodity network subproblems, the first one is linear (for conventional commodities) and the second one is integer (for vehicle flows) and then the authors solve that problem using Lagrangian relaxation. The objective of the previous model is to minimise unsatisfied demand through the planning horizon. De Angelis et al. (2007) maximise the total demand satisfied by considering the limitation on the supply and presume the amount of food supplied to the various localities should satisfy some lower bound on the percentage of the quantities for each of the affected communities for deliveries of food aid during relief distribution time. This developed model is a real case oriented multi-depot, multi-vehicle routing and scheduling model for the air food distribution in Angola based on the WFP operation on 2001.

Yi and Kumar (2007) constructed an ant colony optimisation algorithm for the vehicle routing construction and multi-commodity delivery. The goal of this model is to minimise unsatisfied demand and unserved wounded people who are waiting for health care services. Ozdamar (2011) is focusing on helicopter routing, scheduling and dealing with arc flows into vehicle routes. The model calculates fuel consumptions, determines the refuelling stops and constructs the flying itinerary. The objective of this model is to minimise the transportation and loading time to obtain the information used in the post-processing stage. Another transportation problem is presented by Berkoune et al. (2012), which is explaining about the docking times, loading and unloading time for minimising the total transportation time. Shen et al. (2009)

proposed two-stage stochastic programming model for generating the routes in advance of any emergencies and for the delivery quantity decision. The model is aiming to minimise the combination of unmet demand and arrival time at each node, and allowing for the arrival time as a subordinate objective. Tabu search heuristic approach is used for the solution method of this model.

Yan and Shih (2009) proposed a static bi-objective, multi-commodity, multi-modal network flow problem to minimise the time required for emergency roadway repair and relief distribution during an earthquake. The model is solved by using the weighted-sum method and implementing a heuristic. Bemley et al. (2013) proposed a relief distribution model by using the multi-objective programming method for designing relief delivery systems. The model features three objectives: minimising the total cost, minimising the total travel time and maximising the minimal satisfaction during the planning period.

There is some stochastic approach also presented to manage the challenges during relief distribution. For example, Tricoire et al. (2012) present a stochastic optimisation model for minimising the total cost and uncovered demand for the vehicle routing problem. The authors considered these constrains that a certain percentage of people can decline to go to the nearest distribution centre, distribution centres are tour stops, uncertainty on the demand and more than one type of vehicle. Finally, the authors adapted the model by using the sample average and then compared an exact approach with a heuristic algorithm for analysis of the model's performance. For the solutions approach, Tricoire et al. (2012) compared the performance of an exact algorithm and a heuristic algorithm while Lin et al. (2011) provided a comparison between solution and algorithms to provide the exact changes of demand satisfaction per time period, which demonstrated the efficiency of the model. In the above two cases comparing the solution, algorithms are more effective as this can give the exact changes of demand satisfaction for specific time period. Afshar and Haghani (2012) demonstrated an integrated model based on FEMA's logistical structure to improve the movement of several relief items, vehicle routing, pick-up and distribution schedules and location of facilities with the objective of minimising the total unsatisfied demand for disaster victims and it is solved through Cplex®. Snyder and Daskin (2005) proposed a multi-objective approach for the choice of facility location to minimise the operational and failure costs, by considering the increasing transportation costs incurred due to the failure. Two weighted objective functions are combined to solve the above model by using Lagrangian Relaxation. A location-distribution model is explained by using heterogeneous vehicles, controlling the maximum travelled distance by Naji-Azimi et al. (2012). The objective is to minimise the total distance travelled by the fleet and the solution of the model is proposing a heuristic approach incorporated with the pre-processing, initialisation and local search during a response operation.

Hu (2011) presented an integer linear programming model to form the path selection for container supply chain. The author uses a simulation study to show the performance of the model. Though the researcher concentrates on dealing with the complexity of relief distribution by incorporating a higher level of details, still there is a lack of fuel consideration. Suzuki (2012) projected the importance of fuel by implicating the fuel availability in the aftermath of a disaster by maximising the minimum per-capital meal availability among the shelters subject to constraints of fuel. Martinez et al. (2011) conducted more than 40 interviews with the international humanitarian organisations (the international committee of red cross, the international federation of red cross and red crescent society, the world food program and world vision international) to find out the fleet management process and the critical factors which affect the fleet management process of international humanitarian organisation. This study fills the gap in the humanitarian logistic existing literature regarding the vehicle fleet management. It also analyses and explains the importance of fleet vehicle management research for the humanitarian logistics.

2.3.2.1.3 Last Mile Relief distribution

LMRD is the ultimate stage of relief operation (Decker, 2013). This is the stage where the practitioners, responders and volunteers directly connected with the disaster affected population. "Last mile relief distribution is the final stage of a humanitarian relief chain: it refers to delivery of relief supplies from local distribution centres to beneficiaries affected by disasters" (Balcik et al., 2008, p 51). During a disaster situation, the delay of relief supplies can mean life or death.

The following Figure 2.3 will setup the exact location of LMRD during disaster relief supply chain. Mainly Figure 2.3 explains that after a huge impact disaster the relief will reach to central warehouse from the primary hub and from there it will go to the local distribution centre or tertiary hub from where the relief will be distributed according to the affected regions. The Figure 2.3 shows that from the local distribution centre (tertiary hub) the information of demand and supply of relief items are transforming to the nearest nodes and from that nodes, the information follow to the next node and so on. There are a couple of consequences of this structure. First of all, after a large scale earthquake, there is a significant amount of transportation network damage, so transporting the relief items from central warehouse to local distribution centre and from local distribution centre to the affected nodes will be a challenge. And this critical issue can delay the relief chain operation. One noticeable consideration is that every organisation has this relief chain structure. The affected country's government, as well as all the national and international NGOs, have this relief chain structure individually. After a large-scale earthquake, there are a significant number of agencies (governmental, non-governmental, private and many more) reach to the affected area to help the beneficiaries by providing relief and support. As the area is fully affected by building damages, road collapse, so it is actually hard to identify individual facilities for individual agencies to store the relief items. As a result, though the agencies have enough relief it is hard to identify the essential facilities for local distribution centres, which also can cause the delay of relief chain operation.

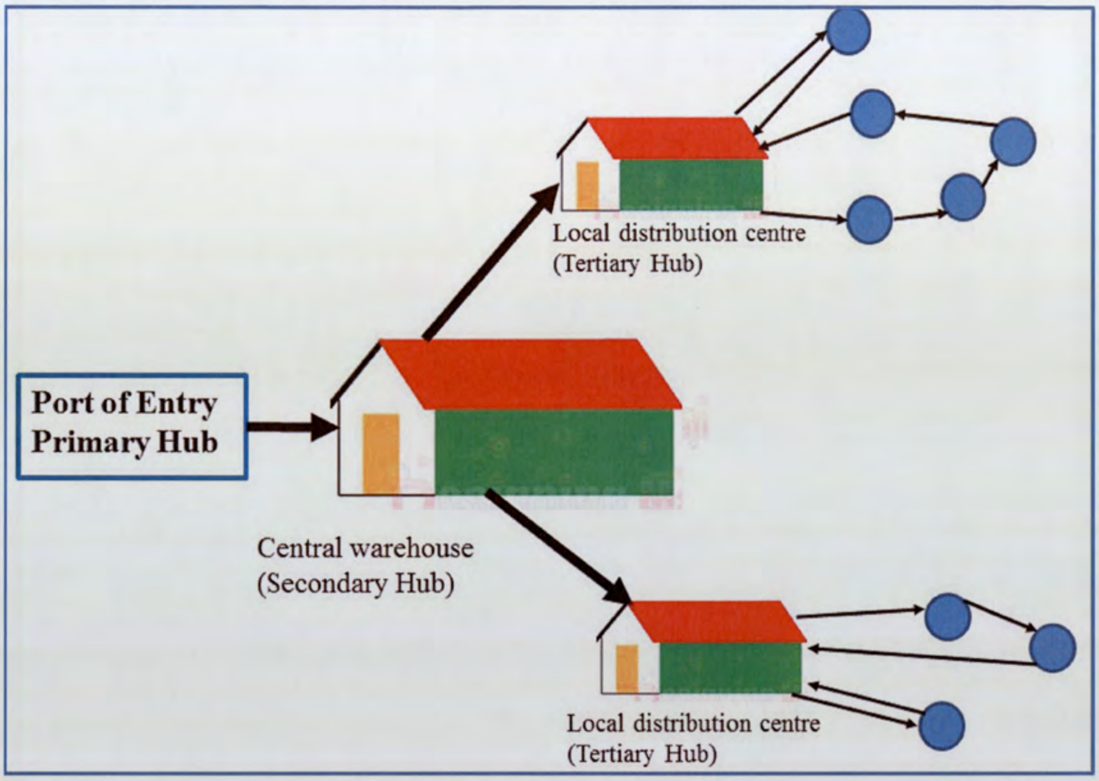

Figure 2.3: Structure of the relief chain (Source: UNDP Disaster Management Training Programme modified by (Balcik et al., 2008)).

LMRD is presented by Knott (1987), who proposed the delivery of food item from a distribution centre to the several camps by using one single transportation. The author proposed a linear programming model to maximise the amount of food delivery and minimise the transportation cost and conclude that this problem is very complicated for classical operational research models and solution techniques. To overcome this challenges the author combined operation research heuristics with artificial intelligence techniques to develop a decision support system for allocation of relief and distribution of relief item (Knott, 1988). Haghani and Oh (1996) demonstrated and solve a multi-commodity, multi-modal network flow model for the transportation of various different relief items to minimise the number of casualties and maximise the efficiency of the rescue operation. Arda (2004) advanced the above model by considering included uncertainties during estimation of resource needs of first aid goods, the vulnerability of resources suppliers and survivability of the routes in the disaster region with a two-stage stochastic programming model. Balcik et al. (2008) presented an optimisation model to minimise the total transportation cost for unsatisfied and late satisfied demand for different types of relief items and the proposed model is solved by heuristics algorithm. A case study is conducted in IFRC for the LMV supply chain strategy (Martinez et al., 2011). The main aim of this research is to analyse the framework of agility, adaptability and alignment for the LMV supply chain including cost effectiveness. The IFRC LMV supply chain can prepare to respond quickly to unforeseen changes in demand due to disaster, which is the outcome of being agile. This study concludes that the agility is achieved by combining flexible vehicle procurement, prepositioning stock for disaster response, quick assessment for demand needs and centralised information system. Battini et al. (2014) presented a conceptual model for the resource allocation and vehicle routing for specifically Haiti earthquake 2001. In this model, the authors consider about the transportation resources in a complex situation, vehicle capacity and delivery time restrictions. Different scenario analysis and sensitivity analysis are presented for the performance of this model. Das and Hanaoka (2014) demonstrated an ABM simulation model for fleet allocation of LMRD after a large scale disaster. In this model, the authors included five agents: aid organisation agent, carrier agent, demand agent, society agent and coordinator agent. This agent base model investigated about the transportation measure and makes a clear understanding about the demand management during relief chain process. The above literature explains the essentiality of transportation decision and mainly fleet management decision during LMRD. In the LMRD, the researcher mostly concentrates on fleet management, transportation management but there is a necessity for more critical evaluation, in the context of increasing the performance of relief distribution efficiency and effectiveness and to recognise and identify the exact challenges which reduce the efficacy of LMRD performance.

Decker (2013) clarified that there are some challenges for example lack of recognition of the importance of logistics, lack of professional staff, inadequate use of technology, lack of institutional learning and limited collaboration are the other challenges which also affect the relief supply chain, mainly LMRD. Primarily in the relief supply chain, LMRD is about the distribution of the accurate amount of demand, at the exact time to the correct place (Decker, 2013) to fulfil the urgent need of the affected people. Table 2.1 shows the performance efficiency measures of emergency logistics. The following Table classifies a summary of performance efficiency measures for LMRD.

Table 2.2: Performance measures of LMRD (Developed by the researcher)

Performance measures of LMRD	**Working definition**	**References**
Cost efficiency	The primary goal of this measure is to minimise the cost	(Balcik et al., 2008, Knott, 1987, Martinez et al., 2011)
Distance efficiency	The aim of this measure is to minimise the distance and maximise the coverage level of the affected area	(Haghani and Oh, 1996, Barbaroso and gcaron, 2004)
Service efficiency	This efficiency measure is concentrated on maximising the fill rate of the relief items, maximising the demand satisfaction of the affected communities.	(Battini et al., 2014, Das and Hanaoka, 2014)

The above literature shows the key role of relief distribution during a disaster. Relief distribution is a complex and challenging task during an emergency situation. Researchers have concentrated on dealing with the complexity by incorporating a higher level of details into the model and combine relief distribution with other activities and introduced multi-criteria approaches. Not only the quantitative approach (Ortuño et al., 2011, Ozbay and Ozguven, 2007, Sheu, 2007a), qualitative approach (Ortuño et al., 2013, Oloruntoba, 2010, Martinez et al., 2011, Beamon and Balcik, 2008) but also some combined approach (Alçada-Almeida et al., 2009, Chang et al., 2007) used to solve the uncertainty and challenges during relief distribution. The following Table 2.3 is a catagorisation Table, which classifies the individual activities for preparedness and response phase. Also the following Table will catagorise the specific applied model, model types used per individual activities and finally the chosen validation technique for the models.

Table 2.3: The summary Table for literature review (Developed by the researcher)

Phases of disaster	Logistical activities	Applicable model	Model types	Validation	Disaster type	References
Preparedness Phase	Facility location	Optimisation	Mono-objective, Multi-objective, Two-stage,	NA, Comparison of the results of the three models proposed with traditional facility location models, Comparison between the results of the three heuristics and Cplex, Scenario comparison, Compare the performance of building backup facilities, allowing existent facilities to become backup facilities, incorporating vulnerability, Comparison between the results of the heuristic and a decomposition technique, Comparison of results between the solution approach and ILOG Cplex, Comparison between the results of the heuristics and Baron	Any (any type of disaster is the dominant) Tsunami and earthquake,	(Dekle et al., 2005, Hale and Moberg, 2005, Jia et al., 2007a, Jia et al., 2007b, Yazici and Ozbay, 2007, Balcik and Beamon, 2008, Ratick et al., 2008, Doerner et al., 2009, Huang et al., 2010, Li and Ouyang, 2010, Mete and Zabinsky, 2010, Rawls and Turnquist, 2010, Görmez et al., 2011, Li et al., 2011, Yushimito et al., 2012)
		Optimisation and GIS, Optimisation	Two-objective, multi-	Comparison between the stochastic model and the equivalent deterministic model and sensitivity analysis,	Floods, Huricanes, Any,	(Chang et al., 2007, Horner and Downs, 2007, Ukkusuri and Yushimito, 2008,

Table 2.3 Continued....

Phases of disaster	Logistical activities	Applicable model	Model types	Validation	Disaster type	References
		and algorithms, Optimisation, Simulation and GIS	objective, mono-objective	Sensitivity analysis, NA, Comparison of the results of the three heuristics on the set of examples presented by Beasley (1990), Sensitivity analysis, Comparison between the current system and the result of the allocation model		Berman et al., 2009, Horner and Downs, 2010, Maliszewski and Horner, 2010, Horner and Widener, 2011, Shiomi et al., 2011)
		Analytic hierarchy process and fuzzy theory	NA	Comparison of the results of AHP and Fuzzy AHP	Any	(Tuğba Turğut et al., 2011)
	Stock pre-positioning	Optimisation and GIS	Two stage multi-commodity and multi-organisation (hierarchy)	Comparison between the stochastic model and the equivalent deterministic model	Any	(Chang et al., 2007)
		Optimisation	Two stage, multi-	Analysis of scenarios; Sensitivity analysis and comparison	Any,	(Mete and Zabinsky, 2010, Balcik and Beamon, 2008)

Table 2.3 Continued....

Phases of disaster	Logistical activities	Applicable model	Model types	Validation	Disaster type	References
			commodity, Mono objective, multi-commodity, Two stage and multi-organisation, Multi-objective and multi-commodity,	between Lagrangian L-shaped method solution and Cplex, Sensitivity analysis, Analysis of extra performance measures proposed, sensitivity analysis, analysis of scenarios; Comparison of the model proposed a model based on cost, another based on shortages and a model based on LP metrics for sensitivity analysis		(Duran et al., 2011, Davis et al., 2013, Bozorgi-Amiri et al., 2013)
		Optimisation and algorithms	Mono objective	NA	Any	(Ukkusuri and Yushimito, 2008)
		Probability and	Multi commodity,	Comparison between heuristics	Any	(Campbell and Jones, 2011)

Table 2.3 Continued....

Phases of disaster	Logistical activities	Applicable model	Model types	Validation	Disaster type	References
		optimisation				
		System dynamics and simulation	NA	Comparison between three scenarios: no preparedness activity (Scenario A), investment in physical preparedness activities (Scenario B, pre-positioning of inventory), and investment in intangible preparedness activities (Scenario C, investing in DMC), comparison of the outcomes of the model to the empirical results of a case study research and sensitivity analysis	Any	(Kunz et al., 2014)
Preparedness and Response phase	Facility location and Stock pre-positioning	Optimisation	Two stage and multi-commodity, Mono objective and multi-organisation	NA, Sensitivity analysis, Comparison of the model adapted to the framework of the model developed by Rawls and Turnquist (2010) and comparison of the performance of the two algorithms with Cplex, Calculation of the value of the stochastic solution and the expected value	Any, Earthquake ,	(Li et al., 2011, Edrissi et al., 2013, Noyan, 2012, Döyen et al., 2012)

Table 2.3 Continued....

Phases of disaster	Logistical activities	Applicable model	Model types	Validation	Disaster type	References
				of perfect information		
Preparedness Phase	Stock pre-positioning and relief distribution	Optimisation	Mono objective and multi-commodity	NA	Any	(Bozkurt and Duran, 2012)
	Stock pre-positioning	Conceptual framework	NA	NA	Any	(Richardson et al., 2010)
Response Phasel	Relief distribution, Stock prepositioning and resource management	Optimisation	Mono objective, multi commodity, multi organisation	Scenario comparison	Any	(Arora et al., 2010)
	Casualty transportation, routing and relief distribution	Optimisation; Optimisation and algorithms	Bi-level and multi-commodity; Mono objective,	NA; Comparison of the results of the heuristic with ILOG Cplex; Comparison of the two-stage modelling approach with a VRP based single-stage	Any, Earthquake	(Ozdamar and Yi, 2008, Barbarosoğlu et al., 2002, Yi and Kumar, 2007, Yi and Özdamar, 2007, Ozdamar, 2011, Najafi et al., 2013)

Table 2.3 Continued....

Phases of disaster	Logistical activities	Applicable model	Model types	Validation	Disaster type	References
			multi-commodity and multi-vehicle; Two stage, multi-commodity and multi-vehicle; Mono objective and multi-commodity;	formulation and scenario analysis; Comparison between the results of the algorithm and Cplex; scenario analysis;		
	Casualty transportation, routing and relief distribution	Simulation and fuzzy theory	NA	NA	Any	(Tatham et al., 2010a)

Table 2.3 Continued....

Phases of disaster	Logistical activities	Applicable model	Model types	Validation	Disaster type	References
	Relief distribution, routing and scheduling	Optimisation; Optimisation and simulation; Analysis of the emergency logistics by semi-structured interview with the International humanitarian organisation's practitioners	Mono objective, multi-commodity, multi-vehicle and multi-period; Mono objective and multi-commodity; Mono objective, multi-period and multi-vehicle; Multi-	Comparison between the results of the algorithm and GAMS, and also comparison of the algorithm on the case study to a greedy heuristic; NA; Comparison of the result of the model with schedules reality; Scenario analysis, sensitivity analysis and comparison of the model to individual models for roadway repair and relief distribution functioning independently	Any,	(Özdamar et al., 2004, Rathi et al., 1992, De Angelis et al., 2007, Shen et al., 2009, Bemley et al., 2013, Afshar and Haghani, 2012, Hu, 2011, Martinez et al., 2011)

Table 2.3 Continued....

Phases of disaster	**Logistical activities**	**Applicable model**	**Model types**	**Validation**	**Disaster type**	**References**
			objective;			
	Casualty transportation and resource allocation	Clustering and simulation and	Multi-period	Analysis of scenarios in the simulation based on HAZUS	Any	(Gong and Batta, 2007)
	Relief distribution	Optimisation; Conceptual framework; Optimisation and GIS; Simulation and GIS; Document analysis and semi-structured interview with disaster	Mono objective and multi-period; Multi-objective; Bi-objective; Bi-level; Multi-criteria; NA;	Comparison between the results of the solution approach selected and a reference model, and with a simple decision tree heuristic; Structural equation modelling on questioners; Sensitivity analysis; NA;	Any, Earthquake	(Rottkemper et al., 2011, Holguín-Veras et al., 2013, Sheu, 2014, Sheu, 2007a, Sheu, 2007b, Huang et al., 2015, Liberatore et al., 2014, Ortuño et al., 2011, Tirado et al., 2014, Vitoriano et al., 2011, Crooks and Wise, 2013, Oloruntoba, 2010, Falasca and Zobel, 2011)

Table 2.3 Continued....

Phases of disaster	**Logistical activities**	**Applicable model**	**Model types**	**Validation**	**Disaster type**	**References**
		managers				
	Last mile relief distribution	Optimisation; Conceptual framework; Agent-based simulation; Conceptual framework;	Mono objective, multi-commodity and multi-vehicle; Mono objective; NA;	Comparison between different instances; NA; Comparison between different size (small and large) of network; Scenario analysis and Sensitivity analysis; NA;	Any, Earthquake	(Balcik et al., 2008, Knott, 1987, Haghani and Oh, 1996, Battini et al., 2014, Das and Hanaoka, 2014, Decker, 2013, Ergun et al., 2014)

2.4 Operations research in emergency logistics

The previous literature review about emergency logistics clarify that among other techniques operational research techniques is also used in emergency logistics literature. The logistical activities are becoming very complex and challenging due to the emergency situation. Altay and Green (2006) described the role of Operations Research (OR) and Management Science (MS) is to include suitable techniques to provide contributions in the emergency logistics perspective. Operations research is a scientific approach for the decision making process, which pursues to understand the design and operate a system within an unusual situation (Winston, 2004). Operations Research include the suitable and the broad set of techniques (i.e. mathematical modelling, probability and statistics, simulation, decision theory and multi-attribute utility theory, fuzzy sets, stochastic programming, expert system and soft OR (Operation Research)) to provide contribution on emergency logistics, as highlighted by Altay and Green (2006). Mathematical modelling is the most commonly used techniques in disaster management, followed by decision theory, simulation, multi-attribute utility theory, probability and statistics (Galindo and Batta, 2013, Albores et al., 2013, Altay and Green, 2006). Galindo and Batta (2013) added conceptual analysis and combined method for the advancement of OR techniques. Conceptual analysis is the "reflections on a field of disaster operation management (DOM) without applying any analytical technique" (Galindo and Batta, 2013, p 204), whereas combined method is to combine more than one method to use the advantage of each method to overcome the challenges in DOM. Conceptual analysis techniques users are growing gradually in emergency logistics (Wassenhove, 2006, Richardson et al., 2010, Akkihal, 2006, Jahre et al., 2007, Kovács and Spens, 2011, Tatham et al., 2009, Beamon and Balcik, 2008, Leseure et al., 2010). A conceptual framework is created to distinguish between actors, phases and logistics processes in disaster relief operation (Jahre et al., 2007). Leseure et al. (2010) proposed the advantage of using the operation research techniques and business techniques in the emergency logistics and the importance of supply chain process through the analysis of academic literature. For example, Hu (2011) combined the mathematical model to optimise the route selection for relief (container) supply chain and simulation to validate the model. (Beamon and Kotleba, 2006) used a mathematical model for the development of inventory strategy during an emergency situation in South Sudan and combine with simulation to validate the model and also use statistical analysis to verify the performance of the model. Again Afshar et al. (2009) used mathematical programming for their optimisation model, combine with monte carlo simulation for verification of the model and also use statistical analysis for the risk estimation. According to Galindo and Batta (2013) "simulation and statistics seem to be the techniques most frequently combined with others" (Galindo and Batta, 2013, p 204) and mostly simulation is used for the validation purposes in the DOM. According to Altay and Green (2006) in DOM there are 11.9% of operational research used simulation techniques, which shows that simulation is also a well-accepted technique in DOM for building a model of a real or proposed system to understand the behaviours of a specific system. The following Table 2.4 is providing the summary of the applicable set of techniques to the identified problems in emergency logistics.

Table 2.4: The applicable set of techniques to the identified problems in emergency logistics (Developed by the researcher)

Identified problems	Applicable set of techniques	References
Facility location, shelter location, supply and storage location, emergency service location or any other location problem	Mathematical modelling	(Dekle et al., 2005, Hale and Moberg, 2005, Chang et al., 2007, Horner and Downs, 2007, Jia et al., 2007a, Jia et al., 2007b, Tzeng et al., 2007, Yazici and Ozbay, 2007, Yi and Özdamar, 2007, Balcik and Beamon, 2008, Ratick et al., 2008, Ukkusuri and Yushimito, 2008, Berman et al., 2009, Doerner et al., 2009, Lee et al., 2009a, Horner and Downs, 2010, Mete and Zabinsky, 2010, Ng et al., 2010, Görmez et al., 2011, Shiomi et al., 2011, Li et al., 2012, Maliszewski et al., 2012, Yushimito et al., 2012, Berman et al., 2013, Lu, 2013, Rath and Gutjahr, 2014) (Huang et al., 2010)
	Probability and statistics	(Li and Ouyang, 2010)
	Mathematical modelling and GIS;	(Maliszewski and Horner, 2010, Coutinho-Rodrigues et al., 2012, Chen et al., 2013)
	AHP and fuzzy theory	(Tuğba Turğut et al., 2011)
Facility location and pre-positioning	Mathematical modelling	(Rawls and Turnquist, 2010, Campbell and Jones, 2011, Duran et al., 2011, Li et al., 2011, Rawls and Turnquist, 2011, Bozkurt and Duran, 2012, Bozorgi-Amiri et al., 2012, Döyen et al., 2012, Noyan, 2012, Bozorgi-Amiri et al., 2013)
Facility location and relief distribution	Mathematical modelling; Mathematical modelling and GIS;	(Han et al., 2011, Horner and Widener, 2011, Widener and Horner, 2011, Edrissi et al., 2013)
Facility location and traffic routing	Mathematical modelling;	(Naji-Azimi et al., 2012)
Stock prepositioning	Mathematical modelling	(Arora et al., 2010, Adida et al., 2011)

Table 2.4 Continued....

Identified problems	Applicable set of techniques	References
	Soft OR	(Richardson et al., 2010)
Stock prepositioning and relief distribution	Mathematical modelling	(Davis et al., 2013, Kunz et al., 2014, Noyan, 2012)
Relief distribution and humanitarian supply chain	Soft OR	(Oloruntoba and Gray, 2006, Oloruntoba, 2010, Perry, 2006, Van Wassenhove, 2006, Jahre et al., 2007, Glenn Richey Jr et al., 2009, Tatham et al., 2009, Tatham and Houghton, 2011, Beamon and Balcik, 2008, Whybark, 2007, Ichoua, 2010, Long and Wood, 1995)
Relief distribution and routing and scheduling	Soft OR	(Martinez et al., 2011)
	Mathematical modelling and simulation	(Chang et al., 2014)
	Mathematical modelling	(Najafi et al., 2013, Rathi et al., 1992, Özdamar et al., 2004, Shen et al., 2009, Bemley et al., 2013, Yan and Shih, 2009, Tricoire et al., 2012, Afshar and Haghani, 2012, Lin et al., 2011)
Relief distribution	Simulation	(Tatham et al., 2010a, Chang et al., 2014, Das and Hanaoka, 2014)
	Mathematical modelling and simulation	(Hu, 2011)
	Simulation and GIS	(Crooks and Wise, 2013)
	Mathematical modelling	(Wu et al., 2013, Liu et al., 2013, Tricoire et al., 2012, Arora et al., 2010, Holguín-Veras et al., 2013, Sheu, 2007b, Sheu, 2010, Huang et al., 2015, Liberatore et al., 2014, Tirado et al., 2014, Ortuño et al., 2011, Vitoriano et al., 2011, Vitoriano et al., 2015)

Table 2.4 Continued....

Identified problems	Applicable set of techniques	References
Relief distribution and casualty transportation	Mathematical modelling, simulation and GIS	(Horner and Widener, 2011)
	Mathematical modelling	(Suzuki, 2012, Özdamar and Demir, 2012, Yi and Kumar, 2007, Yi and Özdamar, 2007, Ozdamar, 2011, Fiedrich et al., 2000)
	Mathematical modelling and AHP	(Barbarosoğlu et al., 2002)
	Simulation and probability and statistics	(Gong and Batta, 2007)
Relief distribution and resource management	Mathematical modelling	(Rottkemper et al., 2011, Martel et al., 2013)
	Simulation	(Kunz et al., 2014)
Resource Management/Inventory management	Mathematical Modelling, Simulation and expert system	(Brown and Vassiliou, 1993)
	Mathematical modelling and simulation	(Beamon and Kotleba, 2006)
	Stochastic modelling	(Beamon and Kotleba, 2006, Ozbay and Ozguven, 2007)
	Mathematical modelling	(Taskin and Lodree, 2010, Ozguven and Ozbay, 2012, Ozguven and Ozbay, 2013)
	Probability and statistics and decision theory	(Taskin and Lodree Jr, 2011)
	Simulation	(Peng et al., 2014)

2.5 Suitability of Simulation technique in emergency logistics

2.5.1 Modelling and Simulation

A model is the prototype of a system, which allows evaluating the decision before actual action is taken in reality. Pidd (2009) defines "a model is an external and explicit representation of part of reality as seen by the people who wish to use that model to understand, to change, to manage and to control that part of reality" (Pidd, 2009, p 10). This leads to identify simulation as a modelling technique. Simulation is an imitation of a system (Robinson, 2014), which implements the reality. According to Ball (1996) simulation is the method of structure for a model of an actual or planned structure under detailed studied situations. The major influence of simulation is the capability to model the behaviour of a system as time progresses. Figure 2.4 explains the representation of simulation process and the connection among the various stages of simulation. Sterman (2002) states that "simulation becomes the main - perhaps the only way we can discover for ourselves how complex system work" (Sterman, 2002, p 525). Repeatability, understand the behaviour of the system, low cost compared with real experiments, control of the experimental conditions, modelling variability, transparency of the system for understanding are the key advantages of simulation (Robinson, 2014).

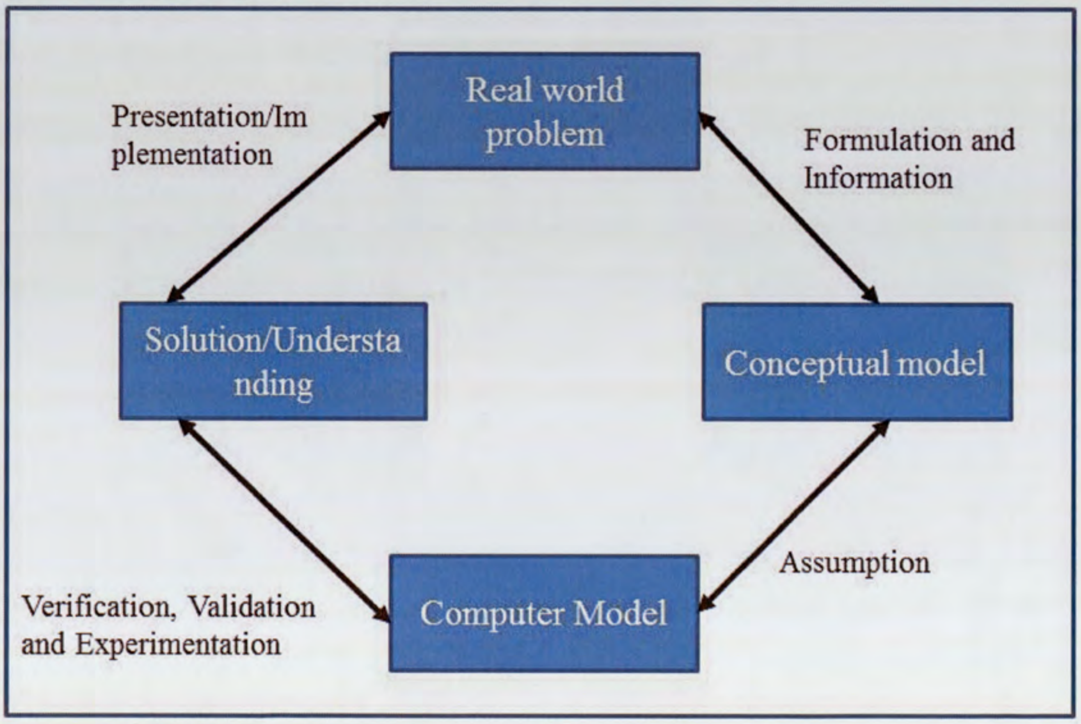

Figure 2.4: The simulation development process (Source: (Brooks and Robinson, 2001))

The above Figure 2.4 is explaining the development of simulation process. At first, the real world problem must be identified. Then the problem needs to be formalised or defined as a conceptual model. Next step is to follow the scenario analysis experimentation and run the model on computer, tailed by the verification and validation of the model. Finally, the solution is implemented in the real world problem. There are different types of simulation techniques which are recognised by the Association for Computing Machinery Special Interest Group on Simulation and Modelling (ACMSIGSIM), for example discrete, continuous, monte carlo, system dynamics, agent base, gaming, artificial intelligence, virtual reality, distributed, web-based, live and in the loop (Owen et al., 2010).

2.5.2 Simulation in emergency logistics

It is very challenging to design and implement the total logistics process during a large-scale emergency situation. Therefore, correct decisions for managing, designing and implementing the logistics process during an emergency are required to be established. Relevant action plans are necessary for the accurate decision-making process. Facility location, shelter location, supply and storage location, distribution centre location (service facilities and schools) are the programmes inside the facility decisions umbrella, where the decision makers need to make a judgement. Transportation decisions (evacuation, routing, traffic routing assignment, and casualty transportation), inventory decisions (Pre-positioning relief stock, inventory management) and distribution decisions (relief distribution, LMRD) also have programmes where the decision maker needs to make judgements for the efficient relief distribution operation. The previous literature review about emergency logistics provides input that optimisation technique is the most frequently used technique in emergency logistics but the other technique like simulation could be beneficial to understand the emergency logistics problem as a simulation can mimic the reality. Consequently, a complex system can be represented with the help of simulation and understand the behaviour of that system as time progressed (Sterman, 2000). Mainly during a disaster situation, if the behaviour of the logistical activities is represented /simulated according to the time, then it provides the decision maker an assumption to make the decisions for that exact time of the situation. For instance, Radwan et al. (1985) proposed a simulation model for the evacuation of rural highway networks under the threat of natural disasters. The author determines the optimum evacuation time. This simulation model is consistent in simulating traffic flow on a street network and this model is useful for the evaluation of different controlled evacuation system. A simulation model is considered for the traffic signal timing during a sudden onset disaster evacuation in an urban area. As in this research, evacuation is outside the scope of the research so this research will not discuss thoroughly evacuation activity.

Horner and Widener (2011) proposed a combination of mathematical modelling, simulation and GIS techniques for transportation network damage during the hurricane. Mainly here simulation is used for validating the model with examining the impact of simulated network failures on hurricane disaster relief planning strategies. Lee et al. (2009a) combined the large-scale simulation with mathematical modelling and powerful optimisation engines for public health facility setup, floor plans, allocation of human and relief resources to understand and mitigate casualties during bioterrorist attack or pandemics. In this research, the authors include simulation for the scenario analysis for the stochasticity of the emergency operations within the facility. Gong and Batta (2007) focused on simulation for validating the probabilistic model for ambulance allocation and reallocation during relief operation. Brown and Vassiliou (1993) combined simulation with optimisation method and decision maker's judgement for task requirements tactical decision during disaster relief operation. The decision support simulator is doing scenario analysis and evaluating alternate action plan during time progressed. The simulator is acting as a coordinating programme between the user and data components. Kunz et al. (2014) adopted system dynamics for the allocation of preparedness budget during a disaster situation. The authors model the delivery process of ready to use therapeutic food items during the immediate response phase of a disaster and analysed the performance of different preparedness scenarios. The findings demonstrate that the best performance can be achieved by combining the preparedness strategies with the allocating of available funding to disaster management capabilities and part to pre-positing of inventory. Beamon and Kotleba (2006) developed and proposed three inventory management strategies, which are applied in South Sudan emergency situation. The authors here combine simulation with mathematical modelling. Simulation here is used for identifying the interrelationships among parameters, which are difficult to determine analytically. The simulation model produces statistical output data on average response time, average annual cost, average number of back orders per cycle, the average cost per cycle and stock out by using inventory system variables (reorder and lot size quantities for emergency and regular orders) and operation data like demand distribution, transportation cost.

2.5.2.1 Simulation in relief distribution

The practice of simulation technique is relatively common in modelling relief distribution activities. (Tatham et al., 2010a) proposed a framework for the emergency logistics response model by using simulation and this model also implicated that emergency logistics decision makers can make better-informed decisions by using simulation technique. The authors developed a monte carlo simulation model to predict the behaviour of the relief distribution and routing activity during response time, which is mainly first 72 hours after a huge earthquake and implemented the model for the Thailand earthquake on 2004. Another relief distribution model is proposed by Chang et al. (2014), the authors combined the multi-objective generic algorithm and simulation to minimise unsatisfied demand, minimise the time of delivery of relief and the transportation cost. The simulation model is experimented with various conditions of limited and unlimited available vehicles and the output results show that the multi-objective algorithm model is positively implemented. Hu (2011) presented an integer programming mathematical model to build the path selection of container supply chain during the emergency relief operations and combined that model with simulation method, which shows the behaviour of the model. A combination of GIS and ABM prototype model is proposed by Crooks and Wise (2013). Mainly the ABM explores the reaction of the affected community during the relief distribution time and also how propagated rumours about relief aid are affecting the affected population. This model is validated by 2010 Haiti earthquake. Another ABM is proposed by Das and Hanaoka (2014) for fleet allocation across various zones during LMRD after a large scale disaster.

2.5.3 Summary

The above discussion shows that simulation is a useful technique in emergency logistics and also in relief distribution as this research is mainly concentrated on relief distribution. In the emergency logistics literature, most of the research combines simulation with other techniques to achieve the objective of the research. Mainly most of the time simulation is used for the evaluation of the model performance (Chang et al., 2014, Hu, 2011) and validation (Gong and Batta, 2007, Horner and Widener, 2011) of the model. According to Tatham et al. (2010a) a simulation model is an advantage for emergency logistics decision makers for better understanding the dynamics, during response planning. In the emergency logistical activity simulation technique will increase the dynamicity of the logistical activity what if analysis for strategic, tactical and operational decision. The output or results of the simulation model can be assessed and interpreted for further scenario analysis. There are some limitations of simulation techniques such as most of the simulation models need a big amount of data, which can be hard to obtain. Other challenges are that simulation software are expensive and for simulation modelling the modeller need to have some required expertise about the conceptual model building, validation and statistics and project management skills (Robinson, 2014). Though simulations have some challenges, in addition, simulations have significant amount of advantages, for example, explore possibilities, diagnose the problems, identify constraints, development of understanding, visualise the plan and build consensus. Simulation technique could be a choice for this research to understand the LMRD system, which is a very complex system for the improvement of decision-making during a relief distribution after a large scale disaster. After the occurrence of a large-scale disaster, the affected country need to manage the affected community effectively and efficiently.

2.7 Gap analysis and research need

The above literature review is noticeable for the undeniable relationship between the different decisions in disaster management for emergency logistics. The dissemination is not equally distributed along the different logistical decisions, primarily for the LMRD. Although there are some articles addressed aspects of LMRD (Balcik et al., 2008, Martinez et al., 2011, Das and Hanaoka, 2014, Hwang, 1999, Decker, 2013), to the best of our knowledge there are no articles addressed the responsible factors, which are affecting the LMRD performance measures. Transportation decision and fleet management is one of the problems during LMRD (Balcik et al., 2008, Martinez et al., 2011) but there are some other problems like resource limitation, field operational planning, identification of practical challenges and last but not the least individual disaster have individual challenges during final relief distribution. There is no article that concentrates on the above problem. Therefore, it is important to challenge that perspective and analyse the possibility to incorporate the above-mentioned limitations into a single decision-making tool to evaluate the results and provides grounds to determine the most suitable approach.

Even in the normal supply chain, the last mile distribution is considered as one of the most expensive section Gevaers et al. (2011), which can cost from 13% to 75% of the total logistical cost (Onghena, 2008). In the disaster situation, the last mile distribution is much more complicated and costly because of the condition and uncertainty. In the previous literature, there is a lack of a framework, which identifies the performance measures of LMRD and the factors which affect the performance for the further analysis of LMRD system. Such framework would be required to reduce reducing uncertainty and complicated situation. Mainly this framework make explicit dynamic interactions inside the LMRD system.

There are three notable gaps in LMRD. Firstly, there is a lack of a detailed model for managing resource allocation and distribution efficiency specifically implemented in LMRD. Secondly, LMRD literature is only focused on LMV problem but not considering the relief distribution operation system in the context of relief distribution procedures and relief allocations. Finally in the previous literature all the LMRD models are generic for all the disasters though some of them are validated through the specific case studies (Balcik et al., 2008, Battini et al., 2014) and there are no earthquake specific models and it is necessary because of the difficulties of earthquake situation for example blockage of road network, cleaning the debris and last but not the least, delay in the relief distribution. During a flood situation, people can easily evacuate as there is early warning system but earthquake occurs suddenly as there is no early warning system. Other challenges are damages of the building, infrastructure creates a large amount of rubble, which need to be moved for relief efforts and earthquake have aftershocks, which traumatised the population and complicate the relief efforts (Ferris, 2010). Therefore it is important to challenge that perspective and analyse the possibility to bridge the gap in the LMRD system for earthquakes.

Subjective and qualitative assessment are valuable. These assessments are not only essential aspects for understanding the practical perspective but also must be supported by more quantitative techniques to provide insight into the operational impact. This research is using simulation as it can provide the prototype of real system, what-if analysis of all the variables, and constraints to understand the system. On the other hand, optimisation technique provides an optimal solution or optimal policy of a specific problem. Additionally, the simulation technique can increase the dynamic impact of the system as time passes. Finally, during LMRD, the involved active agencies and the government need to manage the uncertainty about the relief items, the efficiency of time and cost effectiveness. Consequently, it is necessary to understand the system to overcome the challenges of LMRD to bridge the gap. According to (Decker, 2013), the whole relief system requires more academic and computational experiments to examine the essential frameworks and models. But even more significant is identifying practical solutions, which can be used by relief workers. Table 2.2 demonstrates the performance efficiency measures for LMRD. But in the LMRD it is necessary to identify and analyse the performance measures by integrating relief worker's contribution.

2.7.1 Potential for innovation

The focus of the current research is to fulfil the aforementioned gap. From the initial gap analysis, we have selected this research is only aiming for earthquake disaster as different disaster have different issues and consequently the LMRD challenges are also different.

The scope of the present research will be focused on Indian LMRD system. Mainly this research will identify the main factors which affect the LMRD system in India and evaluate the effect of those factors into the LMRD system in India, particularly around the response to the earthquake. Since simulation is a technique that permits the 'what if' analysis of different scenarios and hence ABM is the simulation techniques which can implicate a complex system and behavioural complexity in terms of the agent. The simulation would be a suitable technique for LMRD as there is an emergency situation (real life problem) and decision maker need to make a decision from the strategic level to the operational level by getting aids out to those disaster affected people within the minimum time frame.

2.7.2 Research Questions

The previous literature has already set the different aspects of the necessity of this research. The research questions to be answered in this research are:

RQ1. What are the factors which affect the last mile relief distribution (LMRD) performance measures?

RQ2. Which of these factors had the biggest influence on the performance of last mile relief distribution (LMRD) in the Indian context?

RQ3. After incorporating the most influential factor in the last mile relief distribution (LMRD) model how will it affect the performance of LMRD in India?

2.7.3 Chapter Summary

The chapter provides a thorough literature review about emergency logistics, mainly in relief distribution and finally LMRD. In this literature review, the author explains the relevant applicable operational techniques to the identified emergency logistics problem. Finally, the researcher analyses the gap from the literature and identifies the research questions for this research project. The following chapter will present the available methodological options to answer the above questions.

Chapter 3: Research Methodology and Research design

3.1 Introduction

Research is a systematic pathway to discover the truth (Saunders et al., 2012). Research is about producing knowledge (Lee and Lings, 2008). The concept of research is broad "the notion that 'research' implies a search for 'facts' which are in some sense precisely observable under replicable circumstances, or, at least, are subject to some statistically measurable experimental error which has been established by multiple experiments by the researcher. It is both difficult to 'experiment' with human beings and difficult to replicate many experiments" (Elder, 1992, p 106). In the management research arena, the individual condition is context oriented and therefore it is hard to replicate in an exact way. The necessity of research methodology is needed to represent the research design with incorporating the number of unrestrained factors and tends to a better representation of the outcome of the research. "Research methodology is a way to systematically solve the research problem" (Kothari, 2004, p 8). There are seven perspectives of management research presented in Table 3.1. These seven perspectives of management views (Easterby-Smith et al., 2008, p 6), explain the period of time when the specific management views are identified, the primary activity of that specific management views and finally the definite types of theory used for the exact management perspective.

Table: 3.1: Seven Perspectives on management (Source: (Easterby-Smith et al., 2008))

Views of management	**Period of dominance**	**Key features**	**Type of theory**
Classical	1910-1950	Functional activities	Normative
Human Relations	1940-1970	Motivating people and managing change	Normative
Decision Theory	1950-1970	Optimizing decisions	Analytic
Work Activity	1970s	What managers do	Descriptive
Competencies	1980s	Skills required for effective performance	Normative
Critical	1990s	Social construction and politics	Analytic
Process	2000s	Learning and Strategizing	Analytic and Normative

This project is developed under two views, which are the decision perspective and the process perspective, by using analytic and normative approach. This research is experimenting with the best possible strategies to learn the best possible outcome for LMRD operation in India for a disaster like an earthquake.

This chapter will explain the selection of an appropriate research paradigm and research design to answer the research questions, which are presented in the previous chapter.
The justification of appropriate research paradigm will start by a brief analysis of the different research paradigms, explaining the importance of research paradigm and clarifying the strength and weaknesses of each paradigm as well as the selection of correct paradigm for this research. This chapter is followed by the detailed research design and justify the appropriate paradigm for this specific research project. This chapter also present the specific methods, techniques and tools for each of the stages to achieve the objective of this research project.

3.2 Research Paradigm

The word paradigm comes from the Greek word paradeigma, which mean by the Oxford Dictionary "pattern, example, sample". In 1962 Thomas Kuhn explained paradigm as the representation of beliefs, principles, directions and techniques, which are accepted by any scientific field at any time (Kuhn, 1962). Each scientific paradigm explains a 'world view' and a complete conceptual framework within which researchers generate knowledge (Healy and Perry, 2000). Saunders explains that the most important research paradigm is that strategy which will allow you to answer your particular research question and meet your objectives (Saunders et al., 2012). It is important to define the overall research paradigm to obtain the objectives.

3.2.1 Philosophical Paradigm

The core debate among philosophers is concerning about ontology and epistemology. "Ontology is about the nature of reality and existence; epistemology is about the best ways enquiring into the nature of the world" (Easterby-Smith et al., 2008, p 61). A disaster is an external event and there is a necessity to explain and control the impact of the disaster. The ontology of this research is based on the idea of a single reality to be analysed and discovered, which can be measured as well. Therefore the ontology of this research is objectivist. In the epistemological perspective, the research is independent and non-interactive phenomenon observed. According to Tennis (2008) "in knowledge organisation research we make implicit epistemic statements about knowledge of concepts, acts (such as representation), entities, and systems. In so doing, we create knowledge, and our epistemic stance dictates what kind of knowledge that is. Some common names of epistemic stances are pragmatic, positivistic, operationalist, referential, instrumental, empiricist, rationalist, realist, etc." (Tennis, 2008, p 103). The knowledge of the world is supposed to be generalisable and impartial, taking into account of an objective perspective, about the disaster and the system to be analysed. Saunders et al. presented a model called as 'research onion', which describes the choices related to management research criteria (Saunders et al., 2012). The Figure 3.1 shows the layered aspects of choices from philosophy to techniques selection for an appropriate research design.

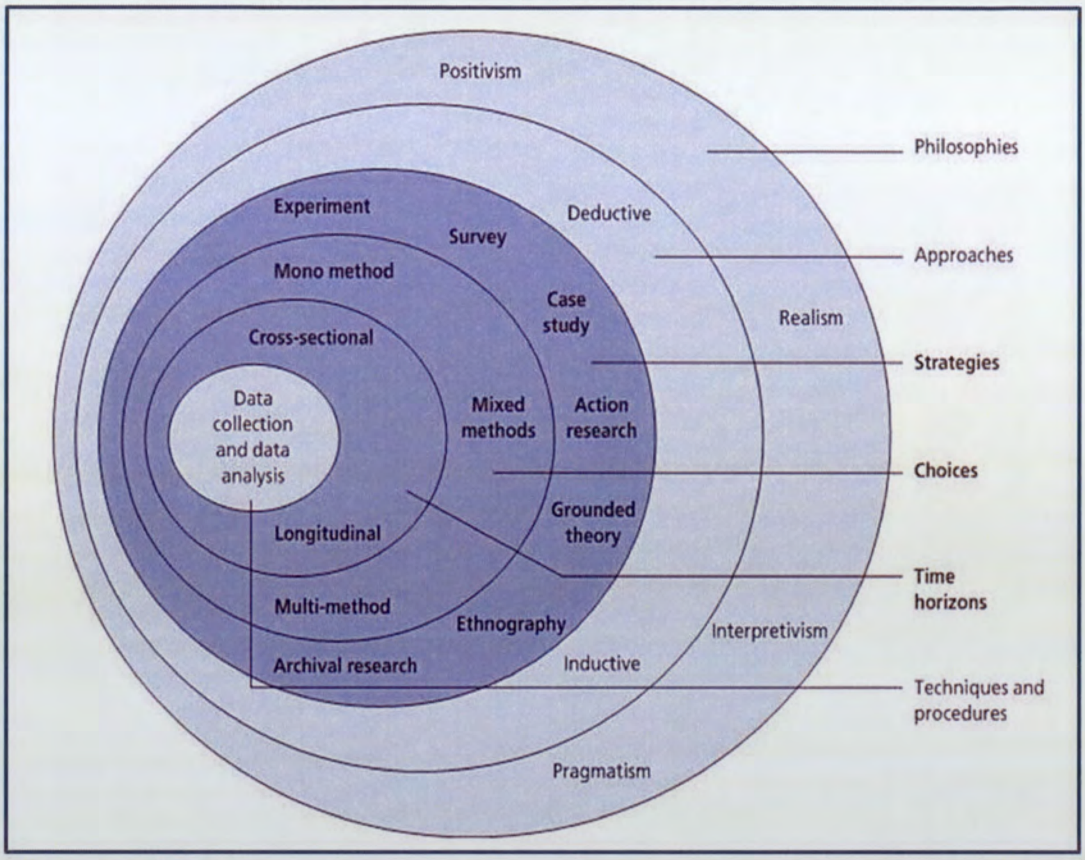

Figure 3.1: The research onion (Source: (Saunders et al., 2009))

There are four philosophical aspects in management research: Positivism, Realism, Interpretivism and Pragmatism (Saunders et al., 2012). This philosophical understanding can help to clarify the research design, as well as it will help to recognise the correct philosophical approach for the research design (Easterby-Smith et al., 2008). The continuous discussions have taken place about the validity of individual research paradigm and their application to a different context. The explanation of the characteristics of the above four philosophical paradigms are provded below.

3.2.1.1 Positivism

"Positivism is an epistemological position that advocates the application of the methods of the natural sciences to the study of social reality" (Bryman and Bell, 2015, p 28). "The key idea of positivism is that the social world exists externally and that its properties should be measured through objective methods, rather than being inferred subjectively through sensation, reflection or intuition" (Easterby-Smith et al., 2008, p 65). The above assumption shows that positivism is indicating objective oriented scientific approach. This characteristic makes positivism approach to investigate the world's reality using manipulative methodology. Positivism specifies the following characteristics (Easterby-Smith et al., 2012):

- Independence: During observation, the observer must be independent.
- Value freedom: The researcher's opinion does not interfere with the interpretation of the outcome or results.
- Causality: Identification of casual explanation and fundamental laws are the aim of the social science.
- Hypothesis and deduction: Science proceeds through a path of hypothesising fundamental laws followed by deducing the nature of observations and demonstrate the truth or falsity of these hypotheses.
- Operationalisation: Necessity to operationalise such a manner where facts can be measured quantitatively.
- Reductionism: Need to reduce a problem to its simplest part for the better understanding.
- Generalisation: In order to generalise it is necessary to select a sample of sufficient size.
- Cross-Sectional Analysis: Comparison of variation across the sample is necessary for the cross-sectional analysis.

There are some strength and weaknesses (Easterby-Smith et al., 2012) of this paradigm, Strengths:

- Positivism can provide an extensive coverage of various situations.
- This approach can be potentially fast and economic.
- This approach is easier to provide justification of policies or decisions.

Weaknesses:

- This approach is tending to be inflexible and artificial.
- Positivism approach is not efficient for process, meanings and theory generation.
- This approach implies for action not obvious.

The above strengths and weaknesses will help the proposed research to identify the appropriate methods for the proposed research.

3.2.1.2 Realism

Refer to Figure 3.1 this paragraph will discuss realism philosophy. According to Bryman and Bell (2015) "realism shares two features with positivism: a belief that the natural and the social sciences can and should apply the same approach to data collection and explanation, and a commitment to the view that there is an external reality to which scientists direct their attention" (Bryman and Bell, 2015, p 29). Empirical realism and critical realism are the two major forms of realism (Bryman and Bell, 2015). Critical realism is recognised by a significant amount of management and organisational research for past years because of the compromise position between the positivism and constructivism (Easterby-Smith et al., 2008). This approach is the feature of a 'structured ontology', which distinguish between three levels: empirical domain (people's perception and knowledge), actual domain (the happened event and action whether they are observed or detected) and real domain (casual unobserved powers and mechanisms, which have real consequences for people and society) (Easterby-Smith et al., 2012). Very few studies adopted the methods of critical realism though these methods are used for structuring the data collection and analysis process (Easterby-Smith et al., 2012).

3.2.1.3 Interpretivism

Interpretivism is "based on the view that a strategy is required that respects the differences between people and the objects of the natural sciences and therefore requires the social scientist to grasp the subjective meaning of social action" (Bryman and Bell, 2015, p 29). The main feature of this approach is to understand the importance of human as social actors (Saunders et al., 2009). The primary challenge of this philosophy is to go into the social world to understand the proposed research subject and comprehend their world from their point of view (Saunders et al., 2009).

3.2.1.4 Pragmatism

In pragmatism, the priority is the proposed research question (Saunders et al., 2009). Pragmatism does not recognise the predetermined theories or frameworks that form knowledge and truth; nor can people conceptualise their own truth out of nothing (Easterby-Smith et al., 2008). The significant argument is that any meaning structures must come from the lived experience of individuals. Pragmatism philosophy is concentrated on process particularly relevant to studies and learning (Easterby-Smith et al., 2008). This philosophy is following the traditions and methods of grounded theory (Easterby-Smith et al., 2008).

3.2.1.5 Philosophical paradigm selection for this research

A research project must have a clear research paradigm. A specific research paradigm assists the researcher to choose the correct research strategies, methods, techniques and tools to have consistency between the research elements. The above discussion about some philosophical discussion provides the concept about different research paradigms. The researcher conducted interviews to understand the knowledge and system of final LMRD during a disaster but the researcher is not conducting any action research, therefore interpretivism is unsuitable in this case. This project is not following realism philosophy as "the essence of realism is that what the senses show us as reality is the truth" (Saunders et al., 2009, p 114). In the logistics literature, positivism is the dominant philosophy as this philosophical paradigm has the goal to explain and predict the reality, where reality considered as objective, tangible and fragmentable (Mentzer and Kahn, 1995). Consequently, Patterson and Williams (1998) and Easterby-Smith et al. (2008) would categorise the paradigm, which supports the proposed research as a positivist approach. They reinforced by the fact that the dominant paradigm accepted in most of the emergency logistics paper is positivism (Adamides et al., 2012, Patterson and Williams, 1998, Mentzer and Kahn, 1995), with the aim to model real objects (Klein and Hirschheim, 1987) and explicate and forecast an objective, tangible and fragmentable reality (Mentzer and Kahn, 1995).

Social constructionism is a new paradigm, which is developed inside the positivism philosophy to the application of the social sciences. The main aim of this philosophy is that the 'reality' is not impartial and external, but the 'reality' is social constructed and given significance sense by people (Easterby-Smith et al., 2012). The following Table 3.2 showed that there are some basic differences between positivism and social constructionism.

Table 3.2 Contrasting implications of positivism and social constructionism (Source (Easterby-Smith et al., 2008))

	Positivism	**Social constructionism**
The observer	must be independent	is part of what is being observed
Human interests	should be irrelevant	are the main drivers of science
Explanations	must demonstrate causality	aim to increase general understanding of the situation
Research progresses through	hypotheses and deductions	gathering rich data from which ideas are induced
Concepts	need to be defined so that they can be measured	Should incorporate stakeholder perspectives
Units of analysis	should be reduced to simplest terms	may include the complexity of whole situations
Generalisation through	statistical probability	theoretical abstraction
Sampling requires	large numbers selected randomly	Small numbers of cases chosen for specific reasons

The aim of the thesis is to identify the practical factors which affect the final relief distribution and develop a way to integrating the factors to investigate the LMRD performance especially using OR/MS tools as these tools are the suitable tools for achieving the objectives. The researcher is trying to understand independently the LMRD operation and answering the objectives with proper explanations and finally generalise the sufficient sample of data for operationalisation of the LMRD. This thesis follows all the characteristics of positivism philosophical approach. Therefore, positivism is the suitable philosophical paradigm for this thesis.

3.2.2 Approaches

The next layer of Figure 3.1 is explaining about the logical approaches relevant to this research project. It is necessary to connect logically the research journey, starting with the critical thinking and judgement and finally conducts the step by step research path. (Lee and Lings, 2008). Induction and deduction approach are essential for the contemplation of the relevant research design. In the deductive approach, the researcher is developing a hypothesis and designing a research strategy to test the hypothesis (Saunders et al., 2009). In the induction approach, the researcher would collect data and develop a theory (hypothesis) through data analysis (Saunders et al., 2009). The first part of this thesis follows inductive approach, is shown in Figure 3.2, as the researcher collected data from the emergency logistics practitioners and then analyse those data to develop the hypothesis

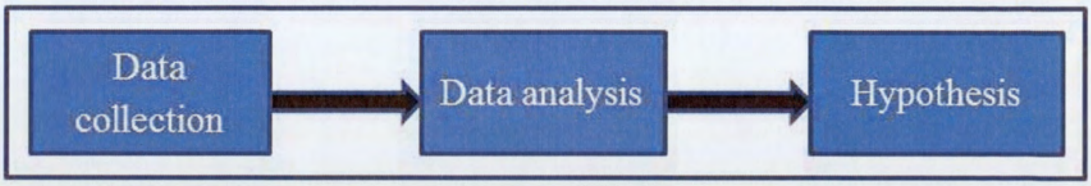

Figure 3.2: Inductive approach of this thesis (Developed by the researcher)

The second part of the thesis follows a deductive approach which is shown in Figure 3.3, as the researcher creates the research design after having the hypothesis and start data collection thereafter.

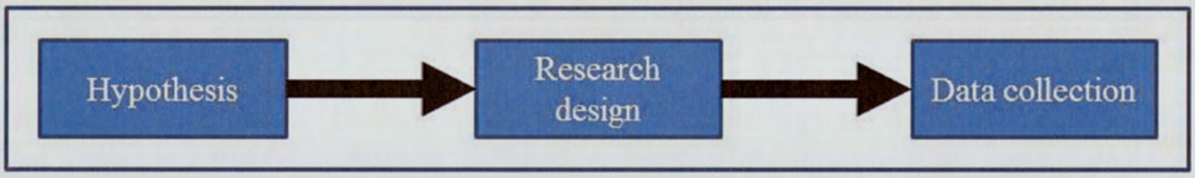

Figure 3.3: Deductive approach of this thesis (Developed by the researcher)

3.2.3 Research design

Yin (2013) describe research design as the consistent categorisation which linked the experimental data to a specific field's research questions and, finally, to its conclusions. A research design should incorporate (Yin, 2013, Easterby-Smith et al., 2008):

- Problem definitions (Research questions) (Details analysis, Scope of the research. Limits)
- Developing methods and techniques
    - Research strategies
    - Data collection
    - Data analysis
    - Modelling techniques
    - Tools selection
- Research process

Referring to Figure 3.1 the other layers like strategies, choices, time horizons and techniques and procedures are integrated into the research design umbrella. The above steps of research design will be described in the following section.

3.2.3.1 Problem Definition

The problem definition is defined in chapter 2 as the version of research questions, which can be summarised as follows:

RQ1. What are the factors affect the LMRD performance measures?

RQ2. Which of those factors had the biggest influence on the performance of LMRD in the Indian context?

RQ3. After incorporating this essential factor in LMRD model how it will affect the performance of LMRD in earthquake in India?

The following research strategies, data collection, development of methods and techniques intended to answer the above research questions.

3.2.3.2 Developing methods and techniques

Saunders et al. (2009) explain that the most important research paradigm is the strategy which allows you to answer your particular research question and meet your objectives. The most common research methods in supply chain management are based on surveys, case studies, action research and modelling (Kotzab et al., 2006). Modelling and case studies are the two selected methods for the proposed research project. A model is a representation of reality. According to Pidd (2009), "a model is an external and explicit representation of part of reality as seen by the people who wish to use that model to understand, to change, to manage and to control that part of reality" (Pidd, 2009, p 10). For this specific research project, the author is trying to analyse the Indian LMRD operation. And finally, for the final research question (how that major factor affects the Indian LMRD?), it is essential to identify the LMRD operational process which is carried out by the use of modelling technique for this specific research project. According to Easterby-Smith et al. (2008), "the case study looks in depth at one, or a small number of, organisations, events, or individuals, generally over time" (Easterby-Smith et al., 2008, p 97). In this research, the author investigates the factors which affect the LMRD during an earthquake. And also, the author tries to identify the major factor for Indian LMRD. For this purpose, the author needs to identify and use the Indian earthquake cases. The following paragraphs will analyse the significance of case study approach and modelling approach for the specific research project.

Case studies are the proposed research methods, using semi-structured interviews, structured interviews, documented reports as data collection tools. Content analysis and thematic analyses are acceptable tools used for the analysis of the collected data. Simulation is the accepted tool for this project. As in this project the researcher combined qualitative and quantitative techniques for the better understanding of this project. This thesis used mixed method research approach. This study is following a cross-sectional time-horizons as this study is considered a particular phenomenon at a particular time (Saunders et al., 2009).

3.2.3.2.1 Research strategies: Case studies

Case study research is now a consistent research methodology considered by operation management researcher "to cope with the growing frequency and magnitude of changes in technology and managerial methods, operations management researchers have been calling for the greater employment of field-based research methods" (Voss et al., 2002, p 195). The strengths of case study research are as follows (Voss et al., 2002):

- This case study method allows being answered the questions of why what and how with the proper understanding of the nature and difficulty of the complete phenomenon.
- The phenomenon and relevant theory can be considered and generated from the knowledge of the actual practice.
- In operations management, the case studies should be concentrated on what processes and systems should be studied, what are the available methods for studying them and how the operating data will be collected from them?

The choice of research strategy is depending on the research objectives, research questions and research philosophy. In this research, the researcher is endeavouring to define the actual factors, which delayed or affect the final relief distribution during a disaster situation. After incorporating this factors into the LMRD system the researcher will identify the performance measures of LMRD in one specific country perspective, which is India. In this case, one mechanism is needed so that the same model can be verified by two real disaster situations in India by using secondary data and then the conclusion can be drawn. The most suitable strategy for this research is the case study, which fulfils the purpose of this research project.

The key advantage of the case study strategy is that case study is a holistic strategy and the conditions can be observed from various perspectives (Gummesson, 2000). In this research, the author is investigating about LMRD system and also about the modelling results outcome. Thus, the case study is used for both to represent the factors for LMRD and also to understand and evaluate the effect of the factors in the LMRD system. There are times when diminutive is recognised as a phenomenon, present viewpoint appears insufficient because they have little empirical confirmation, or they struggle with each other or common sense, which is the relevancy of case study (Eisenhardt, 1989). The above description is a good example of the current situation as the knowledge of LMRD is very limited.

Though the case study approach is the relevant method for this study, but this approach is criticised in a number of ways. Firstly in the reliability and validity purposes, the case study is less rigorous (Yin, 2013). Secondly, the performance of individual case study research is vulnerable in the context of their ethical standpoint and integrity. The importance of the ethical issue in the case study is essential. The complications of reliability are linked to the repeatability but it is hard to find out the repeatability of the findings explained by the researcher. For example, how can anybody know if the proposed findings are repeatable or they are a function of the individual and the procedure of the researcher for conducting the research? The third challenge is the generalisation perspective. Yin clearly mentioned that the case study research can produce 'analytic generalisation' (generalisation to theoretical intention) rather than 'statistical generalisation' (Yin, 2013). The final challenge of the case study research is the enormous quantities of data involved, not only that there is a good amount of time and cost also involved in case study research. The above discussion showed that case study strategy is not an easy option though the above criticism can be overcome by using systematic and rigorous approach.

This paragraph explains that how the challenges of case study approach can be overcome to fulfil this research project. First and foremost, the concern is reliability. Reliability concerns about the outcome of the case study results, which is replicated by the researcher's choice of procedures. This research involves modelling, simulation and thematic analysis and the author is considering the number of key aspects, which increase reliability. For example, the previous literature and practitioner's point of view are clearly monitored when ABM simulation is considered. Another key step is to document the report, so that repetition of this approach will provide similar results. In the generalisation context, this study is based on Indian perspective. This research project is using two different case studies to project the generalisability of this model. In case study research external validity is also very important and must be considered. The question in this context is whether findings from a single case can be generalised or not. That demand the model validation with the other case studies. More than one case study approach is one of the suitable approaches, which is considered in this context. The case study research involves subjective rather than the objective method in the data collection; mainly the hypotheses themselves are qualitative rather than quantitative. There are three strategies adopted for data collection during case study research: using multiple sources of evidence, establishing a chain of evidence and a draft of case study report (Yin, 2013). Lastly, this research project is successfully gone through the Aston University's ethical committee.

3.2.4 Ethical Approval

The researcher submitted the ethical approval form in January 2012 to the Aston University Ethical Committee. The author needs to fill the Aston Universty's ethical application form with appropriate documents (interview questions, consent form, letter for primary communication with the organisation) and a clear explanation of research project proposal. This research project is the part of Aston Crisis Centre. In Aston Crisis Centre my both supervisor Dr Pavel Albores (1st supervisor) is involved in ERGO project (2008 till 2012) and Dr Christopher Brewster (2nd supervisor) is involved in Disaster 2.0 project (2011 till 2013). Both the projects are about a natural disaster. And both of them already had ethical approval confirmation. The researcher used those ethical confirmation certificates to start her data. Finally, this research project receives ethical approval certificate on 2014, which is provided in the Appendix 3.

3.2.5 Data collection

It is necessary to have a systematic approach to guarantee the rigour during the data collection process and to maintain the collected information's validity. In this research project, the main data collection tools are semi-structured interviews, documentary evidence, and archival records, which are discussed in the following paragraphs.

3.2.5.1 Interviews

Interviews are the primary foundation of case study evidence (Yin, 2013). Lee and Lings (2008) also added into the above statement that interviewing is a primary tool for collecting data in qualitative research. Interviews are providing rich data set from different participants. Mainly in case study research, the interviews are likely to be fluid rather than rigid (Rubin and Rubin, 2011). The semi-structure interview is the combination of openness and structure. The base of these interviews is already decided but those act like as topic guides in the interview to identify the necessary and important data to achieve the objectives of the research project. The sequence of questions also can be changed in order to maintain the flow of the conversation and also added questions can be asked for additional perspective, which is not thought during the design stage. In this research, a semi-structured interview is chosen as one of the key data collection tools.

3.2.5.2 Documentation

Documentary evidence is one of the important evidence of data collection during case study and this type of information have various forms and should be the purpose of explicit data collection planning (Yin, 2013). The documents cannot be prepared or modified for the purpose of research, therefore it addresses the concern of biases up to a certain extent (Yin, 2013). Documents are a rapid and informal source of information but it does have difficulties such as availability and declaration of deficiency of prejudice because those are organised for a specific audience (Myers, 2013). The important issue of documentary evidence is the confidentiality of the document which requires major negotiation to access from the government and non-governmental relief organisation. The researcher manages to have the documentary access from the following organisations: Relief web, NIDM (National Institute of Disaster Management), Red Cross, Oxfam, United Nation and some other national NGOs websites are used for the collection of the secondary data set. The documentary evidence (for example reports, previous disaster dataset, a protocol for specific organisations, day to day disaster field report) is another data collection tools used for this research project. There are some advantages and disadvantages are categorised for using the secondary data analysis (Bryman and Bell, 2015):

<u>Advantages:</u>

- High-quality data set;
- Minimise the cost and time for data collection;
- The researcher can analyse the subgroups or subsets of the data;
- There is an opportunity for cross-cultural analysis;
- Data analysis time is extended;
- The wider obligation for business researcher;
- Reanalysis can offer new interpretations;

<u>Disadvantages:</u>

- Lack of familiarity with data set;
- Large set of data is becoming complex;
- No control over the data quality;
- Lack of absence of key variables;

3.2.5.3 Archival records

Archival records are another kind of data collection tools used in this research, which is available online and the examples of archival records are (Yin, 2013):

- Organisational records, budget, files etc.
- "Public use files" such as the government census report, statistical data, made available by federal, state or local government,
- Service records, such as those showing the number of clients served over a given period of time,
- Maps or charts of geographical characteristics of a place,
- Survey data produced by others, about the case's employees, residents, or participants.

There are some archival records analysed from the census board of government of India for the identification of the population of the earthquake affected regions for the case studies.
The strengths and weaknesses of the data collection source of evidence, which are modified by the researcher of this project and are presented here in table 3.3 (Yin, 2013):

Table 3.3: Source of evidence: Strengths and Weaknesses (Source (Yin, 2013): modified by the author)

Source of evidence	**Strengths**	**Weaknesses**
Documentation	• Stable can be reviewed repeatedly • Unobtrusive-not created as a result of the case study • Specific-can contain the exact names, references, and details of an event • Broad-can cover a long span of time, many events and many settings	• Retrievability can be difficult to find • Biased selectivity, if collection is incomplete • Reporting bias-reflects (unknown) • Bias of any given document's author • Access- may be deliberately withheld
Archival records	• [Same as those for documentation] • Precise and usually quantitative	• [Same as those for documentation]
Interviews	• Targeted-focuses directly on case study topics • Insightful-provides explanations as well as personal views (e.g., perceptions, attitudes, and meanings)	• Bias due to poorly articulated questions • Response bias • Inaccuracies due to poor recall • Reflexivity-interviewee gives what interviewer wants to hear

3.2.6 Data analysis

Data analysis is essential mainly for qualitative data set as qualitative researchers always end up with an enormous amount of data, therefore it is hard to include all of the qualitative data in the thesis (Myers, 2013). The qualitative data should be edited into a manageable and meaningful way. Qualitative data is a natural language data and there are seven techniques, which help us to analyse that data set: content analysis, grounded analysis, social network analysis, discourse analysis, narrative analysis, conversation analysis and argument analysis (Easterby-Smith et al., 2008). In this research, the author uses content analysis, where the researcher accumulates the data for hypothesising ideas those have been decided in advance (Easterby-Smith et al., 2008). There is no predetermined hypothesis for the grounded analysis and the researchers should allow ideas to emerge from the data (Easterby-Smith et al., 2008). The following Table is showing the differences between content analysis and grounded analysis:

Table 3.4: Qualitative data analysis: content versus grounded method (source (Easterby-Smith et al., 2008))

Content analysis ⟺	**Grounded analysis**
Searching for content (prior hypothesis)	Understanding of context and time
Causally linked variables	Holistic associations
Objective subjective	Faithful to views of respondents
More deductive	More inductive
Aims for clarity and unity	Preserves ambiguity and contradiction

This researcher is combining the thematic analysis with the content analysis as both are analogous. But thematic analysis pays superior consideration to the qualitative aspects of the material analysed (Marks and Yardley, 2004). Thematic analysis used as "…..a method for identifying, analysing and reporting patterns (themes) within data" (Braun and Clarke, 2006, p 79). The aim of adopting thematic analysis is to identify, interpret and explain the various aspects related to LMRD. The advantage of thematic analysis (Source (Braun and Clarke, 2006)) is explained bellow:

- Flexibility.
- Relatively easy and quick method to learn, and do.
- Accessible to researchers with little or no experience of qualitative research.
- Results are generally accessible to the educated general public.
- A useful method for working within participatory research paradigm, with participants as collaborators.
- Can usefully summarise key features of a large body of data, and/or offer a 'thick description' of the data set.
- Can highlight similarities and differences across the data set.
- Can generate unanticipated insights.
- Allows for social as well as psychological interpretations of data.
- Can be used for producing qualitative analysis suited to informing policy development.

Though the thematic analysis is a very straight forward technique to analyse the qualitative data but still there are some potential drawbacks, which might judge as poor analysis. For example, the main drawback of thematic analysis is time management. The researcher needs a good amount of time to analyse and identify the themes of the specific data set for thematic analysis. Another pitfall is correctly identified the themes and finally, situations where the themes do not appear to work together. In order to avoid these pitfalls, a process is followed as suggested by Braun and Clarke (2006). There are six steps to follow for a successful thematic analysis: familiarising with data, generating initial codes, searching for themes, reviewing themes, defining and naming themes and producing the report (Braun and Clarke, 2006).

3.2.7 Modelling technique: Relevancy of Simulation technique

Simulation is the modelling technique used in this research project. There is a continuous debate going on about the methodology and epistemological perspective of using simulation (David et al., 2010). The methodological perspective concerns about how simulation will produce reliable and credible results, which deal with the robustness of the simulation process. The concern of epistemological debate is the kind of knowledge provided by simulation. The answer to the methodological challenge is to use a clear and proper documented method, which follows the reliable practices in the proposed method. According to epistemological perspective, the symbol of the proposed model can be represented and compared with the real-world empirical phenomenon. Finally, the modeller needs to understand the concepts and symbols used in the proposed model and the connection of this model with the real world. In this research, the researcher conducted a semi-structured interview with the emergency logistics practitioners (which will be thoroughly explained in Chapter 4). The outcome of that interview will be analysed and examined by using simulation. The simulation will mimic the Indian LMRD system and examine the effect of the outcome results into the Indian LMRD (In chapter 5 the thorough modelling aspect will be explained).

Owen et al. (2010) explain that there are three main types of simulation techniques in Operation Research: System Dynamics (SD), Discrete Event Simulation (DES), and Agent Based Modelling (ABM), which are used in supply chain management. This research will consider the above statement as relief chain is also inside the umbrella of the supply chain. This section introduces the principles and characteristics of the above three methods with a special consideration of ABM, as this technique will be used in the later section of this thesis.

System Dynamics (SD): System Dynamics is introduced by Forrester (1958) who applied the philosophy of control engineering for the solution method of management problems and introduced a new approach called 'Industrial Dynamics'. Later this 'Industrial Dynamics' considered as System Dynamics (SD), which is considering the micro level issues, affecting the organisation, for example, some qualitative issues like the objective of the organisations, leadership quality, managerial influence Forrester (1995). SD is the method to understand the system, which varies over time Sweetser (1999). The relation between the variables in SD model is described as 'casual loop diagram'. In an SD model, state changes are continuous Martin and Raffo (2000) and also could be discrete because of the difficulty of the expression of the variables (Doebelin, 1998). The aim of the SD model is depending upon the system and its structure, which controls the overall performance of the model (Pidd, 1998). Last but not the least SD is occasionally engaged to analyse the large complex system.

Discrete Event Simulation (DES): Discrete event simulation (DES) is presented around late 1950 with the early stages of development of computer (Taylor and Robinson, 2006). Fishman (1978) defines DES as a deviations value or state at distinct instants of time rather than endlessly with time. The basic difference between SD and DES is time for example in SD time is considered as continuous and in DES time is treated as discrete. Another feature of DES is the focus, which is always at the entity level upon the system. In the system, entities are the individual objects; and can be active or passive. The queue system is an example of DES, as in a discrete event time changes it's position. Like queuing system there will be other system also can be represented with the help of DES framework. DES is one of the most commonly used tools in operational research (Hollocks, 2006). Pidd (1998), Robinson (2014) and Hollocks (2006) clarify the evaluation of DES approach can provide more information about DES. Sweetser (1999), Tako and Robinson (2009) concentrated on comparing between DES and SD for the better understanding of the approach. Owen et al. (2010) explain that the DES applies mainly in the operational and planning decisions rather than the strategic and policy decision. On the other hand SD is suitable for tackling micro level issues for strategic and policy level and lastly, ABM is applicable from the strategic level to operational level.

Agent-Based Modelling (ABM): Agent-based modelling is relatively new field than DES. ABM is introduced by Gleick (1997) and is a micro-level simulation technique to model the individual behaviour of a detailed entity of the system (Davidsson, 2001). North and Macal (2007) described the overall modelling approach and summarise the model building process into five stages, which is shown in Figure 3.4.

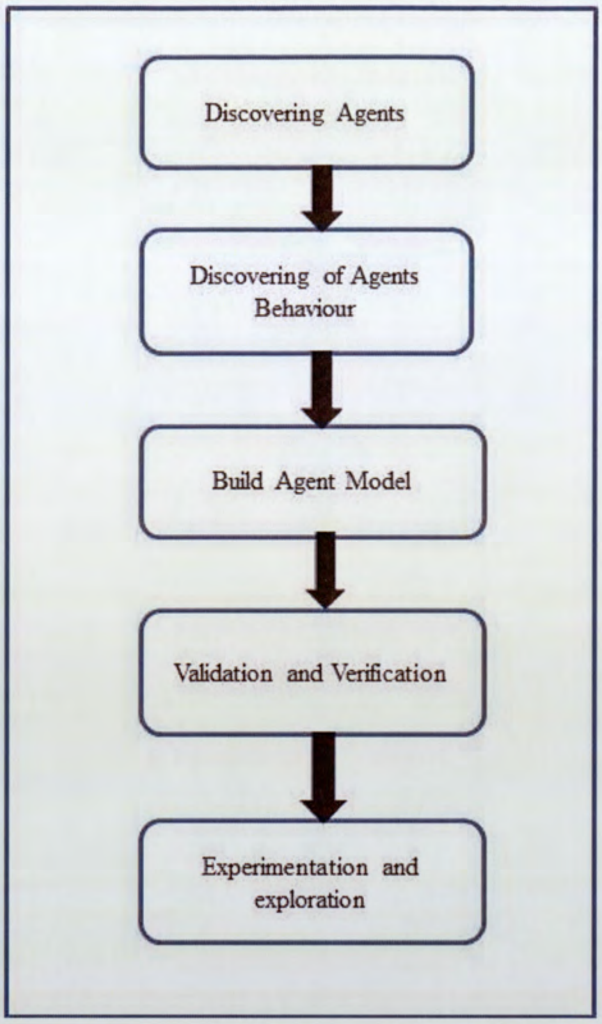

Figure 3.4: The ABM approach (Source: (North and Macal, 2007))

In ABM theory, there are two core components: Agents and Emergence.

(a)Agents: Any type of independent component is modelled in the system is called agents. There is no clear definition of the agent but North and Macal (2007) define that agents are the decision-making mechanisms in complex adaptive organisations. According to , the primary piece of an agent is the competence of the element to make autonomous choices. The agents can be humans, firms, countries etc. whatever signifies the decision-making entity in the system. Adaptability, mobility, communication, modelling concepts are the major characteristics of an agent (Davidsson, 2001).

(b)Emergence: Another important component of ABM is emergence. Emergence is the behaviour or connections among the implemented agents in the system, which is responsible for the total system evaluation (Macal and North, 2005).

The advantage of ABM is that a complex system can be represented in terms of agents. SD always considers a global view of the system, whereas ABM concentrates on the agents, which are the main focus of the modelling perspective. Selection of the appropriate simulation method is depending upon the investigated system. Modelling emergence, flexibility, natural description, detailed hypothesis testing these characteristics accomplished ABM as suitable simulation techniques (Bonabeau, 2002). The agents have the ability to represent an environment as discrete or continuous and also ABM allows detailed hypothesis testing as the agents are the major focus of the modelling perspective (Helbing, 2012). Macal and North (2005) described that agent simulation is suitable to study the emerging patterns and identify the formation of system level structure, which cannot be identified by the behaviour of the individual agents. The advantages of ABM is the objects of the system which can be represented as an agent. And these agents can adopt and change their behaviour; have a dynamic relationship with other agents and that relationship can form or dissolve; have a spatial component to their behaviour (Macal and North, 2005). While agents are the beneficial feature to understand the complex system but still there are some limitations of ABM. As ABM is relatively new therefore the limitations are mainly literature, suitability and validity. Primarily the actual development of agents is difficult due to the difficulty of structural and decisional independence (Drogoul et al., 2003).

The literature review section described the literature for simulation techniques used in emergency logistics. The previous paragraphs also enlightened and compared the three main simulation techniques: System Dynamics, Discrete Event Simulation, and Agent-based Simulation. It is clearly explained that how a system can be represented in a simulated model. Now it is necessary to understand which modelling technique will be suitable for LMRD system. Christopher David Owen compares the above three simulation techniques in the terms of modelling aspects and modelling implications (Owen, 2013). This research will adopt that Table 3.5 for the clarification of Agent-Based Simulation techniques for LMRD system.

Table 3.5: Representing system elements (Source Owen (2013))

Modelling Aspect	System Dynamics (SD)	Discrete Event Simulation (DES)	Agent-Based Modelling (ABM)	Modelling Implications
Model Elements	Stocks flows, causal loops, delays	Entities, resources, flow charts	Agents, rules, state charts	**SD** - if the structure is known, but the dynamic response of the structure is the aim of the investigation. **DES**- requires knowledge of structure, how things are related to each other. Requires definition of entities, resources. **ABM** - the key is to define agents and the rules for their interaction. Key modelling feature is the agent. Does not require the structure to be defined.
Individual entities	Aggregated and represented as stocks and flows	Can be represented as entities	Can be represented as agents	**SD** - systems being modelled need to consist of reasonably homogeneous entities (is there a limit to this? If so, what is it?) Possibly more efficient at systems consisting of large numbers of entities (populations) rather than small groups or individual entities. SD also suited to modelling continuous phenomena such as liquids and processes rather than physically distinct phenomena. **DES** - Individual entities can be represented, with resources treating them differently depending on what they are. Able to model heterogeneous groups of entities. Maybe more efficient at modelling from small groups to large groups (the middle ground?). **ABM** - Individual entities can be represented with their own rules for how they interact. So perhaps inherently more suited to

Table 3.5 Continued....

Modelling Aspect	System Dynamics (SD)	Discrete Event Simulation (DES)	Agent-Based Modelling (ABM)	Modelling Implications
				modelling individuals / small groups / heterogeneous populations.
Treatment of time	Continuous	Event based	Event based	**SD** - Continuous treatment of time. Inherently suits system where changes occur gradually over time and are cumulative/integrative rather than where change is inherently discrete i.e. the level of detail change and the treatment of individual events is a priority in modelling the system. **DES and ABM** - both treat time as discrete. Suited to systems where modelling the detailed (and differentiated behaviour) of individual entities and resources is the paramount requirement.
System structure is represented by	Stocks, flows, causal loops.	Flow charts connecting resources through which entities flow.	The structure is an emergent property of the system which comes about from the interaction of agents.	**ABM** - If system structure is unknown and the study intends to investigate how the interaction between individual agents creates structure, ABM could be the correct tool. **SD** - If the system is already known, but the study intends to investigate the response of the system to dynamic changes, SD is suitable. **DES** - Allows evaluation of different system structures in relation to each other.
Spatial relationship between entities	Is not represented in the model explicitly because entities are aggregated.	No reason why the distance between entities in the model cannot be calculated and used	Can be calculated and can be a key driver in the model. For example, in Any logic Bass Diffusion model, the distance between	**SD** - if the spatial relationship between entities is important then SD will not be the best modelling approach. **DES** - Can take account of distance between entities and resources (I think - need to check this) **ABM** - this is the strength of ABM. Individual agent behaviour can be influenced by spatial relationship.

Table 3.5 Continued....

Modelling Aspect	System Dynamics (SD)	Discrete Event Simulation (DES)	Agent-Based Modelling (ABM)	Modelling Implications
		in logic to drive system logic.	entities is used as a factor in calculating the likelihood of user adoption.	
Feedback	Explicitly modelled through causal loops.	Can be intrinsically modelled through the flow chart.	Intrinsically modelled through agent behaviour (state chart)	**SD** - If the intent of the modelling exercise is to understand the impact of feedback in the system, SD is a good fit, **DES** - Limited feedback of entities can be modelled, but taking a systems view is more difficult, **ABM** - Feedback is not modelled 'overtly' but is a function of the interaction and behaviour of the agents. Better suited for open, investigative modelling exercises where very little is known or understood about system behaviour?
Treatment of randomness/ uncertainty	Can be represented as 'noise' or 'randomness' in the system input	Different distributions of entity arrival time can be modelled. Resource breakdowns can be modelled based on different distributions.	Randomness in the behaviour of individual agents is defined within the agent state chart	**SD** - treated at an aggregate level as noise in the system or variation in the input signal of the system. **DES** - good for modelling the detail randomness or uncertainty in the behaviour of individual entities in the population. If the behaviour of interest is in the random behaviour of individuals then DES could be a suitable tool. **ABM** - any randomness in behaviour is reflected in the decision making logic in the state chart of the individual agent. Thus ABM could be good for studying randomness in behaviour as emergent phenomena based on the decision making of individual agents - (consider the program 'Boids').

Table 3.5 Continued....

Modelling Aspect	System Dynamics (SD)	Discrete Event Simulation (DES)	Agent-Based Modelling (ABM)	Modelling Implications
State changes	Changes in state are typically continuous and are driven by formulas. However, 'step changes' can be modelled.	Changes in the state of entities are controlled by the logic of the model and the executive.	State changes are controlled by the state chart associated with the agent.	**SD** - models assume that state changes are smooth **DES** - model efficiency good because of executive advances from event to event rather than in equal time steps. Suitable when state changes are not continuous and maybe the focus of interest. **ABM** - suitable if the focus of the modelling is the individual agent and the changes that it experiences?
Human Agents typically represented as	Either as stocks and flows (if entities within the model) or as decision makers via causal loops	As entities or resources.	As agents.	**SD** - Best suited to modelling aggregated behaviour of people in large groups or populations where the assumption of homogeneity stands **DES** - Good for the middle ground, representing groups and individuals and their interactions. **ABM** - Agent-based modelling has some particular strengths for modelling individual's behaviour and small groups, especially if heterogeneous nature is important.
Proactiveness/ Self determination	Decision making structures can be modelled in causal loop diagrams	Individual entities can be given decision-making rules	To some extent, can be modelled within the logic of the individual entity	**ABM** is the only approach where this can be modelled?

Table 3.5 Continued....

Modelling Aspect	System Dynamics (SD)	Discrete Event Simulation (DES)	Agent-Based Modelling (ABM)	Modelling Implications
Mathematical formulation	Coupled mathematical equations	Logic based	Logic based	**SD** - inherently suited to phenomena that can be represented by linked mathematical equations - i.e. continuous phenomena **DES and ABM** - suited to modelling systems where the focus of interest is logic based interactions between entities.

The above Table 3.5 provide a strong categorisation among three simulation modelling techniques which enable the researcher to choose the correct simulation technique.

There is no need to be a definite structured in ABM. The agents are the major components of the ABM. In the context of Indian earthquake disaster, every involved agency can be considered as an agent. As every involved organisation have their own code of conduct, policy and working protocol, therefore distinct individuals can be represented with their own rules for their interaction. Therefore, ABM integrally more suited to model individuals. In ABM individual behaviour of the agents can be prejudiced by special association. Finally, ABM is the strongest technique where human behaviour and the decision-making process of human can be modelled and which will conclude that for LMRD modelling. In the Indian context, ABM is the appropriate simulation technique for LMRD for the above reason. In Chapter 5 more detailed relevance of ABM will be provided.

3.2.8 Tool selection

Simulation modelling needs some specific simulation software packages. 90% of simulation models build using these packages, so it is necessary to understand the relation with the simulation point of view (Pidd, 2003). In this research, the researcher uses NetLogo software for ABM. NetLogo is a simple programming language. NetLogo is the ABM software (NETLOGO, 2014). This programming language is relatively understandable and easy to learn and comprehend the environments. The primary instruction of this software is that the turtle (mobile agents) can move over the grid of patches (stationary agents). Every agent has their own behaviour. Link agents connect two agents to create a network.

3.3 Research process

The above discussion provides an in-depth knowledge and understanding of the methods and techniques suitable for this research project. This section interconnects the different strategies and techniques with each of the research questions in different stages to answer the research question efficiently. Figure 3.5 showed the purpose of the methods, strategies, techniques and tools to achieve the challenges of this project. The following Figure 3.5 stated individual research questions and showed the chosen pathway to answer the research question with a proper research methodology. The following chapters 4, 5, 6 and 7 are describing the exact methodology for individual research questions.

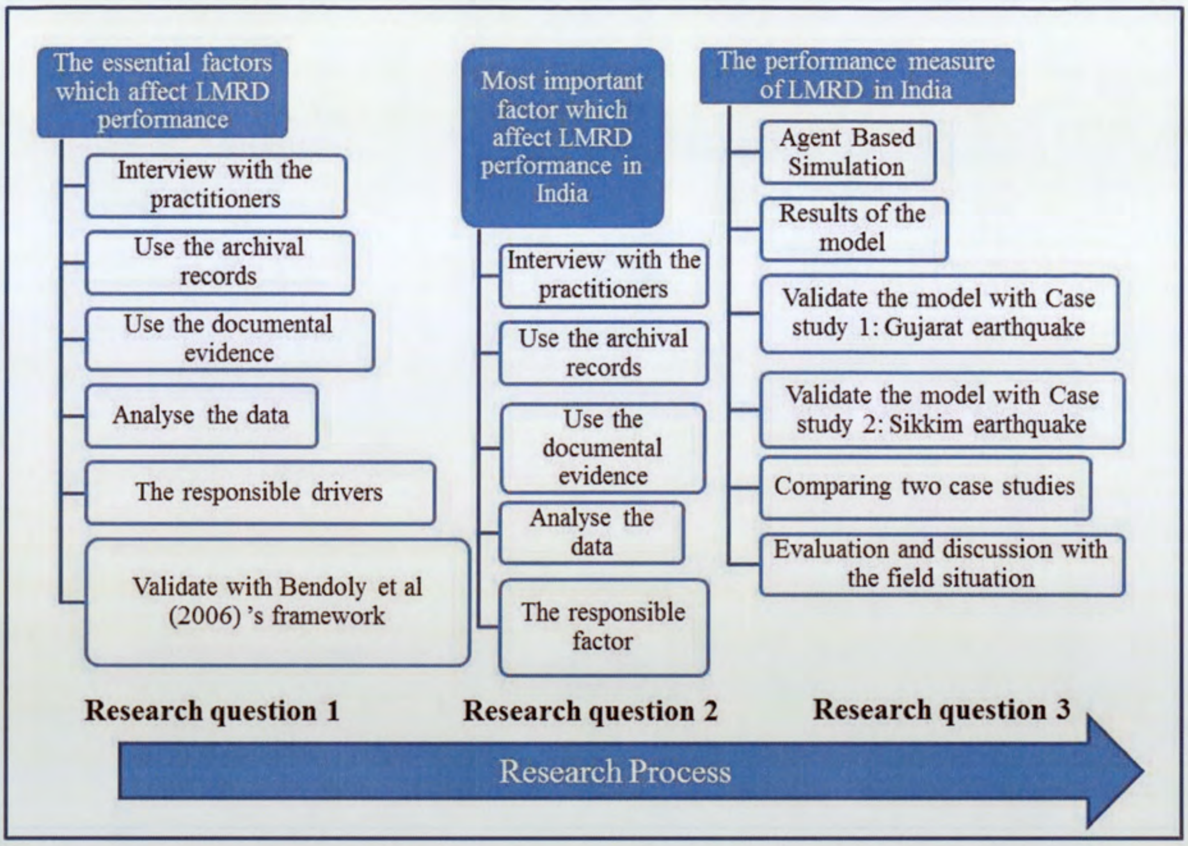

Figure 3.5: Use of the research strategies (Developed by the researcher)

3.4 Summary

A proper research design is the baseline of a successful research project. This research project follows a positivist philosophical paradigm with a case study research strategy to achieve the objective of this project. The choice of methods used in this research is the combination of qualitative method and simulation which accomplishes that mixed method, is the appropriate choice of method used in this research. The discussion of methods, techniques are carefully addressed with some of the criticism of case study research for reliability and generalisability. The chosen methods are fulfilling the objectives of this project. Table 3.6 showed a summary of the research approach referred to the research onion Figure 3.1

Table: 3.6: Summary of research method choices (Developed by the researcher)

Research Philosophies	Positivism
Research Approaches	Inductive and Deductive
Research strategies	Case study
Research choices	Mixed-method
Research time-horizons	Cross-sectional
Research techniques	Semi-structured interviews, Documents, Archival records, Agent Based Simulation
Tool	NetLogo (for ABM simulation), Content analysis and thematic analysis (for interviews and documents analysis)

Chapter 4: The factors for Last Mile Relief Distribution (LMRD)

4.1 Introduction

The second chapter explained the relevant literature about emergency logistics, mainly LMRD, and exhibited the relevant gap in LMRD. The objective of this thesis is to bridge that gap. Chapter 3 explained the appropriate methodological approach of this research to achieve the objectives. This chapter will deal with the individual research questions, which are focusing on the appropriate methodologies and how each strategy will be beneficial to answer the research questions.

4.2 Research trail

The previous chapter provides a comprehensive knowledge and understanding of the methods and techniques suitable for this research project. This section interconnects the different strategies and techniques with each of the research questions at different stages. The purpose of this work is to answer all the research questions. The following flow diagram Figure 4.1 is presenting the methodological pathway to achieve the objectives of this research project.

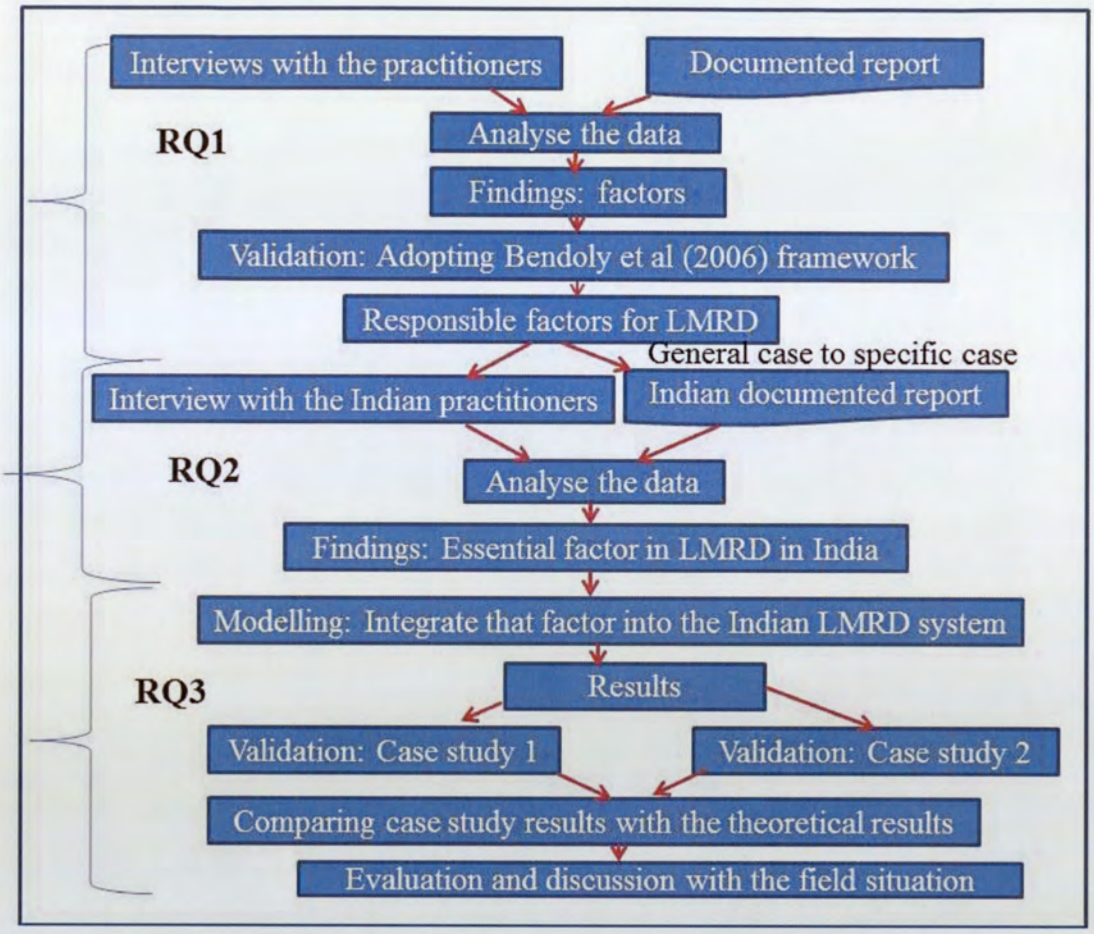

Figure 4.1: Flow diagram of research trail (Developed by the researcher)

4.3 General data collection

The researcher attended the ISCRAM summer school in Netherlands in 2011. In 2011 the ISCRAM Summer school topic was "Emergency Improvement on Humanitarian Information Management and Logistics", and the case was 'Haiti earthquake' disaster, where worldwide logistical personnel from various agencies (for example UN, Red Cross, Oxfam, Netherland Army, Canadian Army and along with others) came to attend the summer school, which was the reliable source of information in the practical perspective. The researcher started data collection with the participating practitioners, who were attending the ISCRAM Summer School. The significance of choosing that summer school as the chosen case was 'Haiti earthquake', so most of the practitioners will have the expertise to deal with the earthquake. Once the researcher managed to conduct an interview with one person in an organisation, then the researcher endeavoured to use the snowball approach to involve more participants in this study. A total of 20 interviews were conducted. There are 16 documented reports are from UN, Red Cross, Oxfam and WHO were analysed. The length of those reports are from 5 to 15 pages. Mainly those reports include previous earthquake disaster response operations, lessons learnt, problem area faced by the responders, organisational mandates etc. Most of the participants of this research are employees of NGOs. Primarily, it is necessary to recognise the practitioner's point of view, which will help the researcher to identify the practical challenges about LMRD. Generally, NGOs information is available for public access through their website. Primarily, 4 NGOs (UN, Red Cross, Oxfam and WHO) were reviewed to identify potential participants. The significance characteristics for these four NGOs are these NGOs are international, so their working range is vast. These organisations have different departments to deal with different types of disasters. And finally, these organisations actively participate in the worldwide earthquake response relief distribution. The websites of the NGOs often contain contact details of their employees. An initial contact was made through email/phone by using the contact details found on the websites of the NGOs. In this communication, the researcher briefly explained the research project and then requested an appointment to conduct the interview. Please find the email used to make an initial contact in Appendix 4 and the participant information sheet in Appendix 5.

4.4 Structuring interview questions

The researcher identifies the research questions after analysing the gap between the LMRD current practices in literature. The semi-structured interview questions are organised on the basis of the research questions and the knowledge from the literature review. In this case, semi-structured interviews are suitable to understand the important aspects of the practitioner's judgment as "a semi-structured interview is a verbal interchange where one person, the interviewer, attempts to elicit information from another person by asking questions. Although the interviewer prepares a list of predetermined questions, semi-structured interviews unfold in a conversational manner offering the participants the chance to explore issues they feel are important" (Longhurst, 2003, p 103). According to van Teijlingen (2014) in the semi-structured interviews, the same key questions are asked to all the participants, but there is certain flexibility in what way the questions are asked and which questions should be the follow-up questions to continue the discussion. The interview questions are as follows and a sample of transcripts are provided in Appendix 6:

- Please describe your role in the relief organisation/governmental organisation?
    - Name of the organisation:
    - Name of the person:
    - The role of the person:

- Have you participated in any earthquake disaster relief aid operation? How many? Can you please name them? Selecting one of the operations (please state which one) please explain your participation in that operation? (For example, how do you know about the disaster? What was your role? When did you reach that area? What were the decisions you have to take before reaching that area? What information was available to you? Etc.)

- What are the key factors which affect the earthquake response operation?

- How do you manage the whole logistics processes during a disaster?

  - ❖ What are the different logistics steps during the earthquake response operation?

  - ❖ How do you first get informed about the earthquake? How do you know the basic facts – location, size, the number of people affected etc.?

  - ❖ Who decides what kind of relief your organisation will supply? I.e. How many resources to dedicate?

  - ❖ Once resources are decided, what happens next?

  - ❖ How is demand forecasting (requirements) undertaken?

  - ❖ How do you know what resources are available locally, in your international network, and from your suppliers?

  - ❖ How rapid is the response from different locations/departments/suppliers?

  - ❖ What happens at a local level?

- How do you manage the logistic processes in last mile relief distribution (for example managing the relief from the local or field warehouse or distribution centre to the disaster affected area)?

- Rank the factors which will affect the last mile relief distribution (final relief distribution) from local distribution centre to the disaster affected area? Please add any other factors you consider as important (1 is the factor with the highest impact)

Names of the factors	Rank
Coordination	
Funds	
Logistics	
Need assessment	
Volunteers	
Safety and security	
Involvement of local community member	
Others (…………)	
Others (.............)	

- For the set-up of the distribution centres, which are the main issues you need to think?
- How do you measure your success of the work (evaluate your work) for the particular earthquake disaster? OR
- How do you know that the population affected is adequately supplied with resources (food, shelter, water, medicine etc.)? OR
- How do you measure the success of your distribution operation?
- How do you serve the whole affected area? Do you plan for the whole area? Do you divide the affected area into zones or clusters? OR
- Could you please explain the distribution procedure during earthquake relief distribution?
- What is the most vulnerable situation during distribution in response phase?
- Before starting the distribution procedure what are the issues you need to think about?
- What are your strategies to identify eligible recipients?
- Do you have any strategy for the recipients' registration?

The following Table 4.1 will analyse the systematical connection between the interview questions and the research objective.

Table 4.1: The mapping of the interview questions with the objective and the reviewed literature (Developed by the researcher)

Interview question	**Sources**	**Research objective/questions**
Please describe your role in the relief organisation/governmental organisation?	General information	General information
Have you participated in any earthquake disaster relief aid operation? How many? Can you please name them? Selecting one of the operations (please state which one) please explain your participation in that operation?	General information	Information about the disaster challenges
What are the key factors which affect the earthquake response operation?	(Liu et al., 2013, Edrissi et al., 2013, Chen et al., 2013, Nigam and Jethoo, 2013, Najafi et al., 2013)	Research question 1
How do you manage the whole logistics processes during a disaster?	(Rawls and Turnquist, 2010, Campbell and Jones, 2011, Duran et al., 2011, Li et al., 2011, Rawls and Turnquist, 2011, Bozkurt and Duran, 2012, Bozorgi-Amiri et al., 2012, Döyen et al., 2012, Noyan, 2012, Bozorgi-Amiri et al., 2013) (Han et al., 2011, Horner and Widener, 2011, Widener and Horner, 2011, Edrissi et al., 2013)	Research question 1
How do you manage the logistic processes in last mile relief distribution (for example managing	(Oloruntoba and Gray, 2006, Oloruntoba, 2010, Perry, 2006, Van	Research question 1 and Research question 2

Table 4.1 Continued....

Interview question	Sources	Research objective/questions
the relief from the local or field warehouse or distribution centre to the disaster affected area)?	Wassenhove, 2006, Jahre et al., 2007, Glenn Richey Jr et al., 2009, Tatham et al., 2009, Tatham and Houghton, 2011, Beamon and Balcik, 2008, Whybark, 2007, Ichoua, 2010, Long and Wood, 1995) (Najafi et al., 2013, Rathi et al., 1992, Özdamar et al., 2004, Shen et al., 2009, Bemley et al., 2013, Yan and Shih, 2009, Tricoire et al., 2012, Afshar and Haghani, 2012, Lin et al., 2011)	
Rank the factors which will affect the last mile relief distribution (final relief distribution) from local distribution centre to the disaster affected area? Please add any other factors you consider as important (1 is the factor with the highest impact)	(Perry, 2006, Decker, 2013, Balcik et al., 2010, Tatham et al., 2010b, Tatham et al., 2010d, Tatham and Kovács, 2010)	Research question 1 and Research question 2
For the set-up of the distribution centres, which are the main issues you need to think?	(Horner and Downs, 2007, Jia et al., 2007a, Jia et al., 2007b, Tzeng et al., 2007, Balcik and Beamon, 2008, Ukkusuri and Yushimito, 2008, Yushimito et al., 2012)	Research question 3
How do you measure the success of your distribution operation?	(Vitoriano et al., 2011, Sheu, 2007b, Sheu, 2010)	Research question 1, Research

Table 4.1 Continued....

Interview question	Sources	Research objective/questions
		question 2 and Research question 3
Could you please explain the distribution procedure during earthquake relief distribution?	(Özdamar et al., 2004, Sheu, 2007b, Tzeng et al., 2007, Yi and Kumar, 2007, Mete and Zabinsky, 2010)	Research question 1, Research question 2 and Research question 3
What is the most vulnerable situation during distribution in response phase? Before starting the distribution procedure what are the issues you need to think about?	(Balcik et al., 2008, Knott, 1987, Haghani and Oh, 1996, Battini et al., 2014, Das and Hanaoka, 2014, Decker, 2013, Sheu, 2007b, Tzeng et al., 2007, Van Wassenhove, 2006, Whybark et al., 2010)	Research question 1 and Research question 2
What are your strategies to identify eligible recipients? Do you have any strategy for the recipients' registration?	(Sheu, 2007b, Vitoriano et al., 2011)	Research question 3

Among those 20 interviews, 11 interviews took place at Netherlands during ISCRAM Summer school 2011 and the other 9 interviews took place in the United Kingdom on 2012 from January until March. The first 11 interviews are completed within 10 days. And the other 9 interviews took two months as conducting the appointment process with the practitioners are very challenging and time-consuming process. Before starting the proper interview process the research conducted pilot interview process with her colleagues to understand the time frame to learn the interview skills. The estimated time for interview process is 45 minutes. But the time frame totally depends on the interviewee, as the respondents are coming from his or her opinion of a particular matter or a situation. And finally, how much information he or she wants to provide and discuss.

The details about the general participants interviewed in this study are given in Table 4.2.

Table 4.2: Interviews related to the Cases (Developed by the researcher)

Generic Case	Interviewee	Short Description
GCS	GCS- Practitioner1	Position: Coordination Manager in an International Non-Governmental Organisation Experience: 10+ year experience in relief distribution Process: 50 mins interview
GCS	GCS- Practitioner2	Position: Response Officer In an International NGO Experience: 25+ year experience in Response during disaster Process: 45 mins interview
GCS	GCS- Practitioner3	Position: Physician Experience: 20+ year experience in disaster management at health sector level mostly response Process: 45 mins interview
GCS	GCS- Practitioner4	Position: Response officer in an International Non-Governmental Organisation Experience: 20+ year experience in relief distribution Process: 50 mins interview
GCS	GCS- Practitioner5	Position: Project Manager in an International Non-Governmental Organisation Experience: 5+ year experience in relief distribution Process: 50 mins interview
GCS	GCS- Practitioner6	Position: Information Coordination officer in an International Non-Governmental Organisation Experience: 15+ year experience in relief distribution Process: 34 mins interview
GCS	GCS- Practitioner7	Position: Doctor Experience: 30+ year experience serving beneficiaries during emergency situation Process: 50 mins interview
GCS	GCS- Practitioner8	Position: Response manager in an International Non-Governmental Organisation Experience: 10+ year experience in relief distribution

Table 4.2 Continued....

Generic Case	Interviewee	Short Description
		Process: 50 mins interview
GCS	GCS- Practitioner9	Position: Field officer in an International Non-Governmental Organisation Experience: 10+ year experience in relief distribution Process: 50 mins interview
GCS	GCS-Practitioner10	Position: Capacity development officer at armed force Experience: 25+ year experience in relief distribution Process: 60 mins interview
GCS	GCS-Practitioner11	Position: Shelter coordinator in an International Non-Governmental Organisation Experience: 3+ year experience in emergency situation Process: 50 mins interview
GCS	GCS-Practitioner12	Position: Coordination manager in an International Non-Governmental Organisation Experience: 10+ year experience in emergency situation Process: 50 mins interview
GCS	GCS-Practitioner13	Position: Response manager in an International Non-Governmental Organisation Experience: 7+ year experience in emergency situation Process: 50 mins interview
GCS	GCS-Practitioner14	Position: Coordination manager in an International Non-Governmental Organisation Experience: 15+ year experience in emergency situation Process: 50 mins interview
GCS	GCS-Practitioner15	Position: Information management officer in an International Non-Governmental Organisation Experience: 10+ year experience in relief distribution Process: 40 mins interview
GCS	GCS-Practitioner16	Position: Response manager in an International Non-Governmental Organisation Experience: 20+ year experience Process: 30 mins interview

Table 4.2 Continued....

Generic Case	Interviewee	Short Description
GCS	GCS-Practitioner17	Position: Senior logistical officer in an International Non-Governmental Organisation Experience: 10+ year experience Process: 50 mins interview
GCS	GCS-Practitioner18	Position: Logistical manager in an International Non-Governmental Organisation Experience: 5+ year experience Process: 45 mins interview
GCS	GCS-Practitioner19	Position: Coordination director in an International Non-Governmental Organisation Experience: 25+ year experience Process: 50 mins interview
GCS	GCS-Practitioner20	Position: Logistical manager in and International NGO Experience: 15+ year experience in relief distribution Process: 45 mins interview

4.5 LMRD performance vectors addressed by the practice

The LMRD is the ultimate stage of the emergency relief operation, which is associated with the delivery of relief supplies from local distribution centre to the disaster affected population. The scale and challenges presented by the LMRD are reviewed in the literature review section. The researcher begins data analysis by using thematic analysis tool after the completion of interview process. In this tool, the researcher first identifies the codes from the interviews and documents. Then from the codes, the researcher fit the codes inside a theme, which is called as identifying themes. The subsequent process is reviewing themes, where the codes are inside the sub-theme umbrella and those sub-themes are inside the primary theme umbrella. The final process is defining the themes. The whole process is shown in Appendix 7. In conclusion, after thematic analysis of the interviews and analysis of the available documents, the researcher identifies that a successful LMRD system has the following performance measures according to the field consideration:

4.5.1 Minimise the Time delay

Time is an important issue to consider during an emergency situation. The stakeholder's (donors, relief workers) main aim is to send the relief as soon as possible to the disaster affected area. One of the practitioner states that "in the response, the operation time is a major problem, as it is necessary to provide the relief as soon as possible to the affected community to save their lives" (GCS- Practitioner9). Not only the practitioner's point of view but also in the emergency logistics' academic literature minimising time delay is an essential objective function (Özdamar and Demir, 2012, Afandizadeh et al., 2013, Altay, 2012). In LMRD as well it is a very important issue to consider minimum time delay to provide the relief material to the beneficiaries.

4.5.2 Maximise the coverage level

The aim of the responders is to cover all the disaster affected area and supplying the relief to the affected community. One of the practitioner states that "the cause of the delay, to reach most of the affected area during distribution time, is sometimes the shortage of relief items (food, medicine, shelters and others) at the participating agencies" (GCS- Practitioner1). On the other hand, another practitioner states that "it is hard to reach all the affected area during emergency situation because of road blockage, the absence of personnel during relief distribution or bad weather situation" (GCS- Practitioner8). Therefore, covering all the affected area is another essential issue during relief distribution. In the emergency logistics literature, the researcher concentrates on maximising fill rate, maximising demand satisfaction and minimising unmet demand during relief response operation (Sheu, 2007a, Tzeng et al., 2007, Özdamar et al., 2004, Yi and Özdamar, 2007, Mete and Zabinsky, 2010, Ortuño et al., 2011, Chang et al., 2014).

4.5.3 Maximise the distance efficiency

The distance efficiency is also a vital problem as presented by the practitioners during LMRD. According to a practitioner " to cover all the affected area the relief suppliers must need to choose the shortest route but it is hard as in a disaster scenario the availability of route is limited because of the damages of road network" (GCS- Practitioner2). The academic community of emergency logistics is also concentrated on the distance efficiency by minimising the total distance travelled to reach all the shelters (Yamada, 1996), minimising expected distance (Chang et al., 2007, Lee et al., 2009a).

4.5.4 Maximise the demand served

Demand efficiency is another key objective of LMRD, as during final relief distribution time maximising the fill rate of the resources, minimising the unmet demand and maximising the demand satisfaction are primary goals for a successful relief operation. Academic literature also considers demand satisfaction (Özdamar et al., 2004, Sheu, 2007a, Tzeng et al., 2007, Mete and

Zabinsky, 2010, Han et al., 2011, Maliszewski et al., 2012) in the emergency logistics, as a significant issue to contemplate.

4.5.5 Maximise the allocation efficiency

Allocation efficiency (Lee et al., 2009a, Dekle et al., 2005, Ratick et al., 2008, Kimms and Maassen, 2011, Najafi et al., 2013) is also a very important performance metrics during LMRD in the emergency logistics literature. Correct allocation of relief items, personnel and vehicles are significant measures for a successful relief operation. For example, in the literature, Najafi et al. (2013) measures the allocation efficiency by minimising the total unserved injured people, minimise total unsatisfied demand and finally minimise total vehicle utilised in the response operation. The precise measure of allocation efficiency concludes the success rate of relief distribution as well as cost efficiency. One of the practitioner states that "the correct allocation of personnel and relief items are essential for the successful relief distribution operation but during a disaster situation, it is really hard to manage the relief items and volunteers as there is a sudden spike in demand arises" (GCS- Practitioner 13).

4.5.6 Maximise the cost efficiency

The purpose of the relief organisations is always maximum lifesaving. However, the cost is an important issue to all the NGOs as they are depending on donations. Cost efficiency is another essential performance measure of LMRD. In the academic literature of emergency logistics the cost efficiency treated as an essential objective function (Barbarosoğlu et al., 2002, Beamon and Kotleba, 2006, Chang et al., 2007, Rath and Gutjahr, 2014, Han et al., 2011). For example, Barbarosoğlu et al. (2002) measured cost efficiency by minimising the total cost and minimising the maximum tour duration among all helicopters. On the other hand, Beamon and Kotleba (2006) measured the cost efficiency by minimising total cost per unit of replenishment. In the literature, there is significant amount of research considering the cost efficiency (Tzeng et al., 2007, Balcik et al., 2008, Lodree Jr and Taskin, 2008, Doerner et al., 2009, Yan and Shih, 2009, Adıvar and Mert, 2010) by minimising the total cost, penalty cost, minimising relief distribution cost, minimising the maximum repair cost.

4.5.7 Prioritisation of service efficiency

It is important to prioritise the service according to the need of the affected community. The important question is always, which relief item should distribute first and where? According to the practitioner's point of view "correct identification and prioritisation of the services (e.g. hot food, water, medical service, required relief items and other services) for the affected community are vital for the successful response operation" (GCS-pracritomers13). The prioritisation of service efficiency has been already considered in academic literature (Sheu, 2007a, Yushimito et al., 2012). Sheu (2007b) presented an optimisation model for supplying urgent relief demand during an earthquake rescue period. The proposed approach integrates five major mechanisms: (1) time-varying relief demand forecasting, (2) affected area-grouping, (3) determination of distribution priority, (4) group-based relief distribution and (5) dynamic relief supply. Rodríguez-Espíndola et al. (2017) explain that "having more resources in the field does not guarantee to perform better operations. It is having the right resources in the field what matters" (Rodríguez-Espíndola et al., 2017, p 14). The service efficiency is measured by maximising the fill rate, maximising the demand satisfaction and minimising the unmet demand.

4.5.8 Minimise the social, environmental and risk impact

According to field consideration security, equality, reliability, other environmental disruptions also have a clear impact on the LMRD performance. According to a practitioner "for me the first priority is security, it is very easy to lose control during relief distribution, which will create stolen of relief materials and a total chaos of the whole situation" (GCS- Practitioner17). There are other factors identified by the practitioners, for example, minimising partiality during relief distribution and consistency of distribution procedures. These social, environmental and risk impact also considered in academic literature (Adıvar and Mert, 2010, Vitoriano et al., 2011, Oxendine et al., 2012, Coutinho-Rodrigues et al., 2012, Nolz et al., 2011). Vitoriano et al. (2011) proposed an optimisation model for humanitarian aid distribution, and in this model, the author not only considers the time and cost problem but also contemplate equity, priority, reliability and security, which is the major concern for aid relief distribution.

4.6 Additional factors, which affect LMRD performance

The above vectors are presented by the practitioners and supported by the academic literature. According to the practitioners, the above vectors are essential for the successful LMRD operation. There are some other factors, which affect the performance of LMRD. These factors are identified from the collected data. In the following paragraphs, the researcher explains those specific factors.

4.6.1 Coordination

During final relief distribution, coordination is a major issue, which is identified by the practitioners. According to Balcik et al. (2010) "the term coordination to describe the relationships and interactions among different actors operating within the relief environment" (Balcik et al., 2010, p 23). There are two types of coordination: vertical coordination

(coordination inside the organisation among the upstream and downstream agents) and horizontal coordination (one organisation coordinates with another organisation) (Balcik et al., 2010). In the final relief distribution, all the active agencies have the same overall purpose to help the affected population in the means of food, water, medicine and shelter. There is a diversity of involved actors (active agencies) during the relief distribution operation. This can create some challenges such as language barrier, different organisational policies, differences in culture and other factors, which increase the necessity of horizontal coordination for final relief distribution. In the academic literature, Perry (2006) states that a significant amount of aid groups could also interrupt coordination efforts. The low level of coordination and association amongst the participating agencies has regularly been a relief and response operation criticism. Tatham et al. (2010d) identified that there is a significant amount of research already conducted about vertical cooperation, on the other hand, there is a limited work done in horizontal cooperation. The author also examined three case studies and identified the importance of horizontal cooperation in the context of emergency logistics (Tatham et al., 2010d). (Ergun et al., 2014) propose to use information technology tools to facilitate multi-agency coordination and collaboration during LMRD. Balcik et al. (2010) proposed that "most relief chain mechanisms involving international relief actors are horizontal, in that they concern resource sharing and joint-decision making" (Balcik et al., 2010, p 25). According to a practitioner's perspective "the coordination among the involved agencies is lacking for various reasons (for example communication gap, limited resource sharing, limited information and many others) which are a major factor for the uncertainty of relief distribution operation" (GCS-Practitioner10).

The current research and the practitioners have identified the importance of horizontal over vertical coordination, therefore in this context, the researcher focused on horizontal coordination. Mainly horizontal coordination is intended for resources sharing, information sharing and joint decision-making process between different active agencies. In the last three decades, the NGOs are concentrating on coordination for more effective response operation and establishing various coordination bodies. For example, the UN and other relief agencies established OCHA, UNJLC and IASC to continue joint decision-making programme like CERF and other joint programme to improve the coordination within the relief community (Reindorp, 2002, Kehler, 2004, Tatham et al., 2010d). It is necessary to integrate coordination among the involved agencies (local, national, international NGOs and Governmental Organisations) for more effective and efficient operation of the final relief distribution.

4.6.2 Needs assessment

An efficient response operation required a better understanding of the current context, which is called needs assessment. According to practitioners "it is necessary to understand the socio-economics situation of the affected community for a sound needs assessment for an effective response operation" (GCS-pracritomers19). According to Darcy and Hofmann (2003), the term needs assessment used in three different senses: to define basic human needs, to explain a lack of the above and to identify the needs for relief assistance or some other humanitarian intervention.

The primary objective of needs assessment is to deliver clear information for the operational contingency planning during response and relief operation in an emergency situation (Refugees, 1999). Consequently, the correct needs assessment analysis is necessary for effective relief distribution operation. Precise identification of the affected community and the exact need is necessary for the effective relief distribution operation; therefore, the correct use of needs assessment feedback is an additional essential factor which increases the performance of LMRD. The commonly used tools for needs assessment are questionnaires, checklists and visual inspections (Refugees, 1999).

4.6.3 Involvement of local community member and Knowledge of local area

The government and the NGOs consistently try to increase the local community initiatives and understanding about the natural disaster by providing training, communicating with the community and by proper education (Kapucu, 2008). After a disaster, the affected community always acts as first responders and they have the information about the locally available resources, most affected neighbourhoods and most immediate priorities in the sense of relief items. All the above information help the involved agencies to continue the short-term relief operation rapidly. The community member has the correct knowledge about the affected area. According to the majority of the practitioners, the involvement of local community members is providing precise knowledge of local area and increase the efficiency of the performance during relief distribution.

4.6.4 Culture role

Culture role has a big impact on disaster management planning. According to Kunz and Reiner (2012) "the type of market economy, the presence of local suppliers, the level of education of the population, the local culture and religion will oblige relief organisations to adapt their operation to the context, and can affect the performance of humanitarian logistics" (Kunz and Reiner, 2012, p 120). Every geographical region has own culture, food habits, specific clothing habit etc. For example, in northern Indian regions culture (food and clothing habit) is totally different from the southern Indian culture. In that context, one of the practitioner states that "during South Asian Tsunami 2005, the relief organisations were sending plenty of flours to South India but the affected community refuses to accept flour, as they were more used to with rice in their food habit" (GCS-pracritomers10), and that shows wastage of relief items. Another practitioner draw attention to the five key factors for an efficient relief distribution operation and they are "accurate assessment of the situation, prioritisation of the needs, understanding of the cultural aspects where the disaster happened, engaging the host country population in the relief distribution operation and communicate the plan to the host country population" (GCS-pracritomers12). It is essential to understand the disaster affected region's culture first and then supply the relief item according to their needs. Involve community member can be the better source of information for the international responders about their specific culture role, which will reduce the wastage of the relief items as well. Culture role is another valid driver, which affects the LMRD.

4.6.5 Correct knowledge

According to a practitioner's perspective "during relief distribution operation, the suitable knowledge of responders is also necessary, for example how to manage the distribution planning, exact knowledge of logistical issues, proper use of technologies and understanding the previous data" (GCS- Practitioner3). Another practitioner states that "if you have suitable knowledge of the available data and scenario during the disaster strike, then you have something to begin. You have some information to act quickly for first 48 hours through the scenario. From that you can extrapolate, you can do estimation, with the use of your knowledge that you have, you can make a good projection. Then you can continue to collect the information, which will be more accurate. But still, in disaster preparation, I will say that a very important factor is the exact knowledge to understand the needs to begin your work in the field of disaster" (GCS-Practitioner5). After a huge impact disaster, it is necessary to have the correct knowledge for a smooth relief chain process. Inadequate use of technologies, lack of institutional learning, and lack of logistical knowledge are the challenges which decrease the efficiency of relief distribution (Heaslip and Barber, 2014).

4.6.6 Minimising the competing attitudes of the involved agencies

After a disaster, many local, national and international organisations are actively helping the disaster affected population in the field. But it is also true that most of the NGOs depend solely on donations (Balcik et al., 2010). The NGOs need to display the number of the helped beneficiaries to the donors, and that creates the competing attitude in the field during relief distribution. According to the practitioners, minimising the competing attitude of the involved agencies is necessary for effective and efficient LMRD operation. The primary goal is to supply the relief material to fulfil the demand to the disaster affected population as quickly as possible. If the active agencies are minimising the competing attitudes and collaborate and share information between the participating organisations to accomplish the relief operation, then the final relief distribution will be much more substantial.

4.6.7 Trust

Trust described as "an expectancy held by an individual that the advice offered by another individual or organisation can be relied upon"(Curnin et al., 2015, p 2). In relief distribution trust is essential among the responders and also between the responders and beneficiaries, which is a major factor of LMRD from the practical perspective. Though in the academic language, during a disaster, trust is only considered for temporary groups for a temporary timeframe, which is called as 'swift trust'(Meyerson et al., 1996). The opinion of swift trust is more suitable for the temporary organisations, mainly for those who operate in emergency management (Curnin et al., 2015).

4.7 The practical implications of additional factors affecting the LMRD performance conditions

The above discussion stated the performance measures for LMRD. In the literature, most of the researchers consider that LMRD performance requires a better understanding of LMRD. For example, Balcik et al. (2008) proposed the cost efficiency by minimising the total transportation cost for unsatisfied and late satisfied demand for different types of relief items. On the other hand, Battini et al. (2014) focused on time efficiency by managing vehicle capacity and delivery time restrictions. Das and Hanaoka (2014) concentrated on demand efficiency by managing fleet allocation.

The researcher also identified and analysed the factors, which affect the final relief distribution performance. The following Table 4.3 shows the connection of those factors for individual performance measures for LMRD.

Table 4.3: The factors are affecting the LMRD performance metrics (Developed by the researcher)

Performance measures of LMRD	Factors	The effect of the Factors
Minimise the time delay	Coordination, Trust, Correct knowledge, proper need assessment, sharing information and minimising competitive attitudes	If the involved agencies coordinated with each other and have trust among them, additionally with correct knowledge (use of technologies, logistical knowledge) can minimise the time delay and satisfied the demand of the affected community as soon as possible.
Maximise the coverage level	Needs assessment feedback, Coordination, Involvement of local community members, knowledge of local area	Correct use of need assessment feedback, coordination among the agencies, a whole overview of the response plan and the discussion of that response plan with involved community members for the correct identification of the beneficiaries and maximise the coverage level.
Maximise the distance efficiency	Knowledge of local area, Coordination, Correct knowledge,	The knowledge of the local area will provide the alternative routes for transportation as during disaster there are some damaged routes. Correct knowledge of fleet management and coordination are essential to maximise the distance efficiency.
Maximise the demand served	Needs assessment feedback, Coordination, Trust, Culture role, Involvement of local community member	Correct use of needs assessments feedback, Trust among the active agencies and between the affected community and the responders is essential. To understand the culture of that affected community involvement

Table 4.3 Continued....

Performance measures of LMRD	Factors	The effect of the Factors
		of local community members is essential. Lastly, coordination is necessary between the every stakeholder in the field.
Maximise the allocation efficiency	Knowledge of local area, Involvement of local community members, minimise the competing attitude among the involved agencies	Involvement of local community member and knowledge of the local area will provide the most vulnerable neighbourhood and also minimise the competing attitude among the active agencies is necessary.
Maximise the cost efficiency	Collaboration and sharing information between the participating organisations, Need assessment feedback, Coordination	Correct use of needs assessment will reduce the loss, during distribution and transition; collaboration and sharing information and resources
Prioritisation of service efficiency	Knowledge of local area; Knowledge about the Involvement of local community members, Coordination, Trust	Discussion of communication plan with the local community, strong and methodical control mechanism during the relief distribution
Minimise the social, environmental and risk impact	Culture role, correct knowledge of local area, coordination, trust,	Safety and security by the local military and the civilians, coordination and trust among the agencies and beneficiaries.

4.8 Summary

The LMRD performance metrics are identified from the literature and practitioners point of view and also the effect of the factors on the performance of the LMRD is analysed, which showed in Figure 4.2.

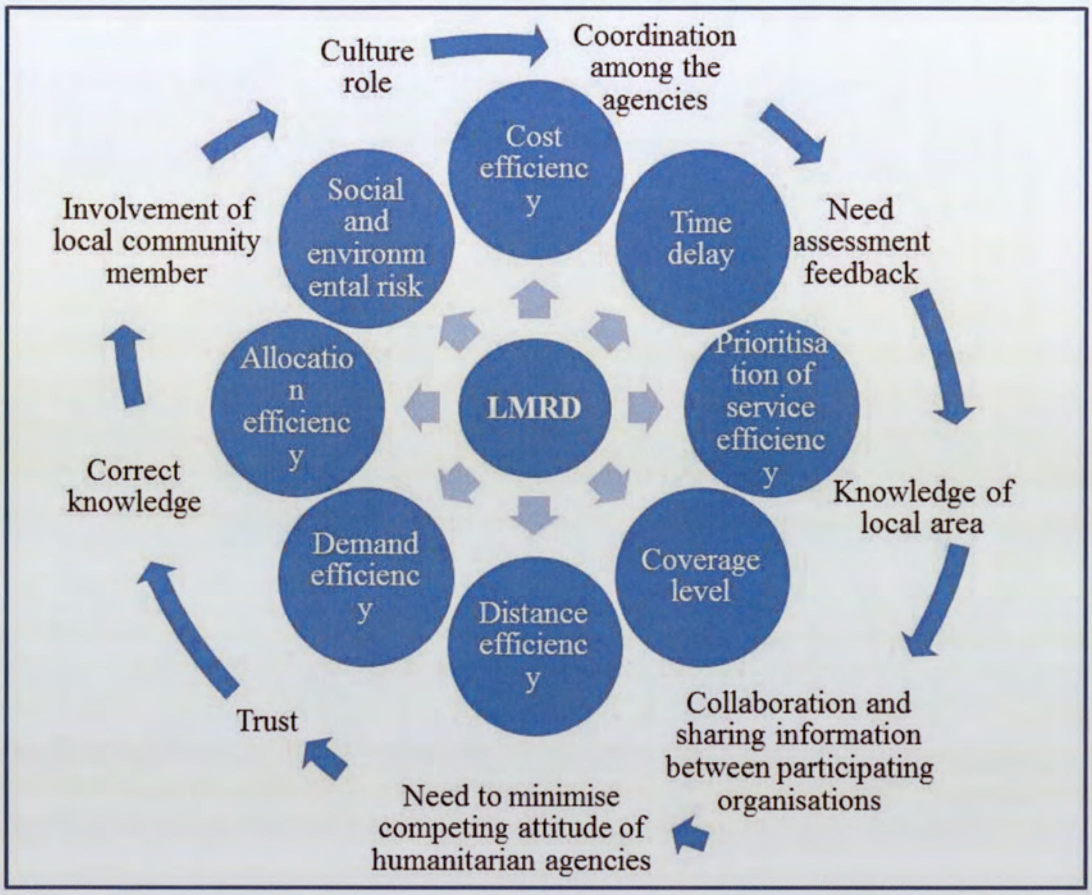

Figure 4.2: The LMRD performance metrics and the factors (Developed by the researcher)

It is necessary to validate the factors. In this case, this is a very challenging issue, as all the factors indicate a commonly involved aspect and that is human behaviour.

During the application of operation management tools, techniques and theory "the success of operations management tools and techniques, and the accuracy of its theories, relies heavily on our understanding of human behaviour. Lack of trust between supply chain partners, incentive misalignment, and natural risk aversion are but three behavioural issues that can negatively impact operational success" (Bendoly et al., 2006, p 737). Coordination, trust between the suppliers and application of correct information are a couple of behavioural issues which could have an undesirable impact on the operational success of LMRD in emergency logistics. In the economics, accounting, marketing, management areas the behavioural issues already introduced and extended tremendously and positively. In the operation research perspective, Bendoly et al. (2006) proposed the benefits of behavioural experiments and contribute directly to the researchers towards a huge area of research.

The objective of this validation part is to adapt Bendoly et al. (2006)'s framework into the emergency logistics and introduce the behavioural factors, which affects the decision-making process during an emergency situation.

The research's intention is to compare the identified factors from the interview and document analysis for affecting LMRD and establish the novelty of those factors into the LMRD performance by adopting this framework.

In the following paragraph, the importance of behavioural issues will be discussed and also the justification of adopting Bendoly et al. (2006)'s framework will be explained. The adopted version of the framework will be established in emergency logistics perspective and validated the LMRD factors.

4.9 The importance of behavioural research and necessity of theory building in emergency logistics

Development of research in emergency logistics is expected to increase as recently natural disaster like floods, cyclones, tsunamis and earthquakes are becoming common incidents around the world. These natural disasters need to be well managed by the efficient management system of logistics. Chapter 2 presented an extensive and thorough knowledge about emergency logistics tools, techniques and current researched issues. A call was issued by Jahre et al. (2009) about the necessity of theory building in the emergency logistics research. The requirement of theory building is essential to manage the complexity of the emergency logistics field proposed by Glenn Richey Jr et al. (2009). Therefore, there is an urgent need for identification of theory in the emergency logistics field to maximise the academic research and predominantly application of that research outcome by the practitioners. There are some issues like coordination, culturally sensitive assessment, information sharing, local leadership affect the emergency logistics planning, which was the observation of logistical managers, engaged in the South Asian Tsunami 2005 response (Perry, 2006). The above factors delayed the decision-making process for providing emergency relief. Some of the above factors are behavioural factors. The behavioural issues are identified as a common factor of operations management research. The first conference about behavioural operation research on 2006 encouraged us to think positively about this issue in OR. Journal of Operation Management special issue on behavioural operation published in the same year showed the importance of this topic in OR (Bendoly, 2006). The annual conference continued and grew each year and also in the INFORMS, POMS, EUROMA etc. operations research society incorporate the special stream behavioural operation. Thus, the field has established and matured. According to Croson et al.

(2013) "behavioural operations is the study of potentially non-hyper rational actors in operational contexts" (Croson et al., 2013, p 1). Recent study explains that from 2006 to 2011 there are 100 papers about behavioural research published in many peer-reviewed journal (e.g. JOM, MS, POM, MSOM and the DSJ) (Croson et al., 2013). The authors analysed that 100 behavioural operations papers and identified that there are behavioural operations research work done in forecasting (4%), service (7%), supply chain (27%), inventory (8%), production (10%), quality (11%), project management and product development (17%) in the operational context (Croson et al., 2013). There is a need of operational context in the research of BOM study. Croson et al. (2013) defined behavioural operation research as the "research being behavioural in nature and dealing with an operations context" (Croson et al., 2013, p 2). In Figure 4.2, the analysed factors of LMRD performance are accountable to affect the operational decisions and the behaviour of all the active agencies. Mainly those factors are analysing the micro level issues of LMRD operations, which makes those factors as behavioural factors. The deep knowledge or understanding of motivation, leadership, fairness and gender is not the goal of the BOM but the goal should be an operational or decision-making process. Therefore, behavioural research will enhance the theoretical insights and predictions of behaviours, will be particularly appropriate for the theory building and development for the emergency logistics.

4.9.1 Necessity for theory building in emergency logistics

The complexity of disaster management domain specifically in the emergency logistics field, there is a need for new tools, techniques and theory to improve the decision-making process of the relief distribution operation and operational research can accomplish that (Albores et al., 2013).

Operations management is dealing with the study of the design and management of the processes in manufacturing and service of an organisation. The challenging part of operations management is building a mathematical model or theory of an interesting phenomenon and testing that theory with field data (derived from surveys, databases, experiments, comparative case studies, ethnographic observations, etc.). Behavioural operations management is a multi-disciplinary area of operations management that noticeably reflects the effects of human behaviour on process performance, prejudiced by cognitive biases, common preferences and cultural norms (Loch and Wu, 2007). Almost all the operations management studies contain human interaction. For example, there are managers making decisions, customers buying products, employees working in and improving processes. The behavioural issues could be the important factors, which support an efficient operational process or decisions making process. Croson et al. (2013) identified by analysing 100 papers that there are various methodological aspects used in behavioural operations research. 6% of those 100 papers used modelling as a methodological technique, 22% used survey, 11% used experiment game, 28% papers used experiment decision task, 14% used archival and finally 15% papers used qualitative conceptual analysis (Croson et al., 2013). Each methodology has their own limitations. Therefore, a mixed method approach allows for better triangulation of results (Croson et al., 2013). In BOM there is 27% work done in supply chain management (Croson et al., 2013). Moritz et al. (2013) used dual process theory to understand inventory decision-making process, while De Vericourt et al. (2013) demonstrated the differences in inventory decisions by gender and risks preferences. In the supply chain context, Riedl et al. (2013) proposed procedural rationality to analyse supplier selection. In the disaster situation, the supply chain process is more complicated and uncertain. After huge impact disasters, it is very challenging task to save the affected population. Relief items are available to the affected community, by the action of relief organisations. This supply chain process must be very rapid and efficient. An effective logistics system is very important to continue a well-organised supply chain process (Chopra and Meindl, 2007). Logistics is responsible for the movements and storage of materials as those move through the supply chain. Consequently, logistics management concerns on demand forecasting, inventory management, material handling, warehousing, order processing and distribution management throughout the entire supply chain process (Chopra and Meindl, 2007). The emergency logistic management needs to be more efficient and effective. Behavioural operations will be a suitable framework for the development of effective and efficient emergency logistics, operational process, as behavioural issues will identify the micro-level issues which will arise during the operational decision-making process. The researcher can adjust the assumptions by understanding the people's reaction and can use that knowledge for creating new models, to improve the decision or validate the responsible factors for the emergency logistics decision-making process. Behavioural issues can be used to expressively improve the predictive accuracy of the decision models.

4.9.2 Behavioural operations management

The behavioural study is a well-established methodology in the field of psychology, sociology, economics and medical science. In the field of marketing, accounting, human resource and business areas this methodology is recognised positively. According to Gino and Pisano (2008), human behaviour conventionally has been ignored or treated as a second-order effect. Boudreau et al. (2003) highlighted the common behavioural assumptions for modelling of the human behaviour into the operational management settings: (1) people are not a major factor; (2) people are deterministic and predictable; (3) workers are independent; (4) workers are not part of the product or service; (5) workers are emotionless; (6) work is perfectly observable and (7) workers are 'stationary' (no learning, fatigue or problem solving occurs). This research clarifies that people play a key role in operational process and performance measurements of a model and this is the fundamental knowledge of behavioural operations management. From 2006 onwards behavioural issues getting attention and the field is getting extended and matured in the operational perspective (Bendoly, 2006, Loch and Wu, 2007, Bendoly et al., 2010, Croson et al., 2013).

The challenge is always how quickly and efficiently the relief will reach to the disaster-affected population and save their life. People are a major factor in the emergency situation. The decision maker must be very careful about the appropriate decisions, as the decisions could affect the human life. In the emergency logistics, Guo 2013 presents a method of defining customer's (affected people) satisfaction attitude based on the cumulative prospective theory. The author used travelling salesman problem with time windows based on customer's satisfaction. This study indicated the value of disaster victim's attitude, which will help the decision maker for better planning (Guo 2013). In the other way, Gralla et al. (2014) incorporates an ethnographic study to define the importance of accurate formulation of the goals or objectives by a human for relief aid delivery planning. The findings of this research show that the logistical manager rather uses policies for the ongoing decisions (Gralla et al., 2014). Comfort et al. (2004) described the importance of coordination throughout the network of responding organisations by simulating the dynamic between increasing demands and decreasing capacity in an actual emergency response system. Tatham and Kovács (2010) explained the importance of swift trust, which is necessary to form networks as a mean of improving relief operations in rapid onset disasters. In summary, incorporating of the behavioural issue in the operational process is providing more sophisticated and easy to use decision-making process in emergency logistics. Operations and behaviour are two elements involved in the above-presented research. The behaviour elements are coordination, customer's (affected population) satisfaction, swift trust. These behavioural elements are considered as a behavioural factor because there is human behaviour involved. For example, the level of coordination and communication between the two human beings entirely depends on their willingness to participate in that coordination and communication. This willingness is the behavioural factor as there is human behaviour involved.

There is some useful framework already exists in another operational field for developing research questions concerning behavioural issues. These frameworks can easily be utilised by the emergency logistics researchers to build the behavioural research in the field of emergency logistics. Among those frameworks, one of the frameworks is developed by Bendoly et al. (2006) to identify the type of behavioural assumptions mainly for analytical operations management model. The researcher uses Bendoly et al. (2006)'s framework to validate the behavioural factors. The primary relevance of this framework is that the researcher can systematically analyse the assumptions of operations management models and their implications on performance. According to Bendoly et al. (2006) "this characterization is helpful for identifying the types of operational problems that could benefit from behavioural research" (Bendoly et al., 2006, p 738). In the following section, one of the frameworks, which is developed by Bendoly et al. (2006), is presented and adopted to the emergency logistics context. This framework is suitable for identification and classification of behavioural assumptions in the existing models.

4.9.3 Behavioural assumptions

Bendoly et al. (2006) proposed a framework for classifying the assumptions which are important to the model. For the development of classification system, the authors provided systematic examinations of models assumptions and then identify the areas where behavioural research will be more suitable. This research is adapted the framework for the same purposes.
Bendoly et al. (2006) organised their analysis by dividing assumptions into three categories: intention, action and reaction. The intention category refers to the goal or objective of the model. This indicates the accuracy of the model. The second category is action, which refers to the decision maker's rules or behaviour. And the third category is about the reaction, how the decision maker reacts to change in their environment (Bendoly et al., 2006). For the identification of the intention assumptions, the behavioural researcher needs to argue about the correct assumption for validation of the goal. Another concern is the gap between what the decision maker's goal should be and what they actually make a difference to the model and model recommendations or not (Bendoly et al., 2006). According to Bendoly et al. (2006), the key questions of behavioural issues about the action of assumptions are:
"Do humans (even in extreme cases) act the way they are modelled? If not, is the difference systemic and predictable, and does it affect model recommendations?" (Bendoly et al., 2006, p 741). In the reaction assumptions, the behavioural factors imply how the decision maker learn and use feedback, assumptions concerning reaction and also involve in better behaviour. This framework provides a simple and well-organised approach for the behavioural accuracy of model assumptions. This framework then identified the gap between the actual and assumed behaviour. In the next section, the framework will be used for the emergency logistics context.

4.9.4 Adaptation of Intention, Action and Reaction framework in Emergency logistics

There are four logistical decisions needed to consider in the disaster situation: facility decisions, inventory decisions, transportation decisions and distribution decisions. There are some activities which are performed in every decision. For example, facility location, shelter location, emergency storage location and distribution centre location are the programmes inside the facility decisions umbrella, where the decision makers need to make a judgement. Transportation decisions include evacuation, routeing, traffic routeing assignment, and casualty transportation. Inventory decisions involve pre-positioning relief stock, inventory management and distribution decisions. To use the intention, action, reaction framework into the emergency logistics perspective the researcher needs to consider the emergency logistics model design. The adopted framework used in the emergency logistics model assumptions and their implications on performance. In the intention framework, it is necessary to identify the objective of the model and need to think, do the objectives are fulfilling the decision maker's purpose? And then to achieve the goal, what action the decision maker needs to consider and finally the result of the action and the feedback of the result are considered in reaction framework. For example, there is an earthquake happened and the affected population need 10,000 blankets. So the decision maker needs to arrange 10,000 blankets, which is an intention framework. Now in the next step, the decision maker will order 10,000 blankets to the supplier, this is an action framework. But if the supplier informs the decision-maker that they have only 8000 blankets, then the decision maker contacts the other supplier for rest of the 2000 blankets, which is a reaction framework. In emergency logistics, optimisation is the dominant technique. Therefore, most models pursue the optimal solutions. For instance, in the emergency logistics perspective, the decision maker wants to select the suitable area for a distribution centre to obtain maximum coverage level for a successful relief distribution operation. This assumption may not hold well in a situation where coordination and trust are critical to handling. This is the intention related example. Similarly, typical action assumption is that during the emergency relief distribution the decision maker always provides priority to the risk like the speed of the process, availability of relief items and efficiency of relief distribution. They may not give sufficient consideration to the risk like thievery of relief items and security of affected people after collection of relief items. Finally, regarding the reaction related assumptions Rottkemper et al. (2011) provided a very good example during an emergency situation the need is to supply of relief items to the affected area but suddenly if there is an uncertainty situation occur in the demand or supply then how to handle the situation. Rottkemper et al. (2011) used penalty cost for unsatisfied demand and incorporate future uncertainties. In this situation, the decision maker needs to use the feedback and also correct knowledge of learning protocol. The following Table 4.4 shows the details of intention action and reaction framework applied to the activity of emergency logistics perspective, which is identified by the behavioural gap analysis of the emergency logistics literature.

Table 4.4: Incorporating intention, action and reaction framework into the emergency logistics area (Developed by the researcher)

Emergency logistics activity	Task example	Intention	Action	Reaction
Facility location and emergency storage location.	Common modelling assumptions	Decision maker makes decisions with the goal of maximising the coverage level in the total network of the facility.	Characterised the associated risks like avoiding disaster prone area and not to exceed the capacity of facilities these are the risks decision maker always think before establishing the facility or storage location	During an emergency situation, a sudden spike in demand can occur at any time. So demand is independent of location selection
	Possible behavioural gaps or implications	The correct information of subset out of the potential warehouses near the affected area and correct information of total population can vary the coverage level.	Availability of particular risk like fix personnel requirements for the facility, and coordination level, trust level among the personnel these are the other risks the decision maker needs to think during the decision-making process.	Correct needs assessment and correct knowledge of local area and correct knowledge of the affected population could make a control in the demand.

Table 4.4 Continued....

Emergency logistics activity	Task example	Intention	Action	Reaction
Shelter location and distribution centre location	Common modelling assumptions	Decision maker always minimising the total shelter (distribution centre) establishment and shelter (distribution centre) running cost.	Fixed cost of establishment of shelters/distribution centres, the capacity of shelters, the available agency for running the shelters, procurement cost per product in the shelters, these are the common assumptions the decision maker needs to think during the shelter location sites and distribution centre selection sites are considered.	Frequent supplies are necessary for running the shelter and distribution centre.
	Possible behavioural gaps or implications	Considering the particular cost instead of total cost make difference in the decision-making process. Also, need to consider the number of people without shelters and number of people sheltered and also a number of active shelters. Need to think	Safety and security issue, coordination issue and swift trust these are the behavioural issues which can affect the optimal configuration.	Supplier relationships and coordination of stakeholders are necessary for the successful frequent supply process. Minimising the competing attitude of the active agencies also another important behavioural gap.

Table 4.4 Continued....

Emergency logistics activity	**Task example**	**Intention**	**Action**	**Reaction**
		about coordinating and collaborating among the shelters		
Inventory management	Common modelling assumptions	The decision maker always aiming for efficient and effective inventory management system to manage the uncertainty of demand during disasters.	The decision maker will use provided information about safety stock, holding cost efficiently.	The decision maker will utilise previous disaster performance feedback and use of emergency management protocol effectively.
	Possible behavioural gaps or implications	Incorporate the lean inventory strategy could provide a better result.	Biased information and knowledge could affect the success rate of performance of inventory management.	Performance feedback and emergency management protocol may be distorted and affect the decision-making process.
Stock pre-positioning of relief items	Common modelling assumptions	Decision maker makes decisions with the goal of minimising the total cost for storage stock of relief items.	High performance tends to pre-positioning relief items and pre-positioning relief items tend to cost. So the decision maker will use the provided budget information for the decision making process	To manage the pre-positioned relief items (perishable, non-perishable, medical) need to be trained workers. Again the stock pre-positioned in one place but disaster strikes somewhere else, so for that need proper management trained worker.

Table 4.4 Continued....

Emergency logistics activity	Task example	Intention	Action	Reaction
	Possible behavioural gaps or implications	Minimising the individual cost of holding cost, the penalty cost making difference in the decision-making process.	The unfairness of information about relief items and budget could affect the performance rate.	During disaster learning and motivation could affect the workload and uncertain situation.
Traffic routing assignment, casualty transportation and evacuation	Common modelling assumptions	Decision maker makes decisions aiming for minimising the total distance travel time.	Decision maker needs to know the information about the impact of disasters, road network and means of transportation for the decision making process.	Decision maker needs to learn the early warning system for evacuation and casualty transportation and also need to implement the system.
	Possible behavioural gaps or implications	Maximising the coordination level of the trained personnel will provide positive results in the decision making process.	The local community members of the affected area could be involved in the identification and information of local disrupted area and also coordination with the decision maker will deliver a better result.	During implementation time the success of the operational system depends on the understanding of decision maker's knowledge and learning capacity. So trust, correct information and correct use of learning capacity will ignore the decision making bias.

Table 4.4 Continued....

Emergency logistics activity	**Task example**	**Intention**	**Action**	**Reaction**
Relief distribution	Common modelling assumptions	Decision maker makes decisions with the goal of minimising the total distribution cost and minimise unsatisfied demand, minimise time.	Decision maker needs to know the number of personnel for the distribution process, a number of the agency involved in the distribution and a total number of affected people for the decision making process.	Decision maker needs to learn the accurate assessment of the situation and correct prioritisation of the needs.
	Possible behavioural gaps or implications	Maximising the demand satisfaction score will be an applicable behavioural objective for relief distribution.	The other behavioural assumptions like criteria on which the distribution will be held, For example after Haiti earthquake in Haiti, the distribution was only among women, control mechanism during the distribution means involves the required local paid worker for the control mechanism.	The decision maker needs to learn some other behavioural issues like understand the cultural aspect of the disaster affected area. Also, the population would be more willing to wait if the plan was communicated to them, the fact they don't understand what is going on making them more worries. So the communication plan is as important as the distribution plan.

4.9.5 Discussion

The above Table 4.4 explains that in the literature there are some dominant objectives for the individual action plans. For example, the primary objective of the decision maker is to maximise the coverage level of the facility when they are considering facility location selection and emergency emergency storage selection for an effective planning of relief operation (Jia et al., 2007a, Balcik and Beamon, 2008, Berman et al., 2009, Doerner et al., 2009, Oxendine et al., 2012, Berman et al., 2013). Again, for shelter location, transportation, inventory management and relief distribution, there are some dominant objectives identified in the previous literature. For example, there is a significant amount of effort to show that the decision maker's objective is minimising the cost in terms of distance and time (Barbarosoğlu et al., 2002) (Beamon and Kotleba, 2006) (Chang et al., 2007) (Özdamar and Demir, 2012). During emergency situation the decision makers also need to think about minimising the distance (Brown and Vassiliou, 1993) (Yamada, 1996, Chang et al., 2007, Jia et al., 2007a, Lee et al., 2009a, Zheng et al., 2013) to the disaster affected area and minimising the delay of time (Özdamar and Demir, 2012); (Afandizadeh et al., 2013); (Bish and Sherali, 2013) for quick relief supply to the affected population. In the emergency logistics operation, there are other important issues like maximising fill rate, maximising demand satisfaction, minimising unmet demand, the number of facilities, accessibility of the affected area, the number of personnel, minimising casualties, the number of allocated vehicles and environmental risk are also enumerated in the literature. The above Table 4.4 demonstrates an instance for the importance of behavioural research in emergency logistics. Incorporating behavioural issues in emergency logistics field will increase the theoretical richness of this subject and improve the predictive accuracy of the available models by identifying relevant behavioural micro level issues for individual objectives. The intention, action and reaction framework (Bendoly et al., 2006) provides guidelines for the behavioural accuracy and assumptions, which could be incorporated in the emergency logistics' available models for precise results.

4.9.6 Validation the responsible factors from the gap analysis of the emergency logistics literature

This thesis has reviewed the relevant literature in the emergency logistics field and observed that there are some behavioural factors, which affect the decision-making process during an emergency situation. Therefore, if those behavioural factors are incorporated in the available models then the models would provide better results. For the establishment of behavioural factors this research used Bendoly et al. (2006)'s framework in the emergency logistics operation and showed the behavioural gap in this field. The above gap analysis clarifies that many behavioural assumptions in the existing models are not incorporated yet in emergency logistics. The implementation of each model into the practical features depends on the knowledge of decision maker. On the other hand, there is a significant amount of human interaction in the emergency logistics area, which indicates that there is a room for improvement in emergency logistics area in the context of behavioural research perspective. This behavioural research provides benefits to the practical aspects and develops the rich theory in the emergency logistics.

A substantial amount of continuous human interaction is identified (from interviews and document analysis), which affect the LMRD performance, as behavioural factors. Coordination, trust, sharing information, sharing resources among the active agencies, minimising the competing attitudes among the agencies, involvement of local community members, correct knowledge, correct use of needs assessment feedback and culture role are few example of significant factors, which affect emergency logistics as well as LMRD. The above factors are identified from the interviews with the practitioners. And in the above section, the researcher adopted Bendoly et al. (2006)'s framework in the emergency logistics for the more accurate decision-making process. The researcher identified that if the researchers consider the micro level issues (e.g. coordination, trust, collaboration and sharing information, culture and others) in the emergency logistics literature, then the performance of those model increase the efficiency, and that conclusion validate the importance of those factors. Therefore, those factors are established and emerged from the gap analysis of the emergency logistics literature.

4.10 Data collection in India

The previous discussion provides the generic factors, which affect the LMRD performance. Those factors are validated by the gap analysis of emergency logistics literature by using a behavioural assumption framework. This research is based in India, thus it is now necessary to identify the factors for Indian LMRD performance measures. The generic vectors, which can increase the success of LMRD performance, are already identified and discussed. In the Indian context, some of the vectors among those generic vectors are liable for the success of LMRD performance. The interesting geographical position and a vast population of Indian subcontinent made the country vulnerable towards natural disaster. The country is very near to the equator; therefore the tropical storm originated from there can affect the vast coastal area, east and west part of India. This major event occurs regularly every year and certain timeframe of the year, and it has a well-established forecast system for government and NGOs for better preparation and operation throughout the year. The other major events of the earth are tectonic plate movement, which is the major cause of earthquake and tsunamis. The interesting aspect of the Indian tectonic plate is that it is still moving towards the north and the friction of Indian plate and Eurasian plate gather enormous amounts of energy. That energy outburst with the earthquake and/or tsunamis, therefore it cannot be a regular event like a previously discussed storm, rain and flood. The challenges about earthquake are sudden and unpredicted. The earthquake creates trauma to the survivals and recovery could be a very long process. It also creates building collapse and huge death and economic loss for the country. Damage to the affected area creates access problem for relief worker. About 59% land in India could face moderate to severe earthquakes, which shown in Figure 1.7 (Daya Kaul and Ayaz, 2009). Vast population and multiple natural disasters are challenging for more effective disaster management planning and mainly final relief distribution planning in India.

In Indian perspective, the participants are mix population of government employees and non-governmental employees from international, national and local NGOs. 9 interviews with government employees and 16 interviews with national and international NGOs were conducted. The interview is conducted in two cities New Delhi (national headquarters) and Kolkata. Once the researcher managed to conduct an interview with one person in an organisation, then the researcher endeavoured to use the snowball approach to involve more participants in this study. A total of 25 interviews were conducted and 19 documented reports from government and NGOs (UN, SEEDS, CASA, Red Cross among others) are analysed. Among those 19 documents, 10 reports are from Indian government and rest of the 9 reports are from UN, SEEDS, CASA, Red Cross. The length of the reports are between 5 to 15 pages. Mainly those reports include previous earthquake disaster response operations, lessons learnt, problem area faced by the responders, organisational mandates etc. The reports are analysed by thematic analysis. The researcher briefly explains the research project and then requests an appointment for a personal meeting. The researcher uses the same questionnaire explained previously in this chapter and two Indian interview transcripts are provided in Appendix 6 for the Indian context.

Please find the email used to make an initial contact in Appendix 4 and also the invitation letter from Indian disaster management centre in Appendix 8.

The details about the general participants interviewed in this study are given below in Table 4.5:

Table 4.5: Interviews related to the Indian Cases (Developed by the researcher)

Indian Case	Interviewee	Short Description
ICS	ICS-Practitioner1	Position: Executive Director at Governmental Organisation Experience: 30+ year experience in relief distribution Process: 30 mins interview
ICS	ICS-Practitioner2	Position: Professor at Governmental Organisation Experience: 25+ year experience in policy development for Indian Government Process: 45 mins interview
ICS	ICS-Practitioner3	Position: Professor at Governmental Organisation Experience: 20+ year experience in response operation Process: 45 mins interview
ICS	ICS-Practitioner4	Position: Response officer at in Governmental Organisation Experience: 20+ year experience in relief distribution Process: 50 mins interview
ICS	ICS-Practitioner5	Position: Consultant of the response Division at Governmental Organisation Experience: 20+ year experience in relief distribution Process: 50 mins interview
ICS	ICS-Practitioner6	Position: Consultant of the response division at Governmental Organisation Experience: 15+ year experience in relief distribution Process: 50 mins interview
ICS	ICS-Practitioner7	Position: Faculty position at Governmental organisations Experience: 10+ year experience serving beneficiaries during emergency situation Process: 50 mins interview
ICS	ICS-Practitioner8	Position: Response manager in an International Non-Governmental Organisation Experience: 10+ year experience in relief distribution Process: 45 mins interview
ICS	ICS-Practitioner9	Position: Head of the Inter-Governmental Organisation Experience: 30+ year experience in relief distribution

Table 4.5 Continued....

Indian Case	Interviewee	Short Description
		Process: 50 mins interview
ICS	ICS-Practitioner10	Position: Programme management specialist at International NGO Experience: 25+ year experience in relief distribution Process: 60 mins interview
ICS	ICS-Practitioner11	Position: Consultant of the Inter-Governmental Organisation Experience: 23+ year experience in emergency response operation Process: 50 mins interview
ICS	ICS-Practitioner12	Position: C.E.O and head of the National NGO Experience: 30+ year experience in Relief operation Process: 40 mins interview
ICS	ICS-Practitioner13	Position: Head of Disaster Response team in an International Non-Governmental Organisation Experience: 27+ year experience in emergency situation Process: 40 mins interview
ICS	ICS-Practitioner14	Position: Response manager in an International Non-Governmental Organisation Experience: 5+ year experience in emergency situation Process: 50 mins interview
ICS	ICS-Practitioner15	Position: Eastern Region head of a national Non-Governmental Organisation Experience: 30+ year experience in relief distribution Process: 40 mins interview
ICS	ICS-Practitioner16	Position: Field officer in a national Non-Governmental Organisation Experience: 20+ year experience Process: 50 mins interview
ICS	ICS-Practitioner17	Position: Logistical officer in an International Non-Governmental Organisation Experience: 10+ year experience Process: 45 mins interview

Table 4.4 Continued....

Indian Case	Interviewee	Short Description
ICS	ICS-Practitioner18	Position: Response manager in a local NGO Experience: 5+ year experience Process: 45 mins interview
ICS	ICS-Practitioner19	Position: Field officer in a national Non-Governmental Organisation Experience: 15+ year experience Process: 50 mins interview
ICS	ICS-Practitioner20	Position: Senior Logistical manager in an International NGO Experience: 25+ year experience in relief distribution Process: 40 mins interview
ICS	ICS-Practitioner21	Position: Response officer in a national Non-Governmental Organisation Experience: 10+ year experience Process: 50 mins interview
ICS	ICS-Practitioner22	Position: Field officer in an National Non-Governmental Organisation Experience: 10+ year experience Process: 45 mins interview
ICS	ICS-Practitioner23	Position: Responders in a local NGO Experience: 5+ year experience Process: 45 mins interview
ICS	ICS-Practitioner24	Position: Field officer in a national Non-Governmental Organisation Experience: 25+ year experience Process: 50 mins interview
ICS	ICS-Practitioner25	Position: Senior Response Officer in a national NGO Experience: 25+ year experience in relief distribution Process: 40 mins interview

4.11 Indian LMRD performance metrics

In section 4.5 the researcher identified the generic objective functions considered for the final relief distribution (LMRD) planning. According to the practitioners, due to the vast population and higher disaster prone area, it is challenging to cover all the affected area and fulfil all the demand. One of the practitioner comments that "though in disaster situation the agencies are coming with relief items and supply the relief to the affected population, to continue the relief operation for the long term the agencies need to consider minimising the cost as the NGOs are running by the donors" (ICS- Practitioner2). Another practitioner comments that "most vulnerable and poor community generally migrate and live in the hazardous lands and under unsafe shelters. They lose everything after an earthquake, so, a continuous demand always occurs" (ICS- Practitioner1). Among 25 practitioners 85% of them identify demand and coverage efficiency as the most important vectors and 80% of them identified cost efficiency as the major vectors for LMRD. 65% practitioners recognised time efficiency and distance efficiency is important for LMRD, 63% practitioners acknowledged the importance of service efficiency and finally, 20% practitioners recognised allocation efficiency and social and risk impact. According to the practitioners' point of view in the Indian context, there are three major performance vectors.

- Cost efficiency;
- Demand efficiency;
- Coverage efficiency;

The rest of the objectives are also important and considered in Indian LMRD planning but the above three are the most important and considerable vectors according to a practical point of view. Section 4.5 already explained the individual terminology; therefore this section places the importance of the above three according to Indian perspective.

4.11.1 Maximise the Cost efficiency

India has the largest economy in South Asia but this nation is the second most populous country in the world. The Indian subcontinent is the world's most disaster-prone areas with a vast area and widespread poverty. A natural disaster is a very common phenomenon in India, therefore most of the time in the year this nation is affected by more than one natural disaster. The government, NGOs and other stakeholders need to manage these disasters impartially and neutrally for the entire region and for that they need to maximise the cost efficiency. According to practitioner's point of view, there are some incidents such as "relief material loss during transition", "inadequate planning for managing the relief items" occurred during LMRD planning in India (ICS- Practitioner8). The cost efficiency can be measured by minimising the replenishment cost, by minimising the total relief distribution cost, minimising the facility cost by reducing the number of facilities and identifying the most convenient facility to supply the relief.

4.11.2 Maximise the demand served

The affected population and insufficient planning during LMRD always make challenging to maximise the fill rate of the resources, minimise unmet demand and maximise the fulfilment of demand for the affected population, and those are the measures of demand efficiency. One practitioner provides an example of incompetent planning during LMRD stating that "it is necessary to serve the relief items to all the affected population within the minimum time. But because of proper planning and fewer resources, some of the communities need to wait and suffer for the relief items" (ICS- Practitioner5).

4.11.3 Maximise the Coverage efficiency

This is another major issue to contemplate during LMRD planning in India. In the previous earthquakes (Gujarat 2001, Sikkim 2011, Nepal 2015 and other) there were some issues such as oversupply, shortages of food, medicines, and supplementary items per individual agencies. These are the challenges needed to face during final relief distribution. Maximise the efficiency of coverage is measured by maximising the number of relief items (fill rate of the resources), minimising the unmet demand and maximising the demand fulfilment rate.

4.12 Additional factors which affect LMRD performance in India

Section 4.5 already explained the terminology of the factors which affect LMRD performance. Including those factors, and according to the practitioner's opinion following responsible factors are affecting the LMRD performance during an earthquake in Indian context:

- Coordination among the agencies (prioritisation the task, goal selection, risk sharing, mutual adjustment, proper communication among the agencies);
- Collaboration and sharing resources among the participating agencies in the field (multi-source information, mutual aid);
- Coordinated (Joint) decision making for relief distribution (knowledge sharing, protocol sharing, joint decision structuring and analysing);

During the LMRD all the active participating agencies need to collaborate and communicate to fulfil overall goal to help the beneficiaries by supplying the relief items and keep the affected community safe. According to Balcik et al. (2010) in the disaster context, the term coordination generated as the communication and interaction among different active agencies within the relief environment. For example, prioritise the tasks, identify the proper risk and share that information with the other agencies. The mutual adjustment is necessary as the situation is not a normal situation. Knowledge sharing, joint decision making and last but not the least mutual aid distribution are some of the activities needed to perform during the relief distribution. The agencies need to coordinate to perform those activities.

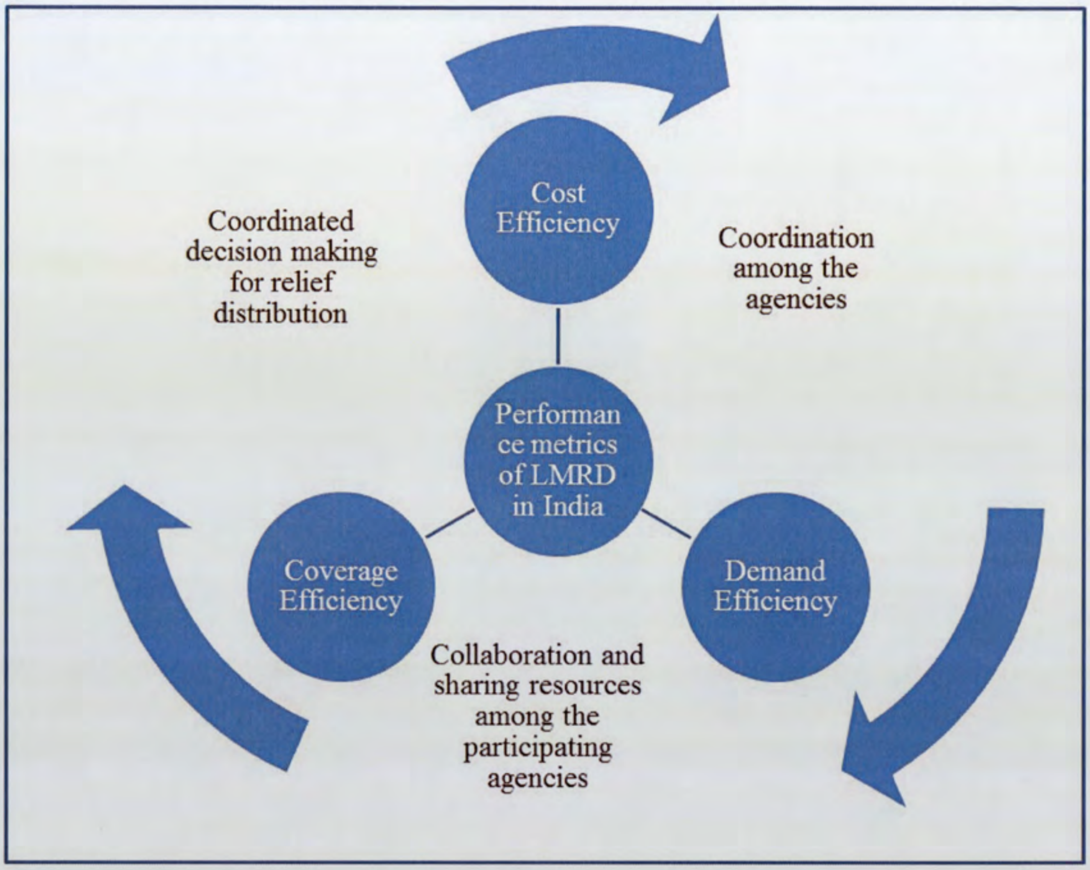

Figure 4.3: The identified factors for Indian LMRD performance (Developed by the researcher)

The above three responsible factors should be understood as one single concept, which is coordination and already explained this terminology in section 4.5.1. Here coordination means horizontal coordination (one organisation coordinates with other organisation) (Balcik et al., 2010) as all the active agencies are participating with each other to perform the above activities. According to the practitioner "if the organisations will do joint decision making and share information and knowledge then it will be easy to fulfil the demand of all the affected community and there will be no oversupply or less supply" (ICS- Practitioner15). Next step will be to incorporate this responsible factor into the Indian LMRD system for the experimentation and identification of the noticeable changes in the system.

4.13 Chapter Summary

This chapter investigated the data collection and data analysis to achieve the objective of this research project. This chapter categorises the important objective functions need to consider during LMRD planning from generic case to specific case (India) and also identifies the other responsible factors, which affect these objective functions. The behavioural framework (Bendoly et al., 2006) is used to validate the responsible factors in the generic case as most of the responsible factors are behavioural factors. The most important factor is coordination, which is identified by the Indian practitioners. The findings of this chapter are to identify the answers of the RQ1 and RQ2, which is as follows:

RQ1. What are the factors which affect the LMRD performance measures?

RQ2. Which of these factors had the biggest influence on the performance of LMRD in the Indian context?

The next chapter will use Agent-Based Simulation to incorporate coordination in the LMRD system in India.

Chapter 5: Modelling

5.1 Introduction

In the previous chapter the researcher identifies coordination as the major factor for Indian LMRD performance. The aim of the current chapter is to integrate that factor into operation and decision making process of the final relief distribution in India by using Agent Based Simulation. First, it is necessary to understand the structure of LMRD in India. Next, this chapter will analyse the relevance of Agent-Based Simulation technique for this purpose followed by generic agent structure and introduce the involved agents for LMRD in India. Finally, the explanation of modelling perspective and justification of results are presented. This chapter is concluding with the validation and verification perspective of this Agent Based Model.

5.2 LMRD in India

It is clearly explained in the first chapter that the Prime Minister of government of India is the main decision maker and there are ministries of various departments assisting in the decision making process in India (home-affairs, 2011). Academic institutions, scientific organisations, technical institutions, professional bodies, corporate sectors; NGOs are the relevant communities who continuously incorporate their intelligence for the improvement of disaster management activities in India. The national authority provides the financial, physical, logistical and manual support on the basis of State government and District administrators information about the gravity of natural calamity, the scale of the relief operation, the requirement of central help, the requirement of international help etc. (home-affairs, 2011). The policies, plans and guidelines are approved by the national authority. The national plan followed by the state plan and followed by the district plan. District Magistrate (District level governmental authority) thoroughly monitors the situation for better strategic planning during the final relief distribution (home-affairs, 2011). A number of active agencies including government and other local, national and international NGOs arrive at the earthquake affected area with their responders and relief items. The aim of every individual agency is to supply the relief items to the disaster-affected community. The beneficiaries are identified from the locally affected area. Every agency should prefer a specific kind of people (old people, women, children or other special people) during the relief and this operation should be executed by the governmental authority's suggestion or chosen by the capacity of the individual agency. The active agencies are working distinctly for the relief distribution. Every agency has their own district warehouse, local distribution centres and responders. The responders are requesting relief from the distribution centre and distribution centres are requesting relief from their own district warehouses. In the local level District Magistrate (District level authority) closely monitors the disaster situation for the strategic plan. There is a specific lead time between the district warehouse and distribution centres, distribution centres and the responders. The relief distribution starts after the needs assessment feedback analysis for the identification of the types and amount of relief items and exact needs of the affected population. The following Figure 5.1 shows the flow of relief in the local level of the relief distribution. In India earthquake response operation and LMRD system are very efficient. Still in the previous earthquakes a couple of challenges are identified by the analysis of the interviews and reports. According to the analysed report "lack of communication and coordination results wastage of relief items by supplying the same relief items to the same community by different agencies" (documented report). One of the practitioner draws attention about the unmet demand, "due to long replenishment time for some agencies it is hard to fulfil the demand of some specific community. This challenge can be minimised by the cooperation of other agencies, who are supplying the same relief items." (ICS-practitioner7). The reported drawbacks for Indian LMRD are oversupply, unmet demand, wastage of relief items, shortages of food, medicines and supplementary items per individual agencies (home-affairs, 2011). These drawbacks are curtailing the efficiency of Indian LMRD system during an earthquake. The aim of this thesis is to overcome those loopholes and present an effective and efficient LMRD system during an earthquake.

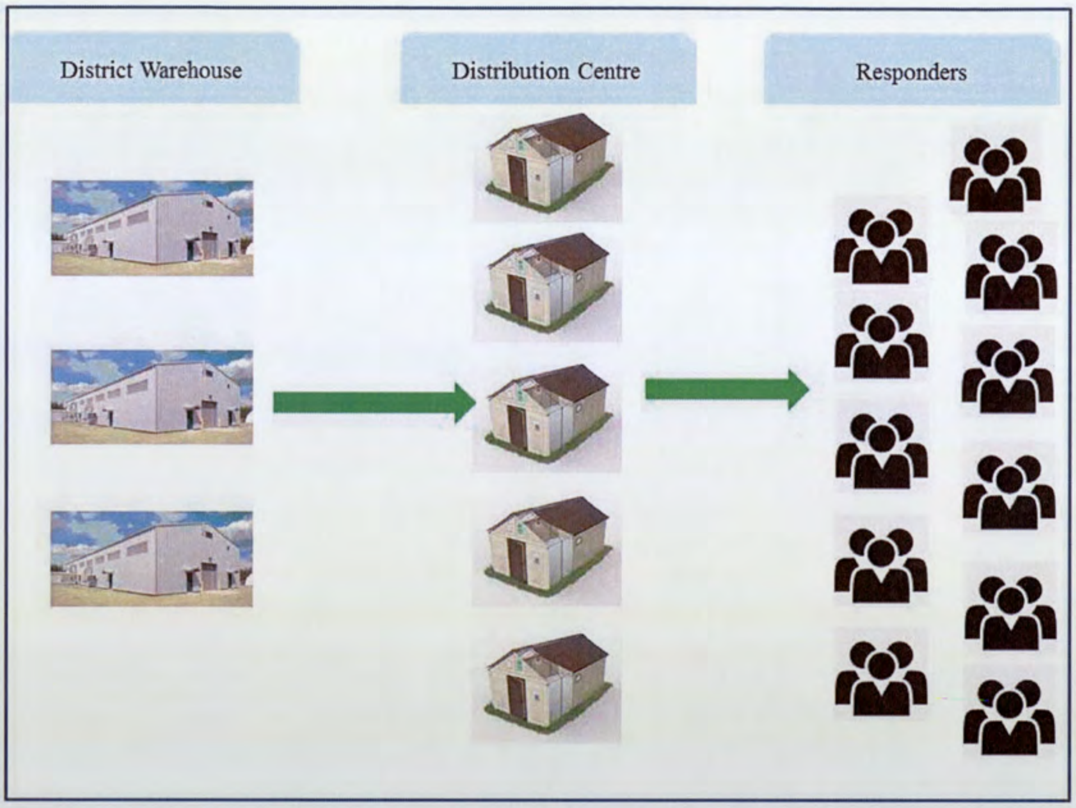

Figure 5.1: Relief flow at the local level (Developed by the researcher)

5.3 Relevancy of Agent-Based Simulation for LMRD purpose

The researcher described the suitability of simulation techniques in emergency logistics in chapter 3, where the three main simulation techniques: discrete event simulation, system dynamics and agent-based simulation are compared. It is clearly explained that how a system can be represented in a simulated model. Now it is necessary to understand, why ABM technique will be suitable for Indian LMRD system.

The individual agency with their district warehouse, distribution centres and responders are participating in the relief distribution operation in Indian LMRD, and that is identified through the analysis of the interviews and reports. Every agency has their own code of mandates and rules to interact with each other. Mainly every agency is following their own working protocols, for example, the specified lead time, the number of volunteers for the response operation, number of facilities, number of served communities, number of vehicles, relief distribution policy, safety and security policy for the volunteers and the relief items and finally the strategic, tactical and operational instructions. The ABM is suitable here to model individual agency's district warehouse, distribution centre and responder as an agent. In ABM individual entities can be represented by their own rules, which is suitable here as in Indian LMRD each agent (district warehouses, distribution centres and the responders) evaluates its conditions and makes decisions on the set of rules. In this case, the time is treated as discrete because the detailed knowledge of resources and information are required. ABM is the appropriate technique where modelling of the detailed (and differentiated behaviour) individual entities and resources are the paramount requirement. The individual agent behaviour in ABM can be influenced by spatial relationship, which is another reason for choosing ABM as a suitable technique in this case. The researcher is integrating coordination into the Indian LMRD by sharing the resources and information among the active agencies and proposing a coordination hub (details about coordination hub is explained later in this chapter), which will have all the information about the active agency's district warehouse for relief items. The coordination hub will send the relief to the distribution centre and finally from distribution centre to the responders. Coordination is considered as mutual aid and information sharing among the active agency.

The researcher is testing scenario experimentation to understand the effects of coordination into Indian LMRD and to understand the behaviour of the agents, wherein ABM randomness in behaviour is replicated in the decision making logic in the state chart of the individual agent. Thus, ABM could be beneficial for studying randomness in behaviour as emergent phenomena based on the decision making of individual agents. Last but not the least ABM is the strongest technique where human behaviour and the decision-making process of human can be modelled. ABM is the appropriate simulation technique for Indian LMRD as "Agent-based model consists of a system of agents and the relationships between them. Even a simple agent-based model can exhibit complex behaviour patterns and provide valuable information about the dynamics of the real-world system that it emulates" (Bonabeau, 2002, p 7280).

5.4 Description of the Agent Based Model

5.4.1 Modelling approach

The objective is to develop an ABM for LMRD system during earthquake disaster in India. The steps for development of ABM followed by the recommended stages from a book called 'managing business complexity' (North and Macal, 2007). It is important at the beginning to identify the generic structure of the agent in LMRD system. There are mainly three agents per individual agencies: district warehouse, distribution centre and responders and certainly every agent have its own rules and responsibilities. There are two link agents, who will connect two agents: demand agent and supply agent. The individual agents can be summarised as a flow of information or material. The following Figure 5.2 shows the structure of a generic agent.

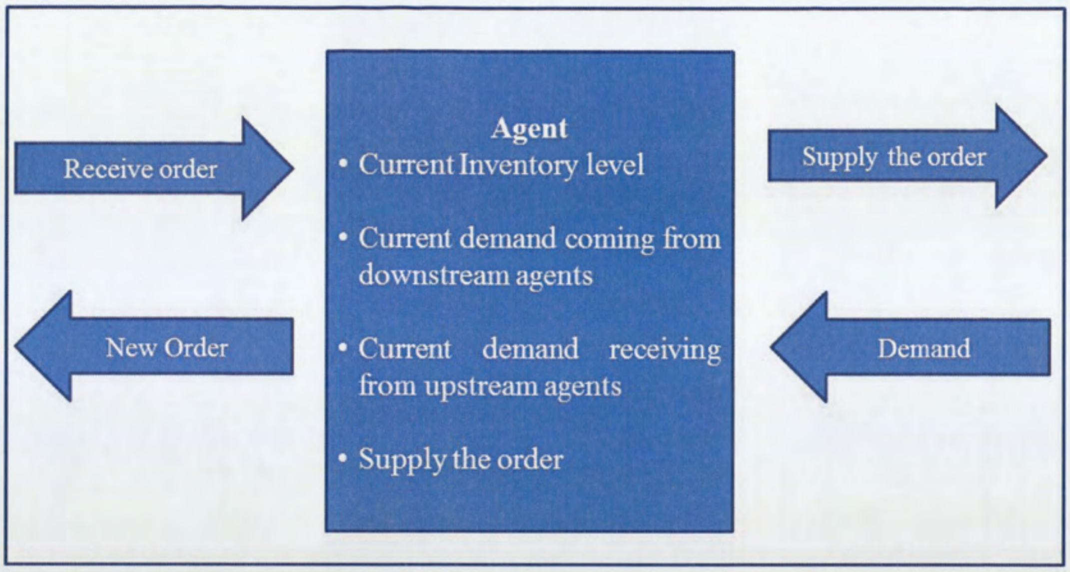

Figure 5.2: Generic structure of the agent (Developed by the researcher)

There are three agents per individual agency and there are three active agencies involved in this ABM: governmental agency (governmental organisation, national, state and district level and other governmental communities), international agency and national agency (civil organisations and NGOs). There are total nine agents involved in this LMRD model: three district warehouses, three distribution centres and three responders. Three active agencies (governmental agency, international agency and national agency) come to the affected area to provide the relief after an earthquake. There are three different relief chains activated to supply the relief during LMRD. The individual agency is supplying the relief to the different community according to their potential. The agency's distribution centre is placing an order to the district warehouse of that agency and district warehouse is supplying the order to the distribution centre and finally, the responder agent is ordering the resources from the distribution centre and distribution centre is fulfilling the demand, which showed in Figure 5.3.

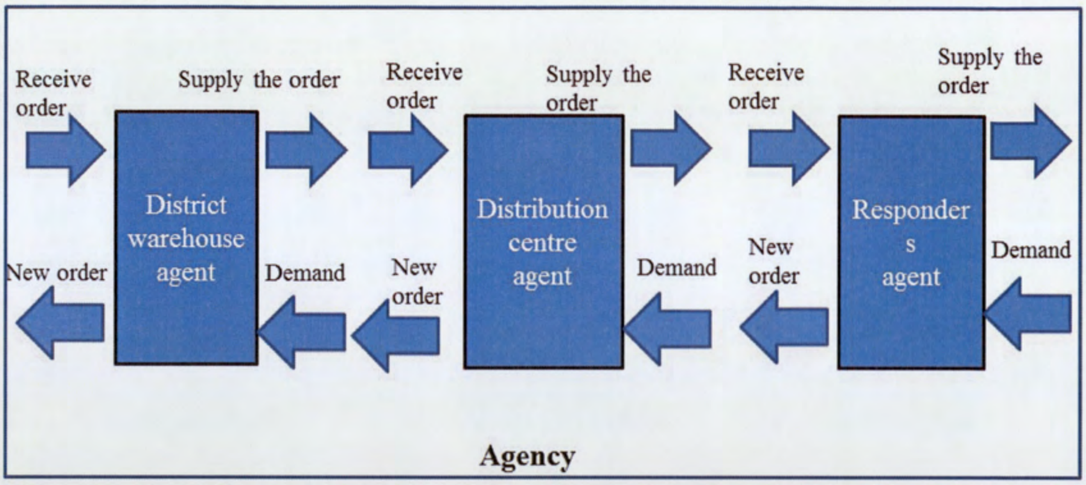

Figure 5.3: The flows of supply and demand in the LMRD model (Developed by the researcher)

The proposed ABM is following the LMRD system in India during earthquake and aiming towards the demand fulfilment from the responders. This NetLogo model comprises a number of key stages to build the structure of the model. The first stage is to declare all the involved agent types as variables for this modelling purpose. Agent types are identified as 'breeds' in NetLogo. The second stage is the 'setup' phase, where the model is originated, and the agent space is positioned and all the variables are setup. The next stage is 'run'; where the model starts activating with calling the required sub-routines. There are two linked agents in this NetLogo modelling: demand link agent and supply link agent. Demand link is essential for transmitting the demand signal from downstream agent and supply link is for supply the relief item to the downstream agent. The following state diagram (Figure 5.4) is describing the generic agent's behaviour in this NetLogo model (North and Macal, 2007)

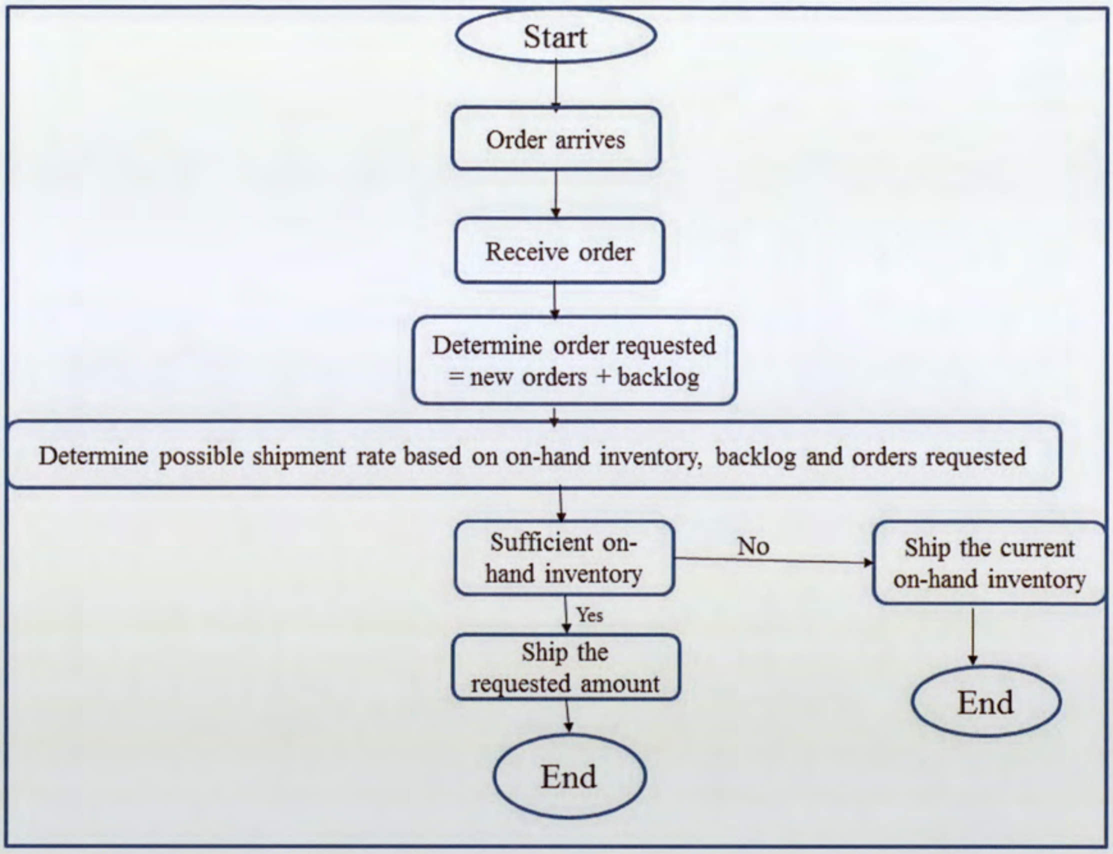

Figure 5.4: State diagram of the generic agent (Developed by the researcher)

5.4.4 Modelling Description

In NetLogo, this is a simplified network relief chain model, as it is the root beer game for instance (Wilensky, 2003). Individual agencies of Indian LMRD system involve one district warehouse, which has supply from the state level warehouse and there are distribution centres and responders. Every district has different subgroups in India either it could be municipality or village related authority. The municipality office could be used for the distribution centres during disasters. The distribution centres could be any numbers between 50 and 100 depending on the size of the district and the capacity of each distribution centre will depend on the population of each municipality. This is a prototype model for Indian LMRD. The researcher assumes a community for 675 people in an earthquake-affected area for the simplification of sample model. The lead-time between the coordination hub and agency is 3 days and the lead-time between the agency and responders is 2 days. The justification of the chosen lead time will be given later in this chapter. There is three distribution centres in this model, which is aggregated as the governmental agency, national agency and international agency. The survival buildings, schools, municipality office can be selected for the distribution centre if those constructions are safe after the earthquake. The author assumes in this model that the capacity of the distribution centre should be sufficient for the affected people, as the capacity is not considered as a variable. In the facility location, literature uncapacitated facility is a well-researched area (Chudak and Shmoys, 2003, Cornuéjols et al., 1983, Cui et al., 2010, Li and Ouyang, 2010).

Agents should order from upstream nodes and ship to downstream nodes. A daily demand is allocated to each responder, who orders from distribution centres, where relief comes from the district warehouse. It is assumed that all the distribution centres and responders are following the base-stock policy. The definition of base-stock policy is as follows: once the inventory position drops below the base-stock level, then the agents immediately order the difference between the base-stock level and current inventory position; otherwise, the agent will not place any order. The assumption of this model is that the affected people can get the same amount of relief items which is received by the responders. The researcher also assumes that the affected people should be identified to avoid the duplication of relief items during distribution (people need to sign when they are receiving relief items or the head of the municipality commission is identifying the people from their internal database). The full code of the NetLogo model with descriptive text is presented in Appendix 9. Figure 5.5 shows the graphical interface of the LMRD by NetLogo model.

Figure 5.5: LMRD model in India in NetLogo for without coordination (Developed by the researcher)

This model runs for 45 days, because this thesis is concentrating on sudden onset situation for a short-term response for supplying the relief item to the affected population (Jahre et al., 2007). There are three chances of the probability distribution for day-to-day (daily) demand: binomial, poisson and normal. The daily demand for this LMRD model cannot follow binomial distribution as this probability distribution considers two different outcomes, but not the exact value of demand. It is hard to identify the number of day-to-day demand due to uncertainty of the situation. Normal distribution cannot be appropriate in this case because normal distribution is a continuous probability distribution. There should be stability in the affected area after a certain time and the affected population could try to live their normal life, therefore, they should not have the demand on a continuous basis. Now, poisson distribution is a discrete probability distribution and it usually models the number or count of an event which is occurring in a specific time interval. All the demands are randomly distributed after earthquake for a specific time frame. The above comparison helps the researcher to select poisson distribution for this model because of the profile of the demand behaviour. The above NetLogo version of the LMRD model is fulfilling all the requested demand from the responders.

5.5 Incorporating coordination for LMRD in India

The proposed NetLogo version LMRD model for the earthquake in India fulfils the demand of responders. Now we should incorporate the coordination into Indian LMRD operation. The main objective is to identify whether the coordination in LMRD system in India is affecting the performance measures of the LMRD system or not. Next challenge is to incorporate coordination in the LMRD system in India.

Altay and Pal (2014) elaborated about the information-processing view of the UN's cluster approach for the better performance of the humanitarian operation. Their results exhibit that if clusters act as an information hub, then the information spreads its target quicker and resources utilisation are improved and produce swift humanitarian response operation (Altay and Pal, 2014). This research extended this similar idea by introducing a coordination hub for LMRD model for practitioner's planning.

5.5.1 Coordination Hub

The concept of introducing coordination hub is to incorporate the coordination into the LMRD system in India. The coordination hub has the access to all the active agencies' district warehouses for a clear identification of exact quality and quantity of relief items during final relief distribution. The theory behind this is that the active agency's distribution centres will ask the relief to the coordination hub and it is the coordination hub's responsibility to fulfil the exact demand for the individual agency's distribution centres. Here coordination hub is an integrated approach to manage the huge quantity of relief during final relief distribution. Coordination means to share the resources among the agencies by using the platform of coordination hub (for example SUMA (http://www.disaster-info.net/SUMA/english/)). This concept of coordination hub is not a physical building but it is a cloud platform, which has all the information about the active agency's physically established district warehouse's relief material and quantity of relief items. Telephone lines, internet connection, and electricity all are damaged on that specific affected area after a large-scale earthquake. Generally, government, military and trained personnel act as quickly as possible to restore electricity and roads so that other communication means (telephone, internet and mobile phone) can be restored quickly. Similarly, the involved agencies (NGO and government) always work from there back office to gather information of the affected area. This information could be before or after the disaster strikes the area. The information after disaster strike could be obtained after the restoration of the electricity, roads and satellite link but satellite images of the affected area could be obtained from the back office of the agencies. These could be therefore the perfect example to use the cloud hub, by using the information from the affected area and coordination of different agencies, to act quickly and to supply relief aids without interruption. The involved agency's state office and district office are deciding how much relief, what types of relief and where to send the relief items. They can use the online coordination hub platform for an integrated approach to respond. This thesis is only considering the concept of coordination hub and in future, the working procedure of coordination hub will be extended and elaborated.

5.5.2 Comparing coordination

The objective is to integrate coordination into Indian LMRD system to identify the effect of coordination. Now it is necessary to define the scenarios. The researcher already explained in the introduction that in India all the active agency come to the affected area and supply the relief according to their capacity and relief worker. The researcher considers that normal relief operation without coordination, where the individual agency distributes the relief according to their capacity. The researcher is introducing coordination hub as the main source of information in this thesis, as a second scenario. The coordination hub has all the information about the involved agencies, location and capacity of district warehouse and the type of relief items stored. Individual agency's local distribution centres are requesting for relief items through the coordination hub and that is triggering the supply of the relief to the affected people by individual agency's distribution centre. The responders also have the choice of distribution centre to place the demand (the responders are placing their demand on that distribution centres, where have fewer back orders). Finally, all the active agencies need to coordinate in every stage of relief chain in the local level to define full coordination.

The researcher is comparing three scenarios for coordination in the NetLogo software for LMRD model. The NetLogo version of the model is investigating the scenarios without, partial and with coordination. There is no coordination involved in the first scenario whereas in the second and third scenarios there is limited and full coordination involved respectively. The three scenarios are as follows:

Scenario 1: Three different organisations (governmental, international and national agency) supply relief in an earthquake situation for 45 days in India. There are three relief chains working separately, which are already shown in Figure 5.6.

Scenario 2: Coordination Hub will supply the relief to three agencies distribution centres (governmental, international and national agency) and the individual agency's responders will transmit the demand to the specific agency's distribution centre in an earthquake situation for 45 days in India.

Scenario 3: Coordination Hub will supply the relief to three agencies (Governmental agency, International Agency and National Agency) distribution centres and the responders also will choose the distribution centres for placing their demand in an earthquake situation for 45 days in India. The responders will choose the distribution centre to order by following their back-orders clearance.

The model is for short term relief operation, which starts just after a high impact earthquake and stays between 20 to 60 days depending upon the nature of earthquake and situation of the affected area. Most of the short-term relief operation in India runs for 45 days (home-affairs, 2011). The proposed model is developed and run for 45 days. The agents receive profits or revenue by supplying the relief items. If the agents are not able to satisfy the demand, then the back-orders are created, and the penalty costs occur for the agents. Holding relief items sustains utility and maintenance costs. Agents are aiming to fulfil the demand by managing their order strategy and inventory policy. The outcome result of interview with the Indian practitioners shows that the lead time of agency between district warehouse and distribution centres are between 2 and 5 days and from distribution centres and responders are between 1 and 3 days. The lead time for the NetLogo input is the average from those values identified during the interviews. The lead time between district warehouse and distribution centre is considered as 3 days and the lead time between the distribution centre and responders is considered as 2 days for LMRD model. There are two types of links in the NetLogo model. Demand links are used for order placement and supply links are used for the shipment of the order. The current inventory position is determined by the (on-hand inventory + pipeline inventory – backorders). The agents are ordering the quantity equal to the difference between inventory position and base stock level. The base stock level is calculated according to mean and standard deviation and supply delays "+1" because of the order processing delay. The researcher also assumes that the coordination hub has the unlimited supply. The NetLogo model will recalculate the inventory position after every run. The initial stock of agency's distribution centres and responders are zero. In the disaster situation consideration of revenue is not possible but in this model the researcher consider revenue as customer satisfaction (can be considered as a reward). The revenue is 2 for a distribution centre and 3 for responders per each unit shipped.

Table 5.1: Parameterisation of the model (Developed by the researcher)

Parameters	Number/Formula used
The duration of the model	45 days
The lead time between the coordination hub and the distribution centre	3 days
The lead time between the distribution centre and the responders	2 days
The initial stock of the distribution centre	0
The initial stock of the responders	0
Current inventory position	(on-hand inventory + pipeline inventory – backorders)
Quantity to order	Base stock level – Inventory position
The base stock level	The base stock level is calculated according to mean and standard deviation and supply delays "+1" because of the order processing delay.
Inventory holding cost	0.5
Backlog penalty	2
Added cost	(0.5*holding cost + 2*penalty cost)
Total cost	Cost + added cost

Scenario 1 is already presented here in Figure 5.6; where three different agencies are working separately to supply the relief. The coordination hub has all the access to supply the relief of the individual agency's district warehouse.

The model is working similarly to Figure 5.5 models with a difference that there is one coordination hub instead of 3 district warehouse and that is in scenario 2. The complete code of the NetLogo model with descriptive text is presented in Appendix 10. Figure 5.6 shows the graphical interface of the partial coordinated (this model named partial coordinated model because the individual agency's responders are placing their demand to the individual agency's distribution centres) version LMRD NetLogo model.

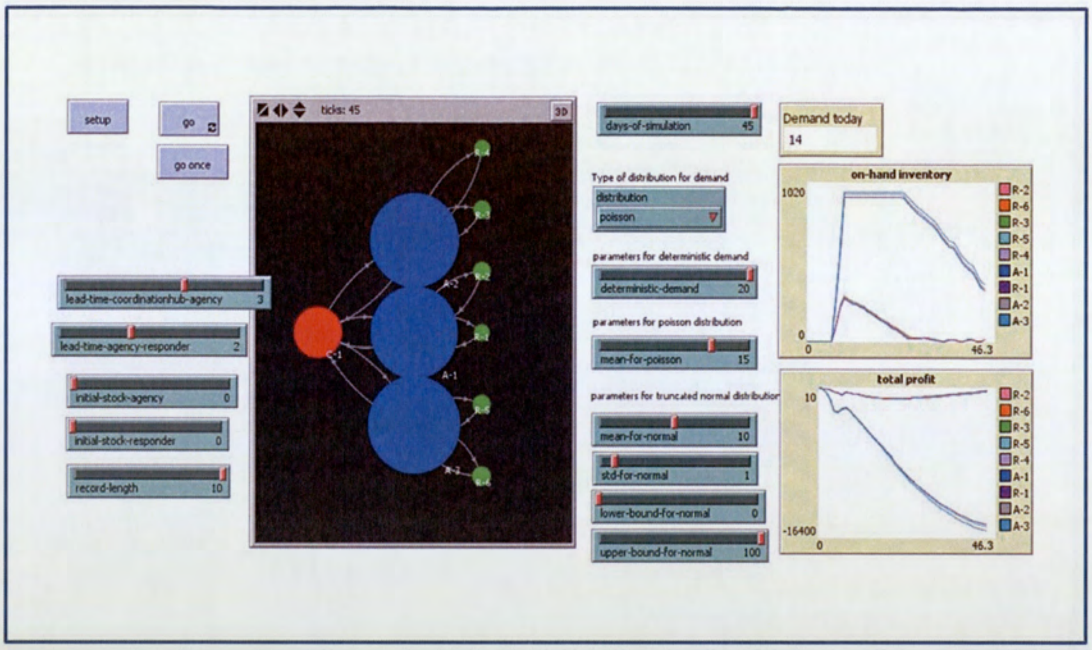

Figure 5.6: LMRD model in India in NetLogo for partial coordination (Developed by the researcher)

Scenario 3 is also working in the same way as scenario 1 and 2, but only difference is that the distribution centres are transmitting the demand signal to the coordination hub and the responders are placing the demand signal to the distribution centre. The choice of distribution centre is according to the back-orders (backlog policy) clearance. For example, the responders will transmit the demand signal to that distribution centre with fewer backlogs in order to receive relief efficiently. The complete code of the NetLogo model with descriptive text is presented in Appendix 11. Figure 5.7 shows the graphical interface of the full coordinated version of the LMRD NetLogo model.

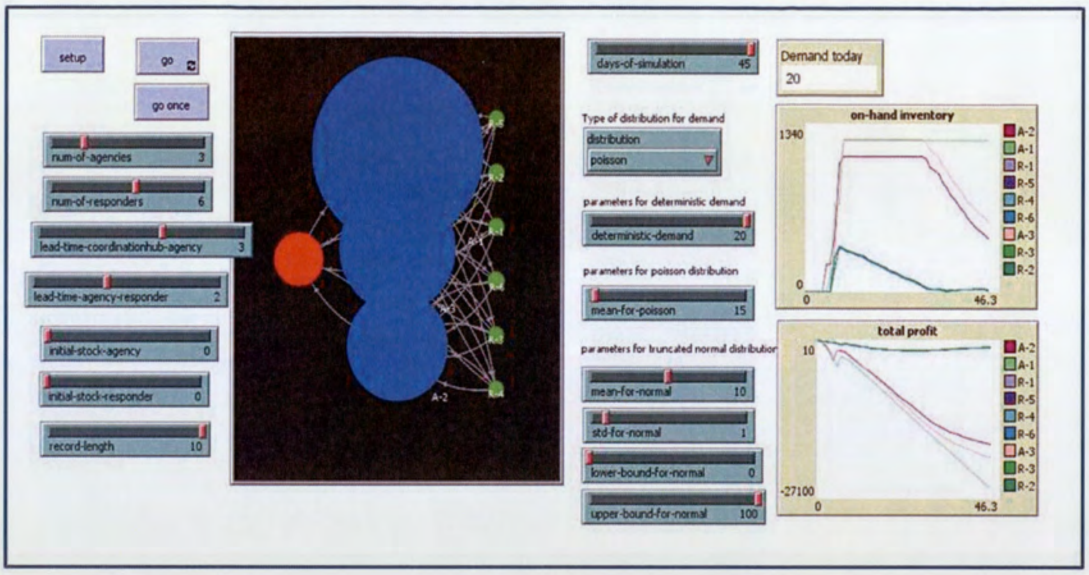

Figure: 5.7: LMRD model in India in NetLogo for full coordination (Developed by the researcher)

The above three scenarios are considered and 'run' to understand if coordination have true effect on the performance metrics of LMRD in India during earthquake situation. The following Figure 5.8 shows the three different interfaces of the above three models.

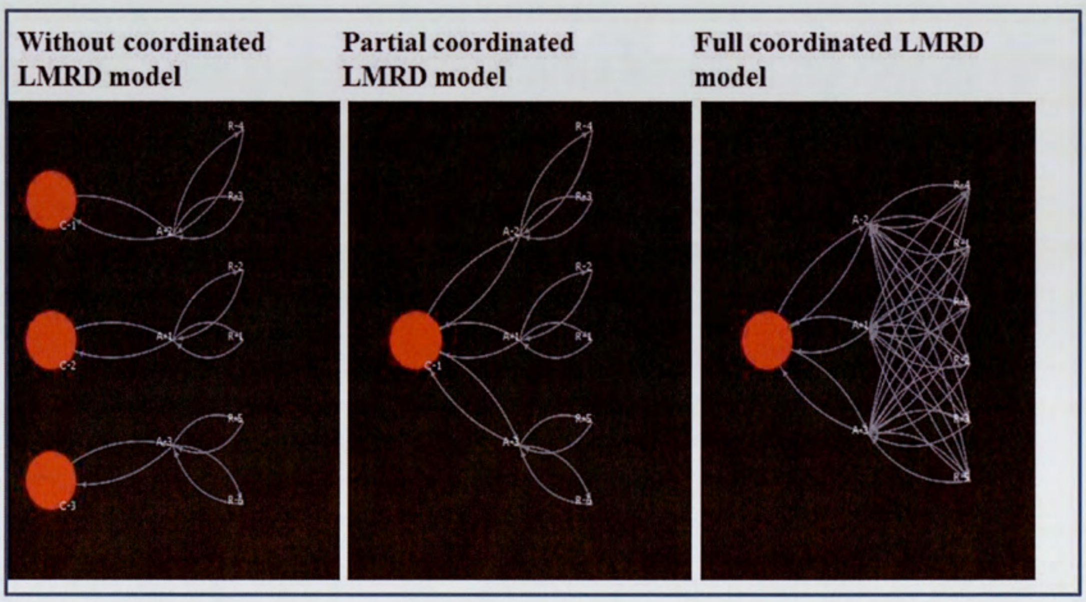

Figure 5.8: Comparison of coordination in LMRD in India (Developed by the researcher)

5.6 Verification and Validation

Model verification and validation are essential parts of the model development process (North and Macal, 2007). This section is describing the accepted stages in developing the models to confirm that the model is performing according to the intended purposes. The relation between verification and validation is shown in Figure 5.9:

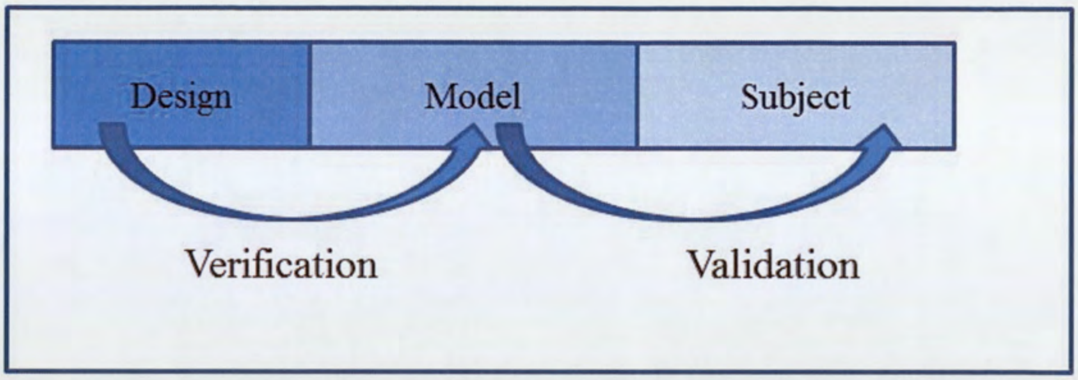

Figure: 5.9: Verification and validation in context (Source North and Macal (2007))

5.6.1 Verification

The modeller needs to ensure that a model can perform and explicate the operational perspective of the anticipated specific system for verification of the model (North and Macal, 2007). The following steps are proposed as verification tools for this purpose.

5.6.1.1 Documentation for verification

Design documentation is a part of the verification of the model. For example, before modelling in NetLogo this chapter provided a generic structure of the agent, the state diagram of the agent and the number of involved agents for the LMRD system, which is considered as a verification step of the model.

5.6.1.2 Unit testing and run the model under simplifying assumptions

The researcher first starts with a very simple case with one district warehouse, one distribution centre and responders, and that simple system helps to test all the activities of the agents before the model is extended and complicated. NetLogo software has a very sophisticated and clear structure of the modelling:

1. Statement section: Need to declare all the variables
2. Agents setup: Necessity to setup all the agents, which is initial setup of the model
3. Individual subroutines
4. Run all the subroutines one by one

This step by step generic structure supports the modeller to verify the functionality of the individual code. Another advantage of NetLogo is that the individual subroutines can be built and verified separately. This simplified approach supports the modeller to reduce the risk of error with the help of the above systematic pathway.

5.6.1.3 Structured code walkthrough

NetLogo software, has a 'watch' function, which permits the modeller to observe the value of an agent during code execution time. This type of tool can reduce the risk of error during model building. This process is considered to match the computer code against the intended design to identify the errors (North and Macal, 2007).

5.6.1.4 Structured debugging walkthroughs

Structured debugging walkthroughs allow straight validation or denial of the existence of the errors (North and Macal, 2007). For example, NetLogo software, has a special functionality which can detect basic errors (syntax error, undeclared variables) automatically during the activation of code. The researcher runs the individual subroutines one-by-one in order to use structured debugging and this approach identifies the errors during the run of the model.

5.6.2 Validation

The modeller needs to ensure that a model represents and reproduces the correct behaviours of a real world system (North and Macal, 2007). This model is representing the decision making during LMRD in India for earthquake disaster. The agents for this model are originated from the interviews with the Indian government and non-governmental organisations and analysis of reports. The agent's behaviour, relationship and interaction process all are validated. The agents are first defined in NetLogo and then replicated in the model. This tends to determine that ABM is easy to scale up and there are additional agents (district warehouses, distribution centres and responders), and those can be easily acceptable for the model. The modeller runs each of the models for 40 times (warm-up period) and then considered the results for the steady-state parameters for consistency. The modeller runs this model for more than 3 agencies (sensitivity analysis) for the robustness of the model and every time the coordinated version of the model showed positive results. The positive result of this model shows that if the active agencies coordinate during the relief distribution for earthquake then they can satisfy the demand of the affected community and also they can minimise the cost by utilising less inventory. Though the researcher uses the above validation techniques, the typical methodology for validation is to take a designated number of cases from the real-world system and attempt to reproduce them using the model (North and Macal, 2007). Next chapter considers two case studies about earthquake disaster in India and applies this proposed model to those case studies to validate the proposed model.

5.7 Results

The three version of the LMRD model are run for 45 days for specific relief items for 675 populations in an earthquake-affected area. The lead-time between the coordination hub and agency is 3 days and the lead-time between the agency and responders is 2 days. The initial inventory in the distribution centre and Responders are zero. The system is run for randomness as the demand distribution process is following a Poisson distribution. The mean of the Poisson distribution is 675/45 = 15. Each day the three agencies will supply to the above demand and within 45 days the three agencies can fulfil the demand.

The above three models are constructed in the same way, and only the supply and demand links for individual agents are changing according to the each instance. The total demand satisfaction for 45 days per individual agency and responders is recorded for three scenarios after running this model. The comparison for three scenarios of the average fulfilled demand shows that the full coordinated version of the model can fulfil the demand with a minimum amount of relief in the system. The NetLogo results are exported into Microsoft Excel from the plot data. The distribution centres of a full coordinated version of the model have fewer inventories than partial and without coordinated version of the model.

Table 5.2: Result 1: The amount of on-hand inventory at the distribution centre per individual agency (Developed by the researcher)

	With coordination	**Partial coordination**	**Without coordination**
Agency (Distribution centres) 1	1731.889	1743.511	1846.2
Agency (Distribution centres) 2	1355.356	1747.422	1854.44
Agency (Distribution centres) 3	1516.8	1751.711	1815.15
Average	1534.682	1747.548	1838.603

Table 5.3: Result 2: Gap in percentage about on-hand inventory on the LMRD system between the models (Developed by the researcher)

Gap between the model	**Average on-hand inventory at the system**
with and Partial coordinated model	14%
With and without coordinated model	20%

It is clearly displayed in Table 5.3 that the coordinated version of the model is fulfilling the demand with 14% less inventory in the system than the partial coordinated model and the coordinated version of the model is fulfilling the demand with 20% less inventory in the system than the uncoordinated version of the model. It shows that if the active agencies coordinate with each other in the context of sharing information and resources, then the success rate of relief distribution (demand satisfaction) is higher than the uncoordinated version of the model with minimum inventory level. The major problem during earthquake is damage of road networks and buildings. The active agencies need to share their resources and information with other agencies to react promptly and save the affected community.

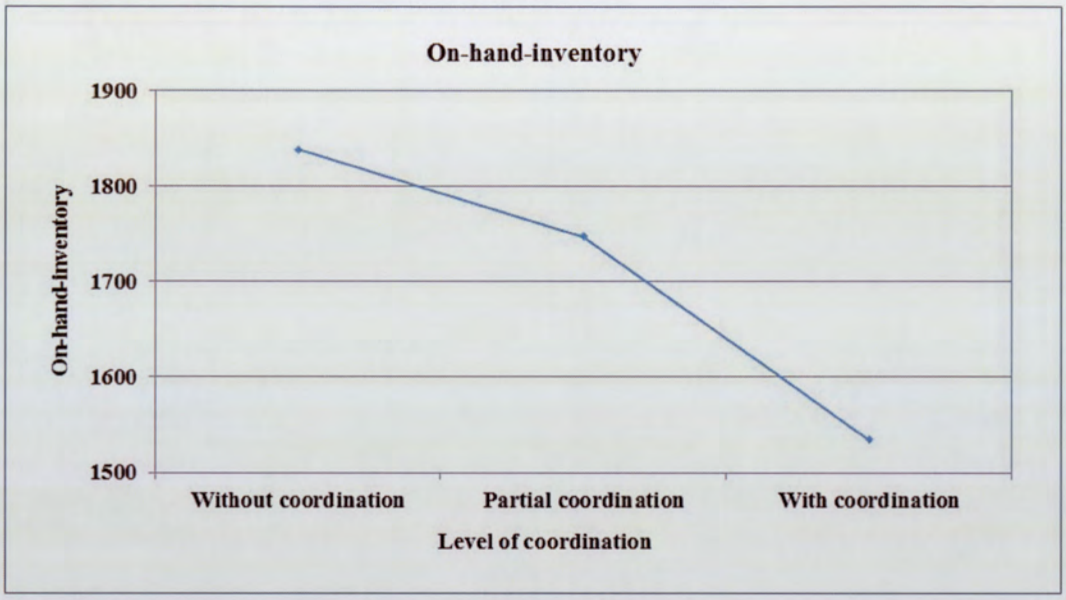

Figure 5.10: Agency on-hand inventory on the LMRD system (Developed by the researcher)

The above Figure 5.10 shows the coordinated version of the model requires minimum amount of on hand inventory and therefore this model is cost effective.

It is understandable if the coordinated version of the model can fulfil all the responder's demand with a minimum amount of relief, then this model has a minimum amount of holding cost of the relief items (Figure 5.11).

Table 5.4: Result 3: Cost efficiency at the distribution centre per individual agency (Developed by the researcher)

	With coordination	**Partial coordination**	**Without coordination**
Agency (Distribution centres) 1	-22144	-22121.6	-22212
Agency (Distribution centres) 2	-17400.4	-20448.2	-21356
Agency (Distribution centres) 3	-17853.4	-20818	-21768
Average	-19132.5	-21129.3	-21778.7

Table 5.5: Result 4: Gap in percentage about cost efficiency on the LMRD system between the models (Developed by the researcher)

Gap between the model	**Average cost efficiency at the system**
with and Partial coordinated model	11%
With and without coordinated model	15%

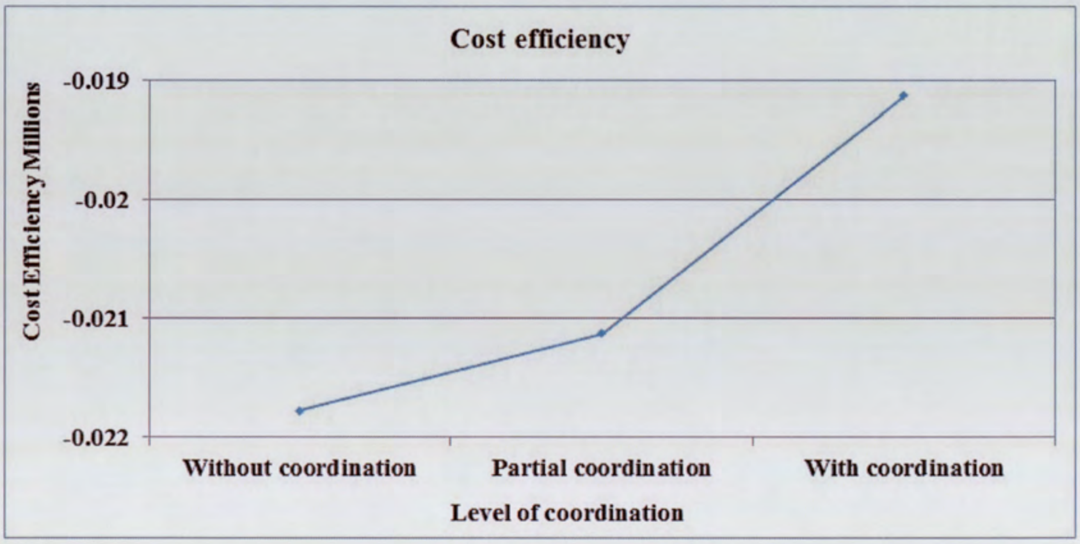

Figure: 5.11: Agency cost efficiency on the LMRD system (Developed by the researcher)

Coordination is the major factor, which affect the LMRD model in India during earthquake disaster. The practitioners' perspective is established after integrating this factor into the LMRD model and the results demonstrate that the coordination is a major factor for the LMRD performance according to the level of inventory and also increase the cost efficiency in India during earthquake situation. Now it is essential to clarify the proposed model's verification and validation to indicate the robustness of the model.

5.8 Sensitivity analysis of the model

The previous paragraph demonstrates that the coordinated version of the ABM for LMRD is cost effective. If the active agencies are sharing relief with each other for demand fulfilment of the affected community, then the agencies can accomplish the relief distribution operation effectively and can efficiently manage their cost. It is necessary to continue more experimentation to understand the reliability of this ABM and to know that the gap between without coordinated model and with coordinated model is consistent. The researcher includes a maximum number of 7 agencies, as within 7 agencies all the involved active agencies can be aggregated. The gap is calculated by the difference between the coordinated and uncoordinated model's result. The following Table 5.6 shows that the coordinated version of the LMRD model shows better performance with the range from 8% till 18% for 7 agencies. The result details are exhibited in Appendix 12.

Table 5.6: Gap between the with and without version of the coordinated LMRD model in the context of cost efficiency (Developed by the researcher)

Number of involved agencies	**Gap between with and without coordinated model about cost efficiency**
2 Agencies	8%
3 Agencies	15%
4 Agencies	15%
5 Agencies	16%
6 Agencies	17%
7 Agencies	18%

The following Figure 5.13 shows the results from the above Table 5.6:

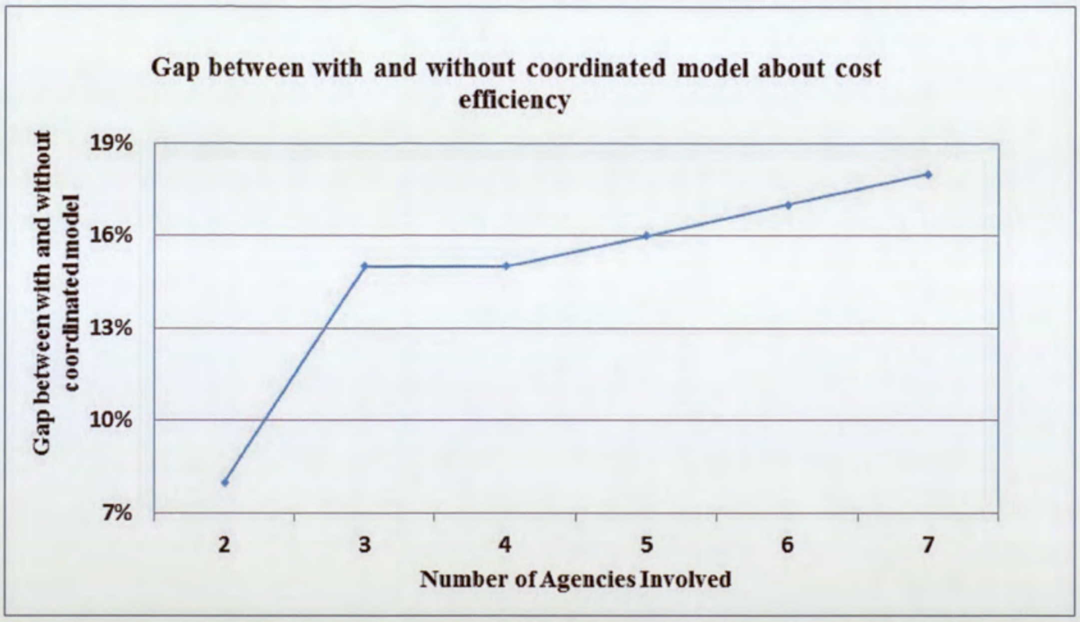

Figure 5.12: Cost efficiency between with and without coordinated LMRD model (Developed by the researcher)

The researcher considers 3 agencies: governmental, national and international agency in this research. All the governmental organisation is considered inside the umbrella of a governmental agency and similarly the entire national and international organisations is considered inside the umbrella of the national and international agency respectively. The researcher did sensitivity analysis and identify that the model can be consistent for 7 agencies. The above Figure 5.12 clarifies that the model is reliable for 7 agencies. The NetLogo version of the ABM can integrate 4 more agencies excluding governmental, national and international agencies. The Figure 5.13 also shows that more the agencies coordinate among each other can increase more cost efficiency in the overall perspective. There are sliders included in the NetLogo version of the ABM for the lead time between two agents (coordination hub and distribution centre; distribution centre and responders), the initial stock of the distribution centre, and the initial stock of the responders which can be oscillated by the modeller. These designs of the model present the robustness of the LMRD system. The OR model construction follows some significant stages: problem definition, conceptual modelling, model coding, model validity, model results, application and learning (Tako, 2008). The proposed model in this chapter followed all the key steps suggested by Tako (2008).

5.9 Discussion

The previous section of this chapter has explored the NetLogo version of the ABM for LMRD mainly for an earthquake. This model is mainly applicable for the decision maker for LMRD in India. The LMRD simulation model shows the importance of the coordination factor and presents how this factor can minimises the cost during demand fulfilment. All the involved relief agencies have their own mandates and they follow that mandates during LMRD and those mandates should not become the obstacles for coordination. This model shows a significant amount of cost efficiency, which increases the requirement of coordinating among them for better performance of the agency as well as the success of the relief distribution. During aid distribution operation adequate information can reduce demand uncertainty (Gilbert, 2008). The researcher uses two case studies of Indian earthquake to show the applicability of the model in this area. In normal supply chain processes cost is a major issue and the agency's strategy is always to be cost efficient in the market. A key concern in the relief chain process is to serve the disaster affected population effectively. In the relief chain if the involved agencies can be cost efficient by coordinating with each other, then coordination is an essential factor.

5.10 Chapter Summary

This chapter is integrating the coordination factor into the Indian LMRD system for earthquake disaster and it is demonstrated that the coordinated version is better than the partial coordinated and without coordinated version of the model. The modeller also explains the verification and validation perspective of this model. The researcher clarifies the robustness of the model after the sensitivity analysis and clarifies that coordination affects the LMRD performance metrics during earthquake disaster. Now it is essential to validate the proposed model using the practical scenarios. Next chapter 6 is explaining about the two case studies selected for this thesis.

Chapter 6: Case Study

6.1 Introduction

The previous chapter already presented the LMRD model and demonstrated that coordination is a major factor, which affects Indian LMRD system for an earthquake. The above statement established that during earthquake situation if the active relief agencies are coordinating with each other in the sense of sharing relief items, then the final relief distribution should be more operative. The main components of the LMRD model and the theoretical results are presented. Now it is important to test the theoretical results with the practical scenarios for the consistency of the results. This chapter elaborates about two Indian case studies used in this context to analyse the performance of the proposed model. The two case studies are illustrated in Figure 6.1 and explained thoroughly in this chapter. The affected regions, the chosen cities for the case study, data collection for the analysis, details about the obtained results are presented in this chapter.

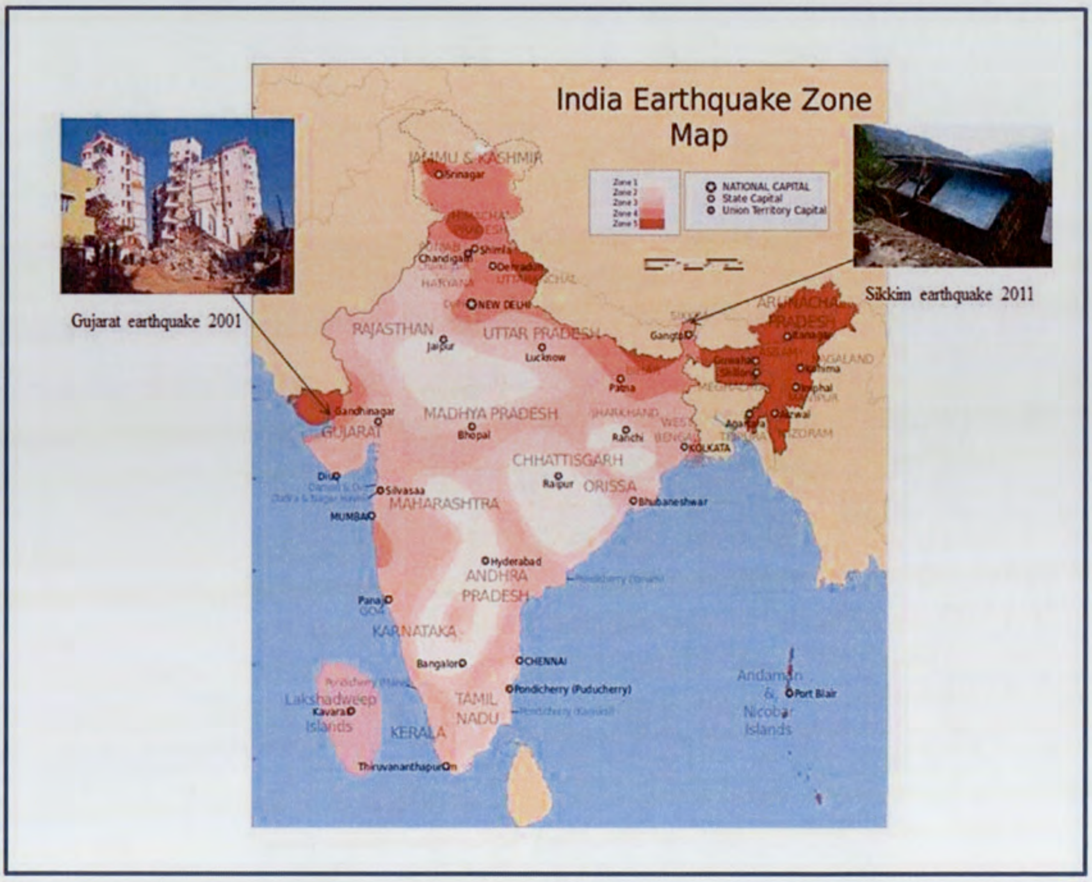

Figure 6.1: Selected case studies in India (Source: (home-affairs, 2007) moderated by the researcher)

The two case studies are selected according to the condition of the areas and the magnitude of the earthquake events, which intended to deliver different relief distribution situation. In an earthquake, a magnitude less than 4.5 in Richter scale can be generally felt for 50 to 100 km around the epicentre, and earthquake magnitude from 4.5 to 5.5 may be felt for 100 to 200 km around the epicentre and termed as 'small scale' disaster event (Coburn and Spence, 2003). This 'small scale' event may cause damage if the intensity of the occurrence of this event happens in weaker building area. This kind of 'small scale' event can be managed by the national and local disaster management authority (Coburn and Spence, 2003). In this context, the researcher chooses two case studies, which consider as 'large scale' disaster event with 7.7 magnitudes (2001 Gujarat earthquake) and 'medium scale' disaster event with 6.9 magnitudes (2011 Sikkim earthquake) and in both the cases the damages were very high (Coburn and Spence, 2003).

Gujarat is a state from western part of India with 1,600 km of coastline, whereas Sikkim is a northeast state located in the Himalayan mountain region. Gujrat state was affected by an earthquake on 2001, with 15,700,000 people affected by this earthquake (Eidinger, 2001a). On the other hand, Sikkim state was affected by another earthquake on 2011 with 575,200 people affected (EM-DAT). The above two cases are selected to obtain robust results considering differences in the geographical situation and impact factor. The purpose is to test the reliability of the system. The following Table 6.1 is a brief description of individual earthquake geographical position.

Table 6.1: Case studies are chosen from the specific earthquakes (modified by the researcher) (Source Goswami et al. (2014))

Date	Location	Epicentre position	Depth, km	Magnitude Mw	Distance from Sea, km	Total number of affected and dead	Total damage ($X 10^9$) $
26 Jan 2001	Gujarat, Bhuj	Latitude: 23.41 Degree Longitude :70.232 Degree	16	7.7	80	15,700,000 people affected and 20,023 people killed in India	2.623
18 Sep 2011	Sikkim	Latitude: 27.72 Degree Longitude :88.064 Degree	19.7	6.9	440	575,200 people affected and 97 people killed in India	0.5

6.2 Data collection and analysis

This thesis used secondary data set for the analysis of the two case studies. Chapter 3 elaborates about the documented reports and archival records as the data collection techniques. In this secondary data analysis, the above two techniques are chosen data collection techniques. The author managed to access to gather some internal data set about the previous earthquakes (in this case Gujarat 2001, Sikkim 2011 from the governmental and NGOs of India. But those field reports, raw data, and raw data analysis reports cannot be presented here because of the intellectual property, security issue and ethical issue. In case study 1 (Gujarat earthquake 2001) there are 12 government organisational documented report, day by day briefing reports (for 30 days) analysed by the national (CASA, SEEDS, BAPS) and international (UN, Red Cross) NGOs, 5 documented reports analysed from the international organisations and 9 archival records analysed from the government and the national agency. In the case study 2 (Sikkim earthquake 2011) there are 10 governmental reports, day by day briefing report (for 28 days) analysed by the national (CASA, SEEDS, BAPS) and international (UN, Red Cross) NGOs, 5 documented reports from international organisations and 6 archival records analysed from the government and the national organisations.

6.3 Case Study 1: Gujarat earthquake 2001

On 26th January 2001 at 8:50 am there was an earthquake of 7.7 Richter scale occurred in Gujrat state, in India. This earthquake stayed for 110 seconds (Pramod.K.Mishra, 2004). It was the worst earthquake to hit India since 1956. There is 2,623,000 US$ economic loss (EM-DAT) with 15,700,000 people were affected by this earthquake (Eidinger, 2001b). Gujarat state has 25 districts among them 21 districts were affected by that earthquake among them Kutch district was the most affected district as the epicentre was about 9 km south-west of the village of Chobari in Bhachau taluka of Kutch district (Figure 6.2).

Figure 6.2: Map of Kutch district (Source: http://www.mapsofindia.com/)

A total of 14,930 people died, and 115,940 people were injured in Kutch district (Eidinger, 2001b). There are 52.56% house destroyed and 37.44% house damaged in Kutch district (Eidinger, 2001b). 10 worst affected talukas in Kutch district were: Bhuj, Rapar, Bhachau, Mundra, Anjar, Gandhidham, Nakhatrana, Abdasa, Lakhpat and Mandvi. Bhachau is the nearest city from the epicentre of this earthquake, therefore, the researcher considered Bhachau city.

6.3.1 Bhachau

Bhachau is a municipality city in Kutch district, located at 23.28 degree North and 70.35 degrees East with an altitude of 134 feet above sea level. It is located 273 km away from Gandhinagar the capital of the Gujarat state.

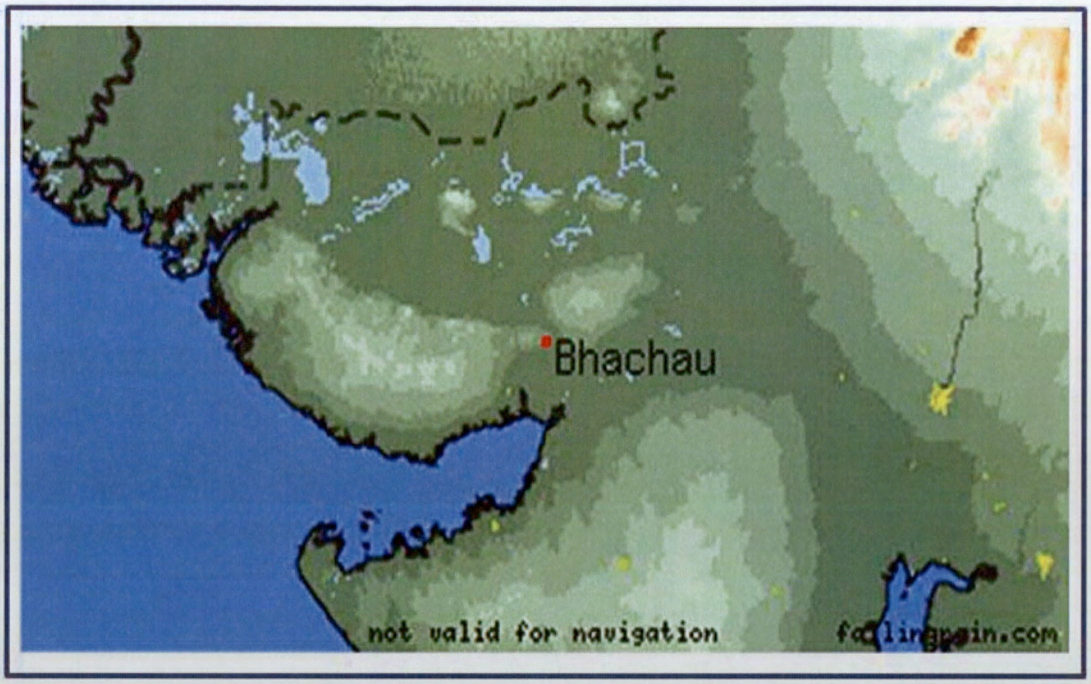

Figure 6.3: Bhachau city location (source: http://www.mapsofindia.com/)

The population of Bhachau city was 23,617 before the devastating earthquake on 2001. Bhachau is only 50 km away from the 8A national highway and also well connected with the other cities by using the major road and railway. Before 2001 Bhachau was affected by the 1956 Anjar earthquake as it is situated within the seismic zone 5 which is a very high-risk zone for earthquake (showed in Figure 6.1).

6.3.1.1 Condition of the 2010 earthquake in Bhachau city

On 26th January, the Republic day of India, there was some flag hoisting ceremony in schools and offices. Around 8:50 a.m. a devastating earthquake struck and as the epicentre is very near to Bhachau (showed in Figure 6.4) therefore, most of the Bhachau city was demolished.

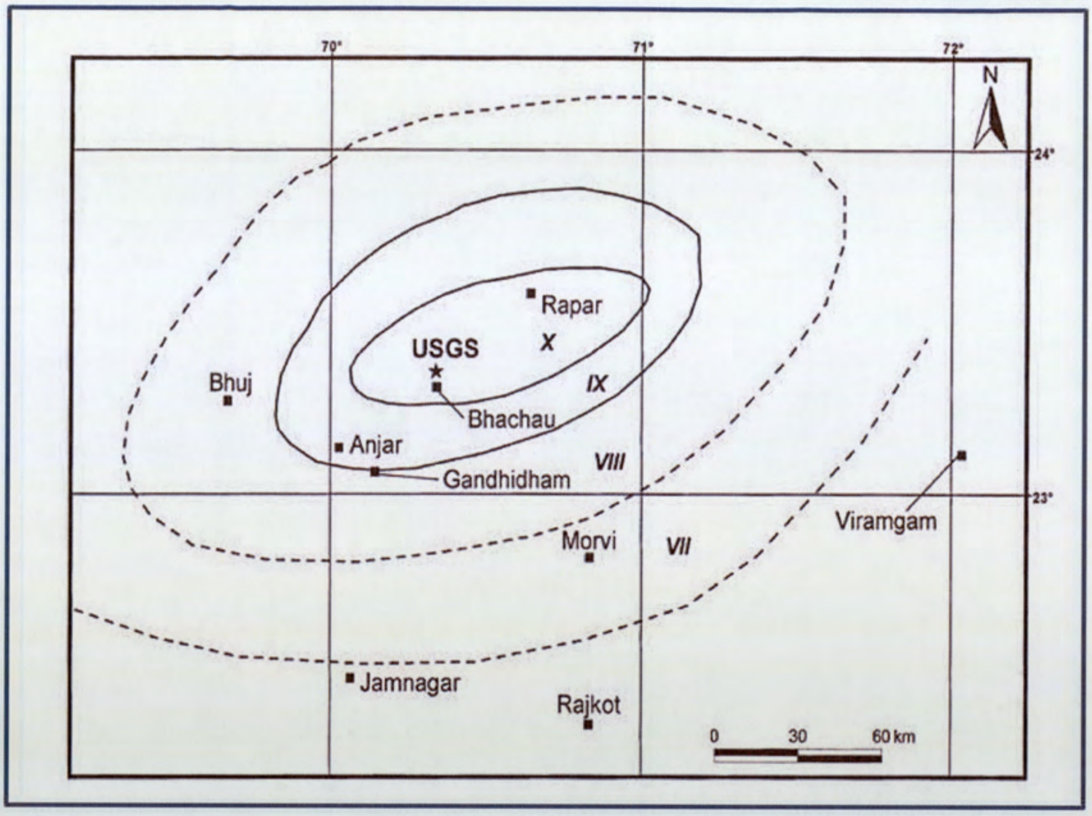

Figure 6.4: Exact epicentre of the earthquake in 2001 (Source (Saraf and Choudhury, 2005))

The damage was significantly high. There were many schools, hospitals, administrative buildings, police stations and rest of the houses destroyed. The major national highway was damaged and the Bhachau rail station was destroyed as shown in Figure 6.5. The earthquake caused widespread power damage through the Kutch district as well as the other affected districts. After the earthquake, the rescue and relief operation was started within 75 minutes in all the big cities in Gujrat states such as: in Ahmedabad, Gandhinagar, Bhuj. Though Bhachau was the nearest city from the epicentre the rescue and relief operation was not that swift. Within 3 days 18 reliefs camp were established in Bhuj city and there were more than 300 relief camps established in Kutch, Patan and Surendranagar districts.

Figure 6.5: Bhachau rail station (Source: from the field report of national agency)

6.3.1.2 Relief items

The Indian government responded immediately. The cabinet committee (the central governmental committee) declared that earthquake as a national calamity and invited international assistance as well. In Kutch district, there is a long disputed border with Pakistan, so there were Indian army and air force bases located in that zone as well (Price and Bhatt, 2009). In Bhachau city there were 15 relief camps (distribution centre) established (Pramod.K.Mishra, 2004). Those 15 relief camps were established by different governmental sectors, national agencies, and international agencies. Those were aggregated for 3 camps by the researcher. The rationality behind this aggregation is that all the government relief camps are aggregated as 1 governmental agency (they all work at the same level), all the national agencies (NGOs) are combined as 1 national agency (they all work at the same level) and finally, all the international agencies (NGOs) are aggregated and considered as 1 international agency (they all work at the same level) for the use of the model.

After the earthquake, hot cooked food was served for twice a day for 45 days by the BAPS NGO (Charities, 2012). Medical kits, cooking utensils kits, blankets, temporary shelter kits, drinking water; clothes, food, edible oil, vegetables and fruits, other items and sanitation kits were distributed after the earthquake to the people of Bhachau city (Pramod.K.Mishra, 2004, Price and Bhatt, 2009, Charities, 2012, Eidinger, 2001b, McConnan, 1998).

6.3.1.3 Demand

In Bhachau city though the relief was supplied according to the need of the affected community, there were some relief items which were in high demand such as blankets, temporary shelter kits (Tarpaulins, GI sheets, Bamboo, Angles), kitchen sets, sanitation kits (Societies, 2001). From the above items kitchen sets, sanitation kits and temporary shelter kits were distributed to the family of 4 people (including female member and children) and blankets were distributed to each person. According to the census report 2001, there were 23,617 people living in Bhachau and everybody was affected by this earthquake. The 15 relief organisations are aggregated based on the government, International and national organisations.

6.3.2 Results

6.3.2.1 Blankets

The three versions (coordination, partial coordination and without coordination) of the LMRD model were run for 45 days (explained in chapter 5). The lead-time between the coordination hub and agency is 3 days and the lead-time between the agency and responders is 2 days (which is explained in the previous chapter). In this case, the model is employed to distribute only blankets to the earthquake affected people of Bhachau. There is mortality information in Kutch district but from the reports and secondary data set the researcher had no clear identification of the exact number of dead people in Bhachau city, therefore the researcher assumed that 100% of people living in the area was affected by the 2001 earthquake in Bhachau city. The researcher also assumed that the affected people are properly identified while receiving or collecting relief items (identification will be carried out either by checking or signing a proper document or the head of the Municipality Commissioner is making sure about the identity of the people from their internal database), so that there is no repetition of distribution to the affected people and no wastage due to duplication of relief items. The initial inventory in agencies and Responders are zero. The system is running for randomness as the demand distribution process is following poison distribution. Therefore, the mean of the poison distribution is 23617/45 = 524.8= 525.

Each day the three agencies will supply the above demand and within 45 days the three agencies can fulfil the demand. The following Table 6.2 showed that the individual agency can fulfil the demand with the following number of blankets in each of the distribution centres.

Table 6.2: The amount of blankets at the distribution centre per individual agency (Developed by the researcher)

	With coordination	Partial coordination	Without coordination
Agency (Distribution centres) 1	23902	26053	27590
Agency (Distribution centres) 2	23605	26057	25590
Agency (Distribution centres) 3	23613	25700	28201
Average	23706.67	25936.67	27127

Table 6.3: Gap in percentage about blankets on the LMRD system between the models (Developed by the researcher)

Gap between the model	Average on-hand inventory at the system
With and Partial coordinated model	9%
With and without coordinated model	14%

The coordinated version of the model can supply blankets with 9% less inventory than the partial version of the LMRD model and with 14% less inventory than the without coordinated LMRD model.

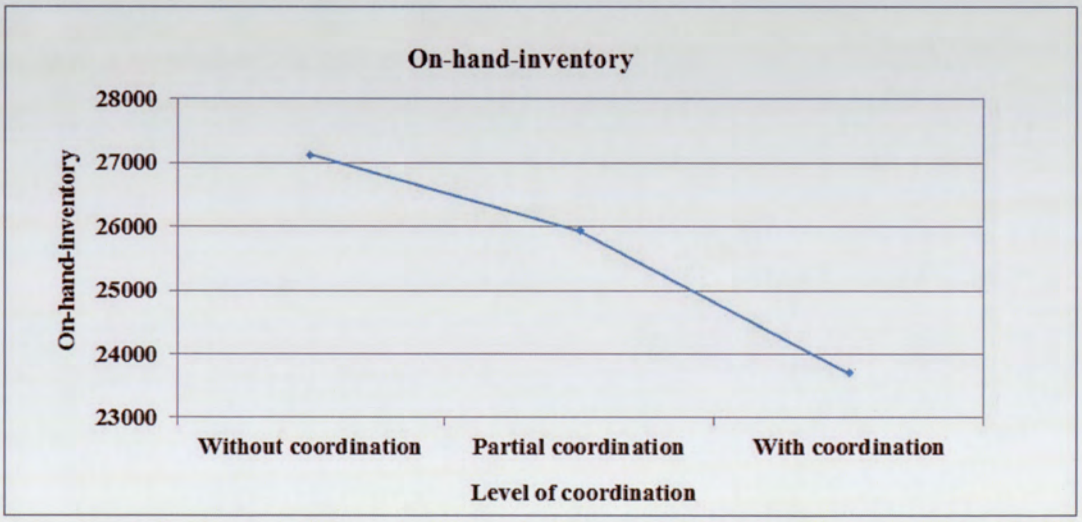

Figure 6.6: Agency on-hand blankets on the LMRD system (Developed by the researcher)

The coordinated version of the model is efficient regarding inventory-wise. Therefore, the coordinated version of the LMRD model is cost efficient that result is presented in the following Table 6.4 and Figure 6.7.

Table 6.4: Cost efficiency at the distribution centre per individual agency (Developed by the researcher)

	With coordination	**Partial coordination**	**Without coordination**
Agency (Distribution centres) 1	-504,636	-542,565	-567,343
Agency (Distribution centres) 2	-494,294	-546,892	-557,345
Agency (Distribution centres) 3	-491,965	-549,613	-594,378
Average	-496,965	-546,357	-573,022

Table 6.5: Gap in percentage about cost efficiency on the LMRD system between the models (Developed by the researcher)

Gap between the model	**Average financial efficiency at the system**
with and Partial coordinated model	10%
With and without coordinated model	15%

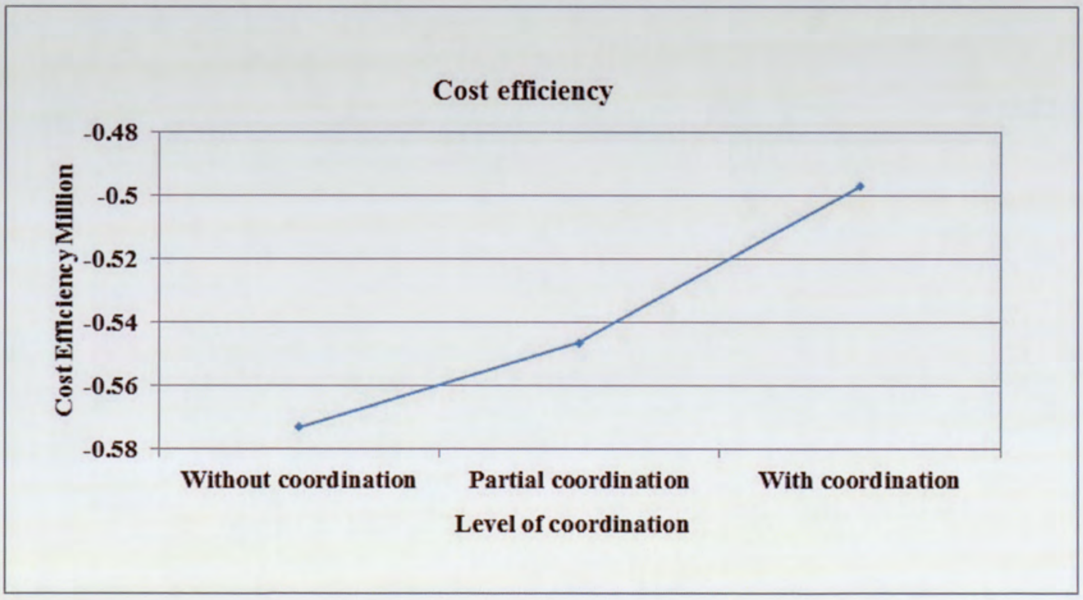

Figure: 6.7: Agency Cost efficiency on the LMRD system (Developed by the researcher)

The coordinated version of the model demonstrates that this is more cost efficient than the other two LMRD model.

6.3.2.2 Sanitation kits, kitchen kits or temporary shelter kits

The three versions of the LMRD model will run for 45 days (explained in chapter 5) and in this case, the model will distribute the sanitation kits or temporary shelter kits to the earthquake affected people of Bhachau city. One temporary shelter kit combines the Tarpaulins, GI sheets, Bamboo, Angles and other necessary materials required to build a temporary family tent, where a family of 4 people can live. The model needs to supply the kits for 23,717/4 = 5,904 kit.
The lead-time between the coordination hub and agency is 3 days and the lead-time between the agency and responders is 2 days. The initial inventory in Agency and Responders are zero. The system is running for randomness as the demand distribution process is following a poisson distribution. Therefore, the mean of the poisson distribution is 5,904/45 = 131.
Each day the three agencies will supply the above demand and within 45 days the three agencies can fulfil the demand. The following Tables 6.6 showed that the individual agency can fulfil the demand with the following number of sanitation kits or temporary shelter kits in each of the distribution centres. The following Table 6.6 and 6.7 demonstrates the average gap between the coordinated model, partially coordinated model and the model without coordination. Detailed results presented in Appendix 13.

Table 6.6: Average amount of sanitation kits or temporary shelter kits on the LMRD system (Developed by the researcher)

Level of coordination	**Agency on-hand inventory at the distribution centre**
Without coordination	6752.667
Partial coordination	6463.34
With coordination	6043

Table 6.7: Gap in percentage about sanitation kits or temporary shelter kits on the LMRD system between the models (Developed by the researcher)

Gap between the model	**Average on-hand inventory at the system**
with and Partial coordinated model	7%
With and without coordinated model	12%

The coordinated version of the model also shows optimistic results, for the sanitation kits and shelter kits, which is presented in Figure 6.7. In Gujarat earthquake 2001, mainly in Bhachau city blankets, sanitation kits and temporary shelter kits are three most demanded relief items for the affected community. The author only considered those relief items as the most demanded relief items for this research.

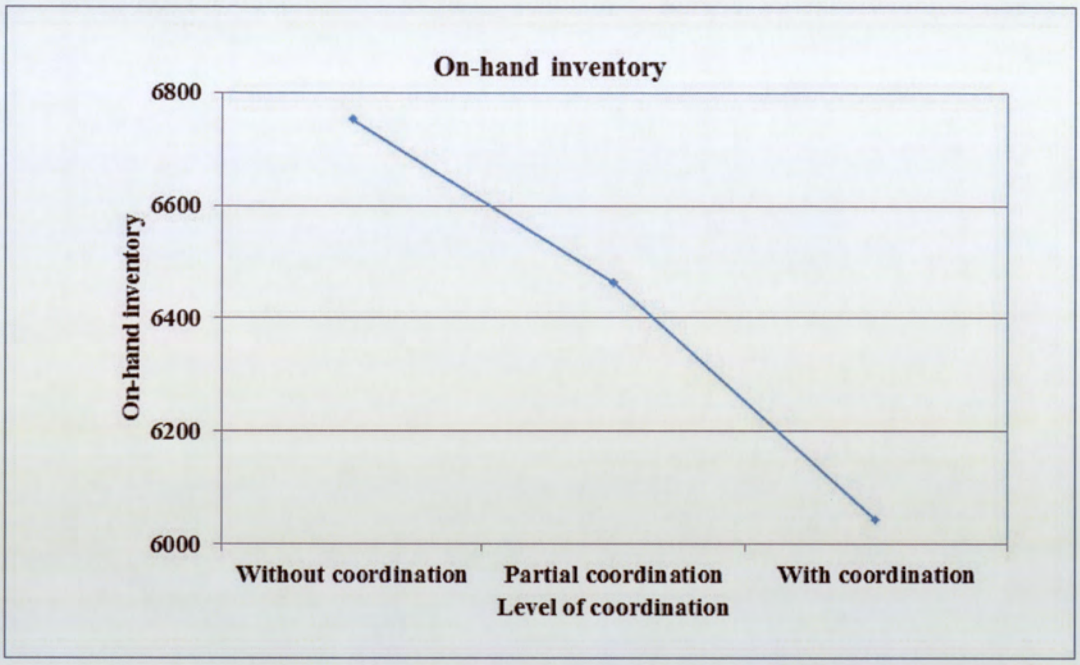

Figure 6.8: Agency on-hand sanitation kits or temporary shelter kits on the LMRD system (Developed by the researcher)

Again the coordinated version of the model is financially efficient as presented in Figure 6.8. The relevant results presented in Appendix 14.

Table 6.8: Gap in percentage about cost efficiency on the LMRD system between the models (Developed by the researcher)

Gap between the model	Average financial efficiency at the system
with and Partial coordinated model	12%
With and without coordinated model	16%

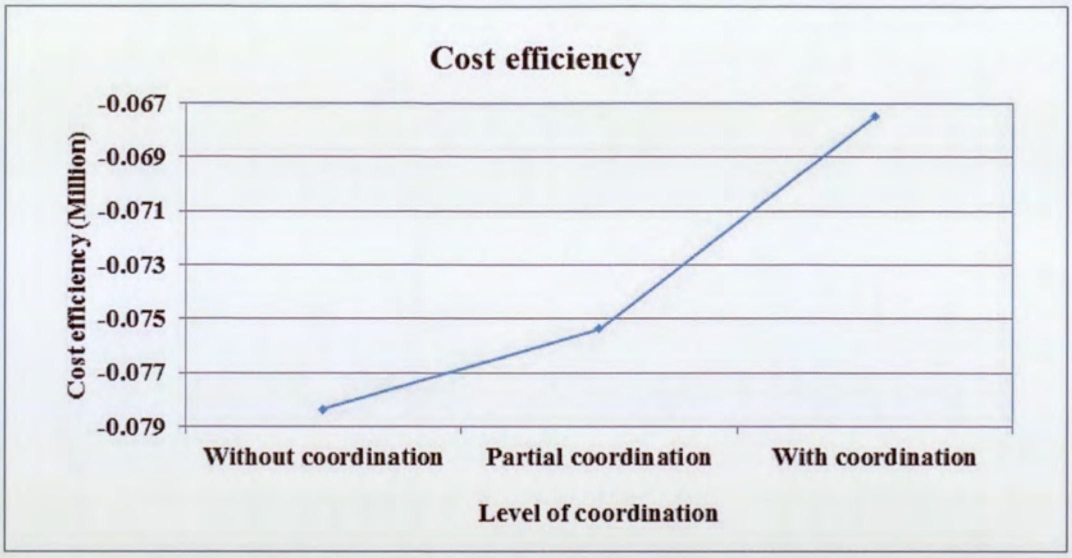

Figure 6.9: Agency cost efficiency on the LMRD system (Developed by the researcher)

The three versions of the LMRD model in the specific city in Bhachau, during 2001 Gujrat earthquake, demonstrates that the proposed model interacts positively in the practical context. It is noticeable that the decision maker in LMRD operation is concentrated on demand fulfilment rate with minimum amount of inventory, which tends to cost efficiency. Another constructive impact is the efficiency of relief distribution by integrating coordination, communication, knowledge sharing, resource sharing and information sharing among the active agencies. 15 active agencies were supplying relief items to the Bhachau city. Among them, 4 of the active agencies were supplying the sanitation kits to a specific individual community to the city but one agency could only supply 39% of sanitation kit to that specific community due to shortages of sanitation kits on that agency (from the field report). The shortages are identified from the lesson learned report of the government of India. On the other hand, if the other 3 active agencies coordinated with that specific agency then 100% population of that community could get sanitation kits. This would overcome the unsatisfied demand of the affected community.

6.4 Case Study 2: Sikkim earthquake 2011

On 18th September 2011 at 18:11 p.m. an earthquake struck in India. The earthquake was about 6.9 Richter scale. There are 5 countries affected by this earthquake: India, China, Nepal, Bhutan, Bangladesh (Rajendran et al., 2011). Among them, India was the most affected country and there were 575,200 people affected by this earthquake in India. Sikkim, West Bengal, Bihar, Assam and Meghalaya were the 5 affected states (Rajendran et al., 2011). Among them, Sikkim was the most affected state (as the epicentre of the earthquake was in the Sikkim district) (Rajendran et al., 2011). Sikkim is situated in the Himalayan region and this entire state lies in the seismic zone 4, which is the high-risk zone for earthquake (showed in Figure 6.1) (IMD, 2011). Sikkim, being located high-risk zone, has been affected several times by previous earthquakes occurred in the Himalayan region (Rautela, January 2012):

Table 6.9: Some major earthquake that has affected the Himalayan region (Source (Rautela, January 2012))

Serial Number	Earthquake	Date	Magnitude
1	Cachar earthquake	10.01.1869	7.5
2	Shillong Plateau Earthquake	12.06.1897	8.7
3	Dhubri Earthquake	02.07.1930	7.1
4	Bihar-Nepal Border Earthquake	15.01.1934	8.3
5	Arunachal Pradesh – China Border Earthquake	15.08.1950	8.5
6	Earthquake near Gangtok	19.11.1980	6.1
7	Nepal-India Border Earthquake	21.08.1988	6.4
8	Sikkim Earthquake	14.02.2006	5.7
9	Bhutan Earthquake	21.09.2009	6.2

The population density is very low in the Himalayan mountain region; therefore, earthquakes did not affect that much in terms of human or animal casualty.

On 2011 earthquake almost 143,800 people were affected in whole Sikkim (Rajendran et al., 2011). In the Sikkim state, there are 4 districts (North, South, East and West) and North Sikkim was the most affected district. The number of lives lost during the 2011 Sikkim earthquake in Sikkim state is combined in the following Table 6.10:

Table 6.10: Number of deaths caused by the earthquake (source (Report, 2011))

Population Figures			No of confirmed deaths
	Population	Density (per square kilometre)	(As per Govt. Data)
Sikkim	607688	86	76
North District	43354	10	58
East District	281293	295	13
West District	146742	196	04
South District	136299	120	01

There were 35,950 people affected in North District. In Mangan city, there were 4,644 people living according to the census report of 2011 and 100% people were affected by the earthquake.

In this case, the researcher is considering Mangan city for the second case study as this is the nearest city from the epicentre of the Sikkim earthquake 2011.

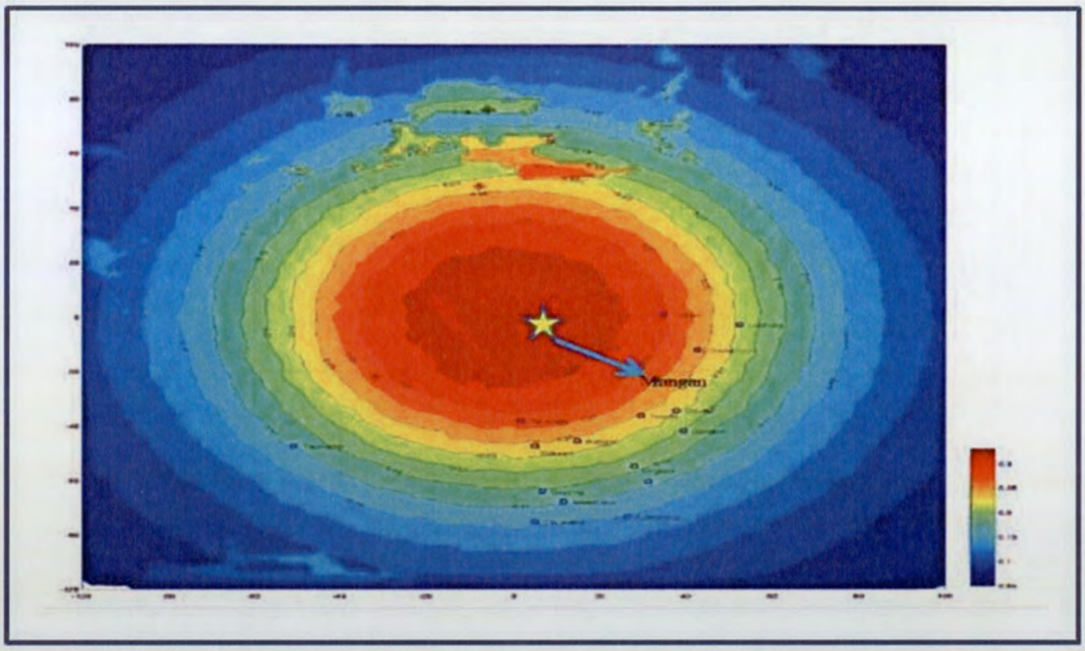

Figure 6.10: Ground movement for Sikkim earthquake 2011 (Source: from field report)

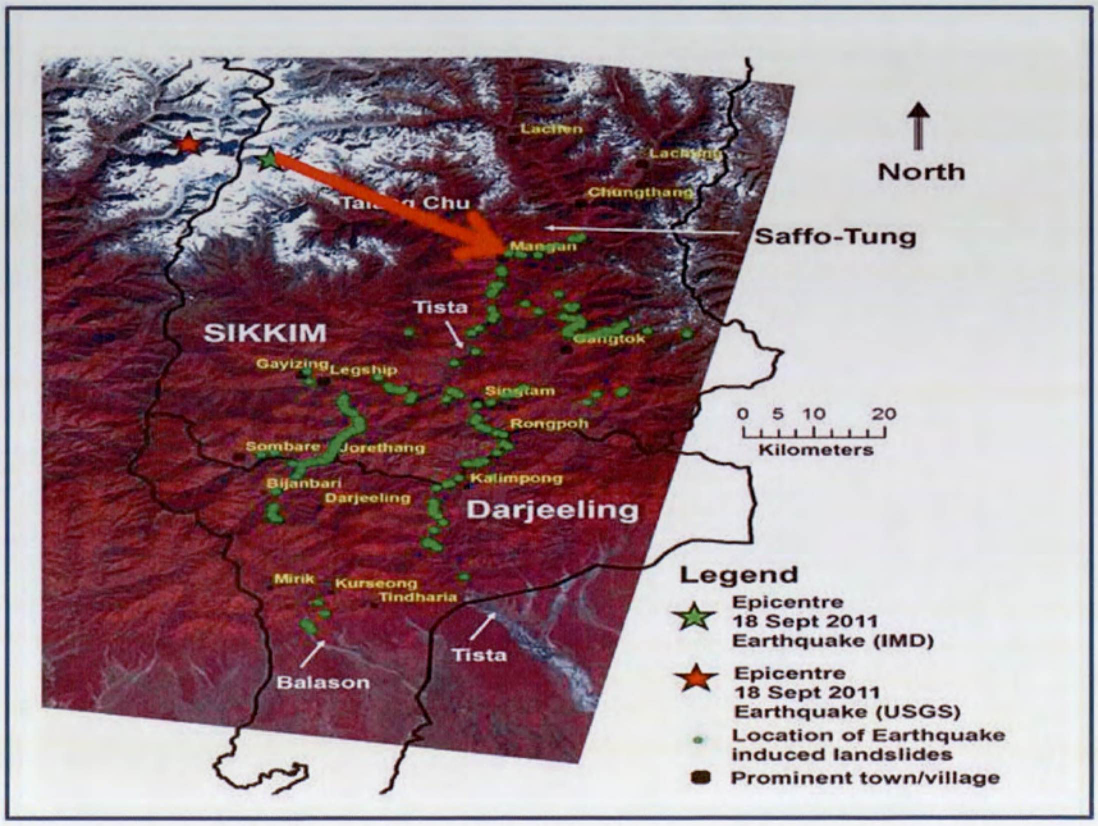

Figure 6.11: Exact epicentre location for Sikkim earthquake 2011 (Source (Indranil Chakraborty, 2011))

6.4.1 Mangan

Mangan city is the headquarters of North Sikkim district. It is located at 27.52 degrees north and 88.53 degrees east with an altitude of 3136 ft. from sea level. Mangan is 54 km away from the capital city Gangtok. This city is divided into 5 wards (administrative division or parts). This city has the population of 4,644 of which 2,456 are males while 2,188 are females as per a report released by Census India 2011 (Sikkim, 2011).

6.4.1.1 Condition of the 2011 earthquake in Mangan city

The Sikkim district was very badly affected, particularly Mangan city as the epicentre was very near to this city (showed in Table 6.1 the exact epicentre position). This high-altitude city was totally blocked as earthquake initiated huge landslide in that region. This earthquake damaged roads, bridges, electric supplies, telephone lines. This earthquake followed by after effect landslides, which collectively disconnected the city from the rest of the world.

The weather was very bad with heavy rainfall coupled with dense fog; therefore, it was impossible for Indian air force personnel to drop relief items by helicopter. Most of the houses are damaged. Mainly in Mangan city, the first responders were the affected population of that city. On 20th September 2011, one of the government officials said that: "The road to Mangan is gradually getting cleared and Army columns with relief material are moving towards the affected areas. We are in constant touch with our troops who have already managed to reach the affected parts and set up camp. Immediately after the earthquake, troops from high-altitude camps started trekking towards the affected areas with whatever material was available. When the weather was improved, Special Forces personnel slithered into affected villages from helicopters. Medical camps were set up and arrangements were made for casualty evacuation" (India, 2011). The earthquake caused widespread of power damage through the whole state. The rescue and relief operation started within 1 hour in Gangtok and within 1 week there were four (among them 1 is governmental camp, 1 is Red Cross, other 2 are national/local NGO) relief camps were supplying the relief to the affected population.

6.4.1.2 Relief items

The Prime Minister of India considered this earthquake as a national calamity and the cabinet committee declared the need to start rescues and relief operations within 24 hours. In Mangan city woollen blankets, shelter tool kits, stoves, kitchen sets, hygiene kits, food, sanitation kits were distributed (Report, 2011, Rajendran et al., 2011, Societies, 2012).

Figure 6.12: Distributed relief and temporary shelters (Source: from the field report of a national agency)

6.4.1.3 Demand

The relief camps were set up after 20th September in Mangan city and relief distribution started after that. All the relief items were in a high demand. As September is monsoon and winter would be knocking on, the most demanded item was woollen blankets. The woollen blankets, which was distributed to every individual. From the census report 2011 there were 4,644 people live in Mangan city and the entire population were affected by this earthquake (as from the reports and documents the researcher could not find the number of people that died in Mangan city), because for the cold weather, in this case study of the LMRD model woollen blankets supply to the affected population. In Mangan city there were 4 relief camps were set up among them 1 is government, 1 is international organisation and another 2 are the national relief organisations (which are aggregated as 1 relief organisation) during the experimentation stage.

6.4.1.4 Results

The three LMRD models are running for 45 days (explained in chapter 5) and in this case, the models are running for the supply of the woollen blankets to the earthquake affected people of Mangan city. The researcher is also assuming the identification of the affected people while receiving relief items (the people need to sign the proper document during the collection of relief items or the head of the Panchayat official is making sure of the identification of the people, collecting relief items, from their internal database), so that the same person would never be served again with same relief items. The lead-time between the coordination hub and agency is 3 days and the lead-time between the agency and responders is 2 days. The initial inventory in agency and responders are zero. The demand distribution process is following poisson distribution. Therefore the mean of the poisson distribution is 4,644/45 = 103.

Each day the three agencies would supply the above demand to three different communities at the Mangan city and the three agencies can fulfil the demand within 45 days. The following Table 6.11 showed that the individual agency can fulfil the demand with the following number of blankets in each of the distribution centres.

Table 6.11: A number of woollen blankets at the distribution centre per individual agency (Developed by the researcher)

	Without coordination	**Partial coordination**	**With coordination**
Agency (Distribution centres) 1	5021.8	4825.9	5000
Agency (Distribution centres) 2	4,824.5	4690	4293
Agency (Distribution centres) 3	5864.6	5479.3	4753
Average	5236.96	4998.4	4682

Table 6.12: Gap in percentage about woollen blankets on the LMRD system between the models (Developed by the researcher)

Gap between the model	**Average on-hand inventory at the system**
with and Partial coordinated model	7%
With and without coordinated model	12%

In case study 2 the coordinated version of the LMRD model is presented and a positive result is showed in Table 6.12 and Figure 6.13.

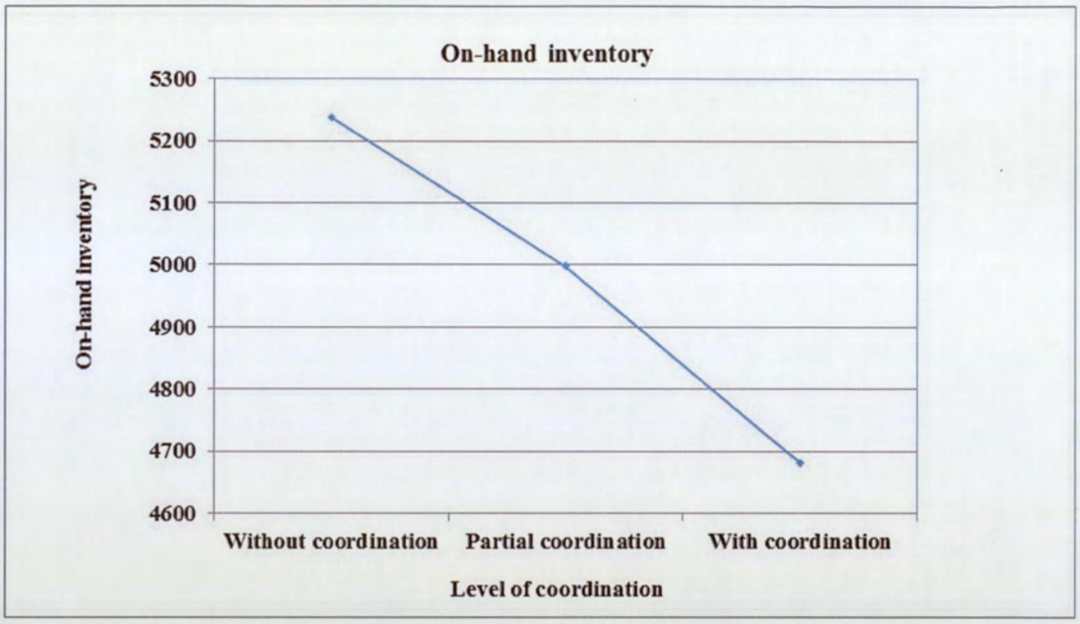

Figure: 6.13: Agency on-hand woollen blankets on the LMRD system (Developed by the researcher)

The coordinated version of the model can fulfil the demand with a lower level of inventory. As a result, this model should be cost effective, which is demonstrated in the following Tables and Figures (Table 6.13; 6.14 and Figure 6.13). The detailed results are presented as follows:

Table 6.13: Average agency's cost efficiency on the LMRD system (Developed by the researcher)

Level of coordination	**Agency financial efficiency at the distribution centre**
Without coordination	-65,889.3
Partial coordination	-63,094.3
With coordination	-56,652

Table 6.14: Gap in percentage about cost efficiency on the LMRD system between the models (Developed by the researcher)

Gap between the model	**Average financial efficiency at the system**
with and Partial coordinated model	11%
With and without coordinated model	16%

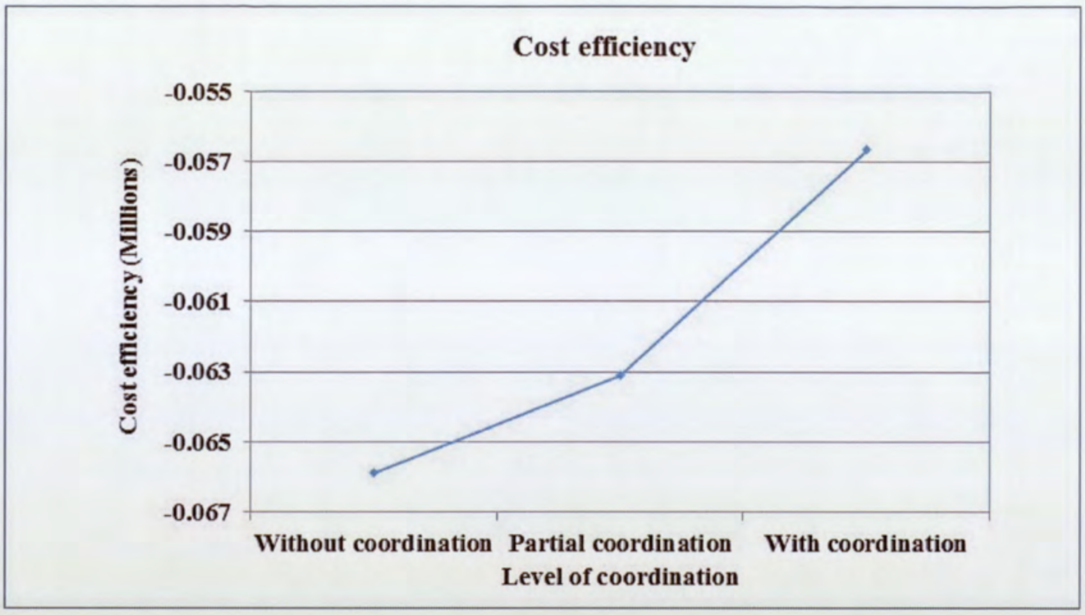

Figure: 6.14: Agency cost efficiency on the LMRD system (Developed by the researcher)

The above paragraphs explained how the researcher performed experimentation and applied the three versions of the LMRD model in the disaster scenario to a specific city in Mangan, which is one of the severely affected city during the Sikkim earthquake. The results (Figure 6.14) demonstrated that the proposed coordinated model can fulfil the demand with minimum inventory. It is noticeable that the decision maker operated during final relief distribution, with the focus on demand fulfilment rate but also considering for cost efficiency.

6.5 Discussion about the case studies results

This chapter has introduced the application and the results obtained for two case studies. Results, lead us that, coordination is a very important factor during relief distribution. Coordinated relief supply not only for fulfils the demand but also serves a more affected population efficiently with less amount of relief items. Therefore, it is the most cost-effective proposal for the decision maker and practitioners in relief distribution. In Bhachau city (case study 1) the coordinated version of the model serves the affected community (23,617) with an average 23,706 relief items, In case study 2, an average of 4682 relief items served 4,644 people with the coordinated LMRD model in the Mangan city. The reliability and justification of model design are validated with the consistent results of two case studies. The maximum holding and maintenance cost of relief items are observed when the items are supplied to the affected community by without coordinated version of the LMRD model because the agencies are counting extra resources for relief supply.

During large scale earthquakes, not only one city but also there is a range of cities, villages and urban areas are affected. The responders and relief officials are aiming for providing the relief to the maximum affected population according to their capacity of relief items. There is a need for proper coordination among the active agencies to provide service to the affected population. Every single relief item counts for saving the human lives in a large scale disaster like earthquake, flood and others. For example, during Sikkim earthquake, 2011 one of the major issues was that the city was completely disconnected from the mainland. Transportation of relief items to the affected city was the crucial problem for the active agencies. All the active agencies already reach to Gangtok (Capital of Sikkim) but no relief agencies could reach near to the earthquake epicentre area within 3 days of the earthquake. After 3 days of the incident because of the landslides, flash floods, and huge dense of fog very limited number of agencies can reach to the affected area. There are other affected villages and urban areas of North Sikkim which were totally detached from the major cities, therefore the coordination among the relief agencies can manage their relief distribution efficiently, and they can serve more affected community in the limited time frame.

Unfortunately, the experimentation of the model is done with two specific cities but not for a district or for a state, therefore it is concluded that the measures of this model can be limited for a large-scale condition.

6.6 Chapter summary

The purpose of this chapter is to describe the robustness of the system by using two case studies in India, followed by the analyses of the results. The details of the two case studies are introduced, and the data collection techniques are explained. Lastly, the results of the each case are introduced and discussed.

The next chapter investigates the assessment of the obtained results comparing with field consideration and discuss the findings.

Chapter 7: Evaluation and Discussion of the field situation

7.1 Introduction

Chapter 6 elaborated on the two case studies and performed experimentation on two cities most affected by earthquakes (2001 Gujarat and 2011 Sikkim). The cases are analysed by using NetLogo ABM for LMRD to clarify that the coordinated version always fulfil the demand with minimum amount of inventory, which minimise the cost as well. The case studies also explained that sharing resources among the active agencies during LMRD has the potential to significantly contribute towards appending the relief chain issues in India. This research aims to identify and analyse the LMRD in the Indian context to reduce the inefficiency of relief distribution, which will reduce the suffering of the poor and vulnerable (who are always the worst affected) community, in the time of disasters. The current chapter discusses the coordination activities, which are performed in the two case studies by the active agencies and also compares the performance of the ABM with the real field situation. Finally, this chapter provides the discussion of the findings and generalisability of this research.

7.2 Description of two case analyses with real field situation

The selected two case studies are different according to a geographical area, affected population and the response operation. In Gujarat earthquake 2001 the relief operation starts within 75 minutes after the earthquake, on the other hand in Sikkim earthquake 2011 the response operation starts within 24 hours of the earthquake. This is because of the geographical location and weather condition of that two affected region. In Gujrat earthquake 2001 the local NGOs (BAPS, CASA, etc.) provided hot cooked food to the earthquake affected population and not only in Bhuj (the main city in Kutch district) but also the local NGOs are supplying the hot cooked food to the other cities like Anjar, Rapar and Bhachau (the most affected cities) during the immediate aftermath of the disaster with the cooperation of local churches and institutions. Stocks were replenished by those local NGOs. Alternatively during Sikkim earthquake the local, government and international organisations can only supply the relief to the Gangtok city (capital of Sikkim), not the other cities because of the landslides, flash floods and the huge dense of fog, therefore during Sikkim earthquake the affected local community starts the response operation according to community capacity. During Gujarat earthquake in Kutch district, 14 local NGOs combined and worked together under the name of 'Abhiyan'. This NGO worked as a coordinator for NGOs activities, needs assessment analysis and information management to understand the needs of the affected community and continue resource management together (Chatterjee et al., 2010). This NGO took part for the recovery phase, mainly for shelter reconstruction in Kutch district. Not only the local NGOs but also the International organisations (NGOs) and UN agencies worked together inside the umbrella of 'On-Site Operations Cooperation Centre (OSOCC)', which was established and set up with the permission of the District Magistrate. The main aim of this centre was conducting inter-agency meeting in the various sector, for example, health, shelter, sanitation, water, education, child protection and logistics to understand the situation and receiving the correct information (Chatterjee et al., 2010). There was another local level coordinator NGO established called 'SETU'. The stakeholders of this institution were the village head, elected members, community members and relief providers. 'SETU' was structuring the network of nodal points for defined geographical clusters of 15 to 20 villages. The aim of this organisation was to organise the facilitation centre for relief and rehabilitation, managing the field level data collection and providing action to manage the complaint (Chatterjee et al., 2010). There were some instances about joint decision-making processes and coordination among the agencies in Gujarat earthquake, but Sikkim earthquake was the totally different situation. According to OCHA situation report no 3 "The devastation caused by the earthquake has also been intensified by seasonal heavy monsoon rains that caused landslides, mudslides and also caused floods that destroyed thousands of homes, buildings and infrastructure. Heavy rain, fog and blocked roads prevented the rapid deployment of rescue workers for the first day of the response in Sikkim state - the worst affected state in India. Rescue teams continue to experience difficulties in accessing some of the remote worst affected areas in northern Sikkim State" (affairs, 2011). This weather situation delayed the rescue and relief operation. According to Red Cross report "in response to the earthquake, the Indian Red Cross Society (IRCS) was able to reach 1,000 families with relief supplies, shelter tool kits and water purification units to address their basic needs for a period of two and half months" (Societies, 2012). In Sikkim earthquake, relief supply to the affected region was a challenging task for the relief workers and agencies. Though the situation was challenging, there were some coordination efforts found. For example, UNDP focal point was on assisting local coordination in Sikkim district, UNDMT was reviewing the existing and emerging needs (affairs, 2011). The government of India was coordinating at the higher level with the armed force and NDRF force to reach those affected regions (affairs, 2011). The Government was also extended the coordination at the local level with the on-site UNDP DRR programme (affairs, 2011). There are some issues which affected the Indian coordination mechanism, for example, government structure, local capacities for response, funding, neutrality of the coordinating body, interactions with local government and the affected community, stakeholder's partnership (Chatterjee et al., 2010). The field analysis for the two case studies demonstrates that in the previous earthquakes response operation coordination was a major issue and the involved agencies concentrated in various ways to coordinate with each other, therefore coordination is a major affecting driver in Indian LMRD system.

This research is stepping up and proposing integrated coordination hub, which has the information to all the active agencies district warehouses and therefore this coordination hub will speed up the distribution process with a proper flow of information and resources operatively in Indian LMRD system. Integrating coordination hub into the Indian LMRD system will accelerate the active agencies to coordinate with each other.

Now the NetLogo version of the ABM for LMRD system will be compared with the real field situation to analyse the performance of the model.

7.3 Comparison with the relief field situation

The methodology for this research is an ABM simulation. In chapter 5 the researcher clarifies the suitability of ABM for this purpose. Now the ABM can be compared with real field situation for the chosen case studies. The researcher is not able to provide the raw data and exact data analysis reports of the field situation by government and NGOs because of the intellectual property and ethical issue.

The researcher assumes that in both the cases there are three active agencies who are supplying the relief items, as within these 3 agencies all the involved active agencies are combined. The researcher does not have proper data about the exact mortality rate in Bhachau and Mangan; therefore, it is considered that in the chosen two cities 100% population were affected. Another assumption is that the individual agencies are supplying relief to the individual community of the specific neighbourhood; therefore, there is less chance of duplication of relief items. Finally, a number of relief items received by the responders will be supplied to the affected community without any loss of the relief items.

The most wanted relief items are Blankets, kitchen sets, sanitation kits and temporary shelter kits in Bhachau city. Whereas woollen blankets are most demanding in Mangan city as most of the city is devastated by flash floods, therefore there is a need for evacuation of the affected population.

The proposed NetLogo version of the ABM model run for two cities Bhachau (case study 1: Gujarat earthquake 2001) and Mangan (case study 2: Sikkim earthquake 2011) for short-term relief operation.

The NetLogo version of the ABM runs for 45 days in three scenarios which are now repeated here for suitability to form the foundation of the case studies evaluation and discussion.

The researcher is comparing three scenarios for understating the effectiveness of coordination in the NetLogo version of the ABM for LMRD system

Scenario 1: Three different organisations (governmental, international and national agency) supply relief in an earthquake situation for 45 days in India. There are three relief chains working separately, which were already shown in Figure 5.6.

Scenario 2: Coordination Hub will supply the relief to three agencies distribution centres (governmental, international and national agency) and the individual agency's responders will transmit the demand to the specific agency's distribution centre in an earthquake situation for 45 days in India.

Scenario 3: Coordination Hub will supply the relief to three agencies (governmental, international and national agency) distribution centres and the responders also will choose the distribution centres for placing their demand in an earthquake situation for 45 days in India. The responders will choose distribution centre to order on the base of back-orders.

The following paragraph will compare the model results with the actual field situation. The field data are coming from the day by day briefing reports of the national and international agencies.

7.3.1 Case Study 1: Gujarat earthquake 2001: Bhachau city

The ABM is running for blankets, sanitation kits, kitchen kits and temporary shelter kits in the case study 1. Every time the coordinated version of the model is fulfilling the demand with fewer amounts of relief items. The following Table 7.1 demonstrates the difference between the model and the actual field situation for the blankets.

Table 7.1: Comparison of blankets distribution in Bhachau city with the actual field situation (Developed from the field report by researcher)

	Coordinated version of the ABM	**Actual field situation**
Average Blanket supplied	23706.67	30584
Demand fulfilment rate	100%	129% (oversupply)

This positively demonstrates the importance of the proposed ABM, which is reducing the oversupply during relief distribution time. The following Tables 7.2, 7.3, 7.4 are comparing the coordinated version of the model with the real field situation. Table 7.2 shows that in the actual field situation in Bhachau city there is 77% kitchen sets supplied, which is reported in the field data (day to day situation report by government of India and other NGOs), which shows the lack of control in relief distribution.

Table 7.2: Comparison of kitchen sets distribution in Bhachau city with the actual field situation (Developed from the field report by researcher)

	Coordinated version of the ABM	Actual field situation
Average kitchen sets supplied	6043	6567
Demand fulfilment rate	100%	77% (less supply)

Table 7.3: Comparison of sanitation kits distribution in Bhachau city with the actual field situation (Developed from the field report by researcher)

	Coordinated version of the ABM	Actual field situation
Average Blanket supplied	23706.67	24022
Demand fulfilment rate	100%	39% (less supply)

7.3.2 Case Study 2: Sikkim earthquake 2011: Mangan city

The situation was more challenging in the case study 2 due to the mountainous region and the weather situation. Sikkim information minister C B Karki said that "The biggest challenge now is to get rescue teams to the affected areas"(Amalendu Kundu & Caesar Mandal, 2011). The NDRF was waiting at the Gangtok city (capital of Sikkim) due to road blockage for 3 days and after that, the NDRF force moved towards Mangan the most affected area. The ABM runs for blankets, as this was the most demanding relief item in Mangan city. The following Table 7.5 demonstrates the difference between the model and the actual field situation for the woollen blankets.

Table 7.4: Comparison of woollen blankets distribution in Mangan city with the actual field situation (Developed from the field report by researcher)

	Coordinated version of the ABM	Actual field situation
Average Blanket supplied	4682	3900
Demand fulfilment rate	100%	83% (less supply)

The above results shows that because of less amount of blankets the 83% population (from the field report) can get the blankets, which tends to be 100% by proper resource sharing and information sharing among the agencies. The coordination (sharing of resources) needs to consider one step further than the proposed coordination activities in the previous earthquakes.

7.4 Discussion and findings

The above comparison with the actual field situation for Bhachau city and Mangan city demonstrates that the model can fulfil the demand with less amount of inventories. The main aim of this research is to show that there will be no wastage of relief and no oversupply. The filed reports and the governmental lesson learnt reports identify that there is some wastage of relief items in both the case studies. The comparison of the ABM result with the real field situation shows the drawbacks in previous earthquakes such as oversupply, unmet demand, wastage of relief items, shortages of relief items and these drawbacks are surely reducing the efficiency of Indian LMRD during an earthquake. This ABM can reduce the above ambiguities and provide an operative and well-organised LMRD system. The literature analysis chapter elaborates about the importance of LMRD as this is the last stage of emergency response management, therefore the success of the whole operation depends on the performance of LMRD, which is about the delivery of the right amount of demand, at the right time to the right place (Decker, 2013). Previous research on LMRD mainly concentrates on the vehicle routing and fleet management (Balcik et al., 2008, Das and Hanaoka, 2014, Martinez et al., 2011) to supply the relief items effectively to the affected community. This research extends a step further and simplifies the resource management problem during the field operation planning of relief distribution at the final level. The impact of this research is significant as it helps to comprehend the actual challenges in the LMRD for the improvement of the LMRD system by conducting interviews with the practitioners (who are actually taking part in the relief distribution operation). The researcher identifies some performance challenges, from the perspective of the decision-maker for LMRD planning. This research also identified some external factors that affect the LMRD performance measures. It is difficult to incorporate those factors into the LMRD system as most of those are not easy to quantify for the modelling perspective. The analysis of a semi-structured interview with Indian practitioners and the reports reveals that 'coordination' is the major operative factor for Indian LMRD. This investigation makes an effort to incorporate coordination in Indian LMRD to satisfy the demand of the affected community. This project would like to establish the objectives of LMRD "to save money and resources" (Decker, 2013).

The investigation of the coordination mechanism is considering resource sharing among the active agencies to minimise the cost and resources with fulfilling the demand. Here the coordination is represented as a coordination hub, which is working as a resource centre platform in the cloud and will facilitate the flow of information and resources to the active agencies and then the relief will go to the affected community. The involvement of government, international and local NGOs into coordination hub to share resources will increase the communication among stakeholders and hence coordination hub will increase knowledge sharing and facilitate better joint decision-making process. But it also needs to consider that individual agencies have different mandates, therefore the involved agencies can communicate to come out with a neutral code of mandates where every agency can work together and coordinate with each other. All the active agencies including governmental and international agencies should be unbiased. The active agencies need to do an exact evaluation of the disaster affected population, which will also reduce duplication of relief supply. An information management system is an additional challenge, which can reduce the efficiency of sharing resources among the agencies. There is a need for correct knowledge of the volunteers to execute the information effectively. The most important issue is trust among the active agencies for coordinating with each other during the field operation planning. The above issues also need to consider for more effective resources sharing during final relief distribution for coordination perspective.

7.5 Generalisability

Two case studies are validating the theoretical result of the NetLogo version of ABM for LMRD system. In terms of external validity, this research followed two earthquake case studies in India from the different geographical position, the different magnitude and different population density of affected community. The challenges of these two earthquakes response operations are different from each other. The analysis of these two different case studies are increasing the external validity of the findings. In addition, the ABM simulation approach is followed as an accepted methodology for the development of this thesis. The methodology and description provided in this work intensify the probability that another researcher ensures a similar methodology to encounter with the same results. Finally, these findings could not be supposed to hold accurate outside the LMRD system in India.

7.6 Chapter summary

This chapter compares the activities of two case studies. It is noticed that in the previous earthquake response operations and relief distribution operations the active agencies are facing problems due to lack of coordination, though the active agencies are constantly trying to incorporate the coordination dimension. The performance of the proposed ABM is analysed and compared with the actual field situation and the researcher concludes that the proposed coordinated version of the model can fulfil the demand with minimum levels of inventory. Hence, the model has proven to be cost-effective by maintaining acceptable levels of inventory. Finally, this chapter provides the discussion of the findings and clarifies the other factors which ought to be considered for resource sharing among the agencies during the LMRD field operation planning in India.

The next chapter is providing a judgement to answer all the research questions asked in the literature review chapter, and it also explains the limitations and contributions of this research to provide recommendations for the future work.

Chapter 8: Conclusion and Contribution

8.1 Introduction

Emergency logistics, primarily relief distribution, is a complex and challenging area. In LMRD many various agencies involved with different capacitates and logistical expertise. The decision maker is still facing problems such as oversupply, resource limitations and lack of field operation planning. This research incorporates the knowledge of LMRD by addressing the gap in the literature of relief distribution and identifying the practical factors, which are affecting the LMRD performance for the earthquake in the Indian context. Additionally, an ABM has been proposed, that integrates the active agents for LMRD in the Indian context. This chapter intends to explain the limitations of this research project with a recommendation of future work and finally, the researcher discussed the contribution made by this research for three main areas: theoretical, practical and methodological on LMRD.

8.2 Evaluation of research questions

The analysis of the literature identified the research questions that are discussed in this section. The research questions are as follows:

RQ1. What are the factors which affect the LMRD performance measures?
RQ2. Which of these factors had the biggest influence on the performance of LMRD in the Indian context?
RQ3. After incorporating the most influential factor in the LMRD model how it will affect the performance of LMRD in India?

The above research questions are identified by detailed literature review and theoretical analysis of the emergency logistics. The overall purpose is to provide guidelines for the relief agency decision maker to understand and identify the most influential factors, which has an impact on the final relief distribution operation. The complete methodology is aiming for answering the above three questions discussed in the previous chapters.

RQ1. What are the factors which affect the LMRD performance measures?

Question 1 is answered in chapter 4 by the semi-structured interviews with the field officers and responders, and also by analysis of the reports of the government and NGOs. The researcher identified that there are some performance measures, which are essential for a successful LMRD system such as minimise the time delay, maximise the coverage level, maximise the distance efficiency, maximise the demand served, maximise the allocation efficiency, maximise the cost efficiency, prioritisation of service efficiency and minimise the social, environmental and risk impact. There are some behavioural factors which affect those performance vectors such as coordination, trust, needs assessment, the involvement of local community member, knowledge of local area, culture role, correct knowledge and minimising the competing attitudes of the involved agencies. This research proposed a framework and demonstrated that how the factors are affecting the LMRD performance metrics. The result is validated by a theoretical gap analysis in the emergency logistics field using a behavioural operations management framework proposed by Bendoly et al. (2006).

> RQ2. Which of these factors had the biggest influence on the performance of LMRD in the Indian context?

The 2nd question is evaluated in chapter 4 by analysing interviews and reports from the Indian government and local NGOs practitioners and concluded that coordination is a major factor which affects the LMRD performance in India. According to the practitioners, coordination is necessary for terms of sharing resources, joint decision making, goal selection, risk sharing, mutual adjustment, proper communication among the agencies and knowledge sharing for the success of the LMRD operation.

> RQ3. After incorporating this essential factor in the LMRD model, how will it affect the performance of LMRD in India?

The 3rd and final question is examined by integrating coordination in Indian LMRD system in chapter 5 using of ABM simulation techniques and validated the theoretical results in chapter 6 with the two earthquake case studies in the Indian context. The case studies are selected to examine the reliability of the theoretical result. The results demonstrated that coordination can increase substantial cost efficiency for the involved active agencies during LMRD in India.

8.3 Contribution

The aim of this section is to describe the nature of the contribution of this research in relation to theory, method and practice.

8.3.1 Theoretical contribution

The contributions that have been made to the theory in the relief distribution area are as follows:

8.3.1.1 Introducing behavioural issues for LMRD

This research initially reviewed the literature of emergency logistics and identified the importance of LMRD. Balcik et al. (2008) analysed that there is a need for further analysis of LMRD problem to overcome the challenges of relief distribution. During the South Asian Tsunami of 2005, there were some factors, which delayed the whole emergency response operation, such as coordination, culturally sensitive assessment, information sharing, local leadership and lack of knowledge (Perry, 2006). The importance of swift trust is necessary to form networks as a means of improving relief operations in rapid onset disasters (Tatham and Kovács, 2010). Again during a high impact disaster coordination is important among all the active agencies, affected country's government and also the affected population to increase efficiency in relief distribution operation. Culture sensitive assessment is another important behavioural factor which needs to acknowledge during the prioritisation of correct relief items (e.g. food, cloths etc.). This research has concluded that the above factors collectively influence the operational decisions in LMRD system. The researcher adopted a behavioural operations framework in the emergency logistics area to identify the characteristics of the above factors (Bendoly et al., 2006). The researcher concludes that the correct analysis of the above factors have a positive impact on the LMRD performance; therefore, the significant contribution of this research is establishing the importance of behavioural factors in LMRD system.

8.3.1.2 Importance of coordination in Indian LMRD

Coordination has sustained to be the essential weakness of the humanitarian action (Rey, 2001). The above statement remained true up to 2013 as Michael Decker explains all the problems and challenges could be overcome by improving coordination among relief actors, but this is still missing for most objectives (Decker, 2013). Coordination has a major impact in emergency response management. It is necessary for the following five clusters: task flow, resources, information, decision and responders (Chen et al., 2008). Essentially for relief operations, there are some coordination mechanisms and supports that are necessary. For example plan of mutual aid, centralised information system, joint decision making, efficient resource sharing among personnel, integration of local and external activities (Chen et al., 2008). According to Indian practitioner's judgment, the following three factors are the major factors which affect the LMRD performance:

- Coordination among the agencies (prioritisation the task, goal selection, risk sharing, mutual adjustment, proper communication among the agencies);
- Collaboration and sharing resources among the participating agencies in the field (multi-source information, mutual aid);

- Coordinated (Joint) decision making for relief distribution (knowledge sharing, protocol sharing, joint decision structuring and analysing);

In the Indian context coordination is primarily essential for having a clear communication among the active agencies. For example if all the active agencies used multi source information, mutual collaboration, sharing aids and finally joint decision making will increase the success of relief distribution operation and reduce the live losses. The assessment of the presented coordination objective from the Indian practitioners are consistent with the general coordination objective presented by Chen et al. (2008), which identifies the importance of coordination is a serious issue in the developing country like India. The findings of this research clarified that integrating coordination in the LMRD system in India can significantly reduce cost. The analysis of the findings supports that there is further potential for incorporating coordination for the strategic and tactical decision making planning for relief distribution.

8.3.2 Methodological contribution

Conceptual analysis and combined method are the advancements of OR techniques in disaster management (Galindo and Batta, 2013). Conceptual analysis is the replications on a field of DOM and it deprived the application of any analytical technique (Galindo and Batta, 2013), whereas combined method is using the advantage of more than one method to overcome the challenges in DOM field (Galindo and Batta, 2013). In the literature review chapter, it is established that in the emergency logistics literature use of the above two techniques increases gradually to solve logistical problems during an emergency relief distribution. This research followed a combined method comprising conceptual analysis and ABM simulation to analyse the LMRD problem. Markus Schwaninger argued about combining two methodologies and made a claim that the necessary methodological progress could only be accomplished on the ground of scientific rigour. This postulate that 'rigour' is not to be confused with a reassurance of 'rigidity'. The necessary methodological principles encouraged here are controlled thinking, a permanent quest for better models (i.e. thorough validation), and the maximum achievable levels of transparency in the formalisations as well as of the fundamental expectations and sources used. Scientific rigor, in this context, also suggests that the combination of methodologies reach beyond merely eclectic add-ons from different methodologies, so that genuine integration towards better adequacy to the issues at hand is achieved (Schwaninger, 2006). In this context, the conceptual analysis technique used to recognise and analyse the actual practical challenges for LMRD in India and that led the modeller to think about a better model by incorporating those challenges into NetLogo version of the ABM in the Indian context. All the agents in the model are based on the practice of LMRD in the Indian context with a significant validation and verification analysis. The originality of this methodology is introducing ABM for Indian LMRD for integrating coordination aspect, which is a new area of application. This research has used a combination of techniques to integrate genuine input into the LMRD system. This is the novelty of the methodology as per researcher's knowledge there is none of the research combined ABM and conceptual analysis particularly in Indian context for LMRD system, which is considered a new area of application.

8.3.3 Practical contribution

This research is based on the LMRD problem, which is the final stage of relief distribution. This is the most challenging situation for the decision makers to identify the exact amount of relief and supply the relief items operatively to all the affected region as this is initiated by the randomness that is given for a disaster relief last mile distribution system (Decker, 2013). The focus of this research is very practical and therefore there are a number of contributions have been made in the practice. The clarification of contributions is as follows:

8.3.3.1 Development of an initial framework for the performance metrics of LMRD

A framework (Table 4.3 and Figure 4.2) is developed to indicate the interaction between the performance measures and the influential factors in LMRD. The researcher would claim that the decision makers need to consider that relationship between the performance measures and the influential factors for LMRD before doing any strategic and tactical decision. Finally, the insight of the effect of those factors into LMRD will reduce the risks and limitations for better decision making process during relief distribution.

8.3.3.2 Importance of coordination in LMRD in India

Decker (2013) explains that in the 1990s relief organisations understood that multi-agency cooperation is significantly important for achieve their common objective, which is relief aid distribution. In addition to the above statement, this research identifies the most influential factor (coordination) for Indian LMRD for an earthquake. This research introduced sharing resources among the active relief agencies in India during LMRD and demonstrated the potential for demand fulfilment and significant impact on cost efficiency. This research also evaluates the different form of coordination between agencies for the better improvement of LMRD operation. This influences the relief agencies to collaborate more in terms of resources, knowledge and information for operative relief proficiency.

8.3.3.3 Field consideration in India during LMRD

In the Indian context, this research conducted a thorough conceptual analysis and established an outline, which will be used as a planner of LMRD before decision-making process in India. The evidence of the conceptual framework are evolving from the interviewees of India and finally the framework is tested by two NGOs of India. The researcher concentrates on the three clusters: resource, information and distribution and identifies the recommended decisions need to contemplate before the LMRD decision making process in the Indian context. Among the recommended decisions some of them are already identified by Chen et al. (2008) for coordination of emergency response management. The following Table 8.1 explains the framework:

Table 8.1: The recommended consideration for Indian LMRD (Developed by the researcher)

Decisions	Recommended consideration	Recommended implementation
Resource	**Safety and security:** During a disaster, the affected community is in a critical condition. First, there is a need of enough protection for the affected community (e.g. for young girl and women and children) as well as need sufficient protection for relief material which will reduce the looting. **Political environment:** The decision maker and the responders should not be politically biased. **Cultural requirements:** Regional and religious restrictions regarding food, clothes that can be consumed. **Mutual aid:** Sharing resources among the agencies need to consider. **Usage priority scheme:** Need to prioritise the relief items according to the need of the affected community. **Resource standardisation:** Need to standardise the relief items. **Potential to manage the relief from the donors:** Adequate and effective plan for managing the enormous quantities of relief which will come from the donors.	**Safety and security:** During a disaster, there is a continuous need of sufficient police and military personnel for overall protection for the community as well as the relief materials and volunteers. **Political environment:** The decision maker and the responders should be a civil servant not the political leader and they (the civil servants) should not be politically and religiously biased. **Cultural requirements:** The government of India has all the country's census report, where it is clearly identified about the religion and region information about the community. The resource management during a disaster should consult with that report for appropriate identification of exact relief items. **Mutual aid:** A mutual aid policy during emergency situation need to be considered. **Usage priority scheme:** The prioritisation strategy and protocol for supplying the most demanded relief items need to be considered after the analysis of the needs assessment. **Resource standardisation:** Joint procurement strategy is necessary for the standardisation of relief items.

Table 8.1 Continued....

Decisions	Recommended consideration	Recommended implementation
	Potential to minimise the relief material loss during the transition: During the mobilisation of relief materials need security.	**Potential to manage the relief from the donors:** There should be a separate warehouse, where all the donated resources will be facilitated, separated and packed for the final relief distribution. There should be a clear and effective strategy to managing the enormous quantities of relief which will come from the donors. **Potential to minimise the relief material loss during the transition:** During the relief mobilisation, there is a need for sufficient police and military personnel.
Information	**Information exchange:** The international, national and local NGOs, Government and other involved agencies need to share information for better understanding of the affected situation **Multi-source information:** Not only need assessment analysis of the individual agency but also there are some other sources of information, for example, media, social network, satellite information (GIS) etc. need to be integrated for the better information of the affected region. **Face-to-face communication among the responders:** It is necessary to have a proper communication (risk sharing, normal	**Information exchange:** There should be a policy to share information between the involved agencies and the host country's government. Social media is a reliable platform but should be used very carefully, as this platform can be manipulated easily. **Multi-source information:** There should be a list or summary for the recommended and reliable source of information, which will be the collective effort by the government, national and international NGOs. **Face-to-face communication among the responders:** There should be some programme about knowledge sharing, risk sharing and normal meeting among the different agency's responders for a successful relief operation process.

Table 8.1 Continued....

Decisions	Recommended consideration	Recommended implementation
	meeting, and knowledge sharing, mutual adjustment) among the different agencies responders for reliable information. **Integrated information operational guideline:** There is a need to identify the generic operational protocol for the collected information. **Communication with the affected community:** Affected community is another source of information, who can clarify about the most affected neighbourhood.	**Integrated information operational guideline:** Though Indian government have a generic operational protocol for individual disaster, that guidelines should be amendable according to the lesson learned. **Communication with the affected community:** There should be some programme about the clear communication with the affected community for an adequate information.
Distribution	**Communication plan with the local population and local authority:** Share knowledge about the distribution process with the affected community members. **Safety and security:** The relief distribution authority need to provide enough security to the affected community after receiving the relief material. The safety and security are also essential for the relief personnel and the relief items. **The time required for distribution:** Need to analyse and provide proper time to distribution and hand out the relief material and avoid a chaotic situation. Night disaster can delay the response until next morning.	**Communication plan with the local population and local authority:** There should be some procedure for the agencies to systematically communicate with the affected community. **Safety and security:** For the whole relief distribution operation there should be appropriate military and police personnel. **The time required for distribution:** There is a necessity of strong guidelines about the exact timing for the distribution process. **Strong control mechanism during the distribution:** No political and religious bias will increase the equality and fairness of relief distribution. Need to integrate clear ethical considerations for the fairness of relief distribution.

Table 8.1 Continued....

Decisions	Recommended consideration	Recommended implementation
	Strong control mechanism during the distribution: Need to make sure a fair relief distribution among the affected community (e.g. need to minimise oversupply, less supply). **Enough volunteers:** To supply and manage the whole relief distribution process need enough volunteers (e.g. responders, governmental bodies and so on) **Managing responders:** Clear communication among the responders. Training will be provided if necessary for the responders. Reducing multi-agency conflict among the responders which is arising due to cultural differences, language barrier, and politically sensitive issues.	**Enough volunteers:** There should be satisfactory consideration about the number of skilled and non-skilled volunteers. And also correct analysis of a number of volunteers. **Managing responders:** Before the relief distribution procedure there should be some common programmes (e.g. meetings and training) for the all active agency's volunteers to consider the fairness of the relief distribution.

8.4 Limitations of this research

Appropriate actions are taken to mitigate the drawbacks of this research project but it is impossible to avoid all the limiting factors. The important limitations are described and clarified below.

In the proposed framework for the identified factors which affect the LMRD performance measures, only coordination is integrated into the LMRD system but there are other important factors such as needs assessments, the involvement of local community member, trust and so on. This research is based on Indian context; therefore, this research is only concentrated on coordination as from the Indian practitioner's perspective this is the major factor, which affect the performance of the Indian LMRD system. But for better performance of the overall LMRD system all the other responsible factors should be integrated, which demonstrates the effect of those factors into the LMRD system and it limits the assessment perspective of the overall LMRD system. However, the gap analysis of the emergency logistics literature with a behavioural operations research framework clarifies the validation of the individual factors for LMRD system.

Additionally, this research is only considering a limited number of cases for the validation perspective. Additional cases would undoubtedly lead to an advanced level of assurance in the generalisability of the outcomes. In both of the case studies, the researcher considers only one city. Unfortunately, the experimentation of the model is done with two specific cities (for two case studies) not for a whole district or for the whole state, therefore it is concluded that this model can be prohibitive for a large-scale condition.

Furthermore another limitation is that this research is unable to provide the raw data analysis reports and documents from government and NGOs for the comparison of the model data with the real field data due to intellectual property and ethical issues.

Finally, this research only proposed the concept of the coordination hub, which is the limitation. The researcher clarifies with proper findings that the coordination hub concept will increase the effectiveness of LMRD system in the Indian context as a result of cost and resource efficiency.

8.5 Future research

There are a number of areas where the further research can be conducted based on the finding of this research project. This section will summarise the proposed areas for future research.

8.5.1 Further development of the framework

The other factors are: trust, needs assessment, culture role, competing for the attitude of the active agencies and so on, which affect the LMRD performance measures in the proposed framework. These can be integrated into the LMRD system to identify the effectiveness, into the overall LMRD performance, that can extend the decision-making process to be more operative.

8.5.2 Further analysis of behavioural issues in the emergency logistics area

During disaster various stakeholders involved. For example government, NGOs, international aids, private sectors, affected population and many others. There are various behavioural issues (coordination, trust, culture, knowledge sharing and others) can affect the efficiency of the whole disaster management system. For the future development of emergency logistics, a comprehensive research is necessary considering the behavioural issues.

8.5.3 Further analysis of needs assessment

Needs assessment is a vital step of relief distribution. Correct needs assessment procedures and analysis of those data have a significant impact on the success rate of relief distribution. Therefore, there is a necessity to understand and consider advanced research in needs assessment protocols and identify a common platform or procedures, which could be adopted by all the government and NGOs.

8.5.4 Other disaster and country domain

This research is only concentrated on the earthquake in India. It would be interesting to test the findings for other disasters and for other countries.

8.5.5 Develop the model for the large scale condition

Further development of this NetLogo version of the ABM for LMRD can be done for large-scale conditions where one district (where several cities and villages will be included) or one state (where several districts will be included) can be considered.

8.5.6 The Working procedure of coordination hub

This thesis is only considering the concept of coordination hub. This concept of coordination hub is not a physical building but a cloud platform. In a further development of the working procedure of coordination, the hub will be extended and elaborated. Finally, further consideration is necessary to identify the proper information and resource flow in the coordination hub for the operative LMRD system in India.

The following section is now describing the contribution of this research project in theory and practice.

8.6 Thesis conclusion

Combining ABM with conceptual analysis provides a suitable modelling framework for LMRD system in India. The contribution of this thesis is categorised and clarified into three parts: theoretical, methodological and practical contribution. Additionally, in the practical contribution section, this chapter concluded with a recommended consideration, which will assist the decision maker in India for better and integrated decision-making process for the LMRD. This thesis advocates the use of an Agent-Based Modelling (ABM) approach to further strengthening inter-agency coordination for the LMRD system.

8.7 Reflection on the PHD process

The researcher was working as a graduate teaching assistant in the Aston University from October 2010 till the end of September 2015 and was also doing PHD. The researcher understands that PHD is a learning process and as time followed the researcher recognised the PHD process gradually.

The RMC was the underpinning of the PHD process. The feedback from faculty members and lecturers was inspiring. The qualifying reports and the viva exams provided an opportunity to improve the self-confidence level and confidence on the research, which is essential for a PHD research student. Not only the RMC course provided by the Aston University but also the researcher attended skill development courses in NATCOR, Case study research methodology workshop in Birmingham University and attended the summer school for ISCRAM. The researcher started conducting interviews from the ISCRAM Summer School, where she got the opportunity to meet the practitioners who are involved in the response operation for the natural disasters. The seminar conducted by the Aston Business School with academics and practitioners provided inputs of the critical thinking for this research project.

The experience of writing the conference papers for ICMR, YOUNG OR (18, 19), OR 56, APMOD conference on the PHD models, was building the writing skills. The guidance of Dr Pavel Albores and Dr Christopher Brewster was a learning experience for enlightening the research's writing skills.

The initial stage for contacting the practitioners from various organisations from different countries (whom I met at the ISCRAM Summer School) and Indian Governmental organisations, NGOs, Red Cross, and UN for the interview purposes was a very rigorous stage and completely new experience to the researcher.

8.8 The learning process

How to conduct research is a very interesting task, mainly for who are new to the business environment. When a researcher has a thorough knowledge of the literature and the subject theme, gradually the level of confidence starts to develop. The justified confidence level is important and in this area, the researcher needed to develop the confidence level to have a position to form an opinion that is supported by a rigorous research.

Other essential lessons learnt were the significance of writing the research opinion from the beginning of the research project.

8.9 Conclusion

This section has framed some reflection of the PHD research process and the learning outcome. Inclusively the process of completing a PHD has been enormously worthwhile and inspiring.

References

ADAMIDES, E. D., PAPACHRISTOS, G. & POMONIS, N. 2012. Critical realism in supply chain research: Understanding the dynamics of a seasonal goods supply chain. International Journal of Physical Distribution & Logistics Management, 42, 906-930.

ADIDA, E., DELAURENTIS, P.-C. C. & LAWLEY, M. A. 2011. Hospital stockpiling for disaster planning. IIE Transactions, 43, 348-362.

ADIVAR, B. & MERT, A. 2010. International disaster relief planning with fuzzy credibility. Fuzzy Optimization and Decision Making, 9, 413-433.

AFANDIZADEH, S., JAHANGIRI, A. & KALANTARI, N. 2013. Identifying the optimal configuration of one-way and two-way streets for contraflow operation during an emergency evacuation. Natural hazards, 69, 1315-1334.

AFFAIRS, U. N. O. F. T. C. O. H. 2011. Sikkim Earthquake India Situation Report No. 3 Relief web: United Nations.

AFSHAR, A. & HAGHANI, A. 2012. Modeling integrated supply chain logistics in real-time large-scale disaster relief operations. Socio-Economic Planning Sciences, 46, 327-338.

AFSHAR, A., RASEKH, A. & AFSHAR, M. H. 2009. Risk-based optimization of large flood-diversion systems using genetic algorithms. Engineering Optimization, 41, 259-273.

AKKIHAL, A. R. 2006. Inventory pre-positioning for humanitarian operations. (Doctoral dissertation) Massachusetts Institute of Technology.

ALBORES, P., RODRIGUEZ, O. & ROY, P. 2013. Operational Research: Key for Successful Disaster Management. Keynote Papers and Extended Abstracts, 47.

ALÇADA-ALMEIDA, L., TRALHAO, L., SANTOS, L. & COUTINHO-RODRIGUES, J. 2009. A multiobjective approach to locate emergency shelters and identify evacuation routes in urban areas. Geographical analysis, 41, 9-29.

ALEXANDER, D. 1997. The study of natural disasters, 1977–97: some reflections on a changing field of knowledge. Disasters, 21, 284-304.

ALEXANDER, D. 2002. Principles of emergency planning and management, England, Oxford University Press New York.

ALTAY, N. 2012. Capability-based resource allocation for effective disaster response. IMA Journal of Management Mathematics, 24, 253-266.

ALTAY, N. & GREEN, W. G. 2006. OR/MS research in disaster operations management. European journal of operational research, 175, 475-493.

ALTAY, N. & PAL, R. 2014. Information Diffusion among Agents: Implications for Humanitarian Operations. Production and Operations Management, 23, 1015-1027.

AMALENDU KUNDU & CAESAR MANDAL, T. 2011. Earthquake toll 74 as rain, slides hamper rescue. Times of India, 20.09.11

APTE, A. 2010. Humanitarian logistics: A new field of research and action. Foundations and Trends® in Technology, Information and Operations Management, 3, 1-100.

ARDA, Y. 2004. A two-stage stochastic programming framework for transportation planning in disaster response. Journal of the operational research society, 55, 43-53.

ARORA, H., RAGHU, T. & VINZE, A. 2010. Resource allocation for demand surge mitigation during disaster response. Decision Support Systems, 50, 304-315.

BALCIK, B. & BEAMON, B. M. 2008. Facility location in humanitarian relief. International Journal of Logistics, 11, 101-121.

BALCIK, B., BEAMON, B. M., KREJCI, C. C., MURAMATSU, K. M. & RAMIREZ, M. 2010. Coordination in humanitarian relief chains: Practices, challenges and opportunities. International Journal of Production Economics, 126, 22-34.

BALCIK, B., BEAMON, B. M. & SMILOWITZ, K. 2008. Last mile distribution in humanitarian relief. Journal of Intelligent Transportation Systems, 12, 51-63.

BALL, P. Introduction to discrete event simulation. Proceedings of the 2nd DYCOMANS workshop on Management and Control: Tools in Action, 1996.

BANOMYONG, R. & SOPADANG, A. 2010. Using Monte Carlo simulation to refine emergency logistics response models: a case study. International Journal of Physical Distribution & Logistics Management, 40, 709-721.

BARBAROSO & GCARON, G. 2004. A two-stage stochastic programming framework for transportation planning in disaster response. Journal of the Operational Research Society, 55, 43-53.

BARBAROSOĞLU, G., ÖZDAMAR, L. & CEVIK, A. 2002. An interactive approach for hierarchical analysis of helicopter logistics in disaster relief operations. European Journal of Operational Research, 140, 118-133.

BATTINI, D., PERETTI, U., PERSONA, A. & SGARBOSSA, F. 2014. Application of humanitarian last mile distribution model. Journal of Humanitarian Logistics and Supply Chain Management, 4, 131-148.

BEAMON, B. M. Humanitarian relief chains: issues and challenges. 2004. 14-15.

BEAMON, B. M. & BALCIK, B. 2008. Performance measurement in humanitarian relief chains. International Journal of Public Sector Management, 21, 4-25.

BEAMON, B. M. & KOTLEBA, S. A. 2006. Inventory management support systems for emergency humanitarian relief operations in South Sudan. International Journal of Logistics Management, 17, 187-212.

BEMLEY, J. L., DAVIS, L. B. & BROCK III, L. G. 2013. Pre-positioning commodities to repair maritime navigational aids. Journal of Humanitarian Logistics and Supply Chain Management, 3, 65-89.

BENDOLY, E. 2006. Incorporating behavioral theory in OM empirical models. Journal of Operations Management, 24, 735-736.

BENDOLY, E., CROSON, R., GONCALVES, P. & SCHULTZ, K. 2010. Bodies of knowledge for research in behavioral operations. Production and Operations Management, 19, 434-452.

BENDOLY, E., DONOHUE, K. & SCHULTZ, K. L. 2006. Behavior in operations management: Assessing recent findings and revisiting old assumptions. Journal of Operations Management, 24, 737-752.

BERESFORD, A. K. C. & BAYASUF, F. 2008. Distribution of humanitarian aid in east africa, post Rwandan civil war.

BERKOUNE, D., RENAUD, J., REKIK, M. & RUIZ, A. 2012. Transportation in disaster response operations. Socio-Economic Planning Sciences, 46, 23-32.

BERMAN, O., DREZNER, T., DREZNER, Z. & WESOLOWSKY, G. 2009. A defensive maximal covering problem on a network. International Transactions in Operational Research, 16, 69-86.

BERMAN, O., HAJIZADEH, I. & KRASS, D. 2013. The maximum covering problem with travel time uncertainty. IIE Transactions, 45, 81-96.

BHANDARI, R. 2006. Disaster management in India, a new awakening. J Disas Dev, 1, 1-26.

BILHAM, R. 2010. Lessons from the Haiti earthquake. Nature, 463, 878-879.

BISH, D. R. & SHERALI, H. D. 2013. Aggregate-level demand management in evacuation planning. European Journal of Operational Research, 224, 79-92.

BONABEAU, E. 2002. Agent-based modeling: Methods and techniques for simulating human systems. Proceedings of the National Academy of Sciences, 99, 7280-7287.

BOUDREAU, J., HOPP, W., MCCLAIN, J. O. & THOMAS, L. J. 2003. On the interface between operations and human resources management. Manufacturing & Service Operations Management, 5, 179-202.

BOZKURT, M. & DURAN, S. 2012. Effects of natural disaster trends: a case study for expanding the pre-positioning network of CARE International. International journal of environmental research and public health, 9, 2863-2874.

BOZORGI-AMIRI, A., JABALAMELI, M. & AL-E-HASHEM, S. M. 2013. A multi-objective robust stochastic programming model for disaster relief logistics under uncertainty. OR spectrum, 35, 905-933.

BOZORGI-AMIRI, A., JABALAMELI, M. S., ALINAGHIAN, M. & HEYDARI, M. 2012. A modified particle swarm optimization for disaster relief logistics under uncertain environment. The International Journal of Advanced Manufacturing Technology, 60, 357-371.

BRAUN, V. & CLARKE, V. 2006. Using thematic analysis in psychology. Qualitative research in psychology, 3, 77-101.

BROOKS, R. J. & ROBINSON, S. 2001. Simulation and Inventory Control (Texts in Operational Research), Palgrave Macmillan.

BROWN, G. G. & VASSILIOU, A. L. 1993. Optimizing disaster relief: real-time operational and tactical decision support. DTIC Document.

BRYMAN, A. & BELL, E. 2015. Business research methods, Oxford university press.

CAMPBELL, A. M. & JONES, P. C. 2011. Prepositioning supplies in preparation for disasters. European Journal of Operational Research, 209, 156-165.

CAUNHYE, A. M., NIE, X. & POKHAREL, S. 2012. Optimization models in emergency logistics: A literature review. Socio-Economic Planning Sciences, 46, 4-13.

CHANG, F.-S., WU, J.-S., LEE, C.-N. & SHEN, H.-C. 2014. Greedy-search-based multi-objective genetic algorithm for emergency logistics scheduling. Expert Systems with Applications, 41, 2947-2956.

CHANG, M.-S., TSENG, Y.-L. & CHEN, J.-W. 2007. A scenario planning approach for the flood emergency logistics preparation problem under uncertainty. Transportation Research Part E: Logistics and Transportation Review, 43, 737-754.

CHANG, S. E. & NOJIMA, N. 2001. Measuring post-disaster transportation system performance: the 1995 Kobe earthquake in comparative perspective. Transportation research part A: policy and practice, 35, 475-494.

CHANTA, S. & SANGSAWANG, O. 2012. Shelter-site selection during flood disaster. Lecture Notes in Management Science, 4, 282-288.

CHARITIES, B. 2012. Gujarat Earthquake rehabilitation and relief work report.

CHATTERJEE, A., GUPTA, D. & JAIN, N. 2010. Coordination of Disaster Response:Potential and Challenges from Indian Experiences. Knowledge community on children in India.

CHEN, L. & MILLER-HOOKS, E. 2012. Optimal team deployment in urban search and rescue. Transportation Research Part B: Methodological, 46, 984-999.

CHEN, M., CHEN, L. & MILLER-HOOKS, E. 2007. Traffic signal timing for urban evacuation. Journal of urban planning and development, 133, 30-42.

CHEN, R., SHARMAN, R., RAO, H. R. & UPADHYAYA, S. J. 2008. Coordination in emergency response management. Communications of the ACM, 51, 66-73.

CHEN, Z., CHEN, X., LI, Q. & CHEN, J. 2013. The temporal hierarchy of shelters: a hierarchical location model for earthquake-shelter planning. International Journal of Geographical Information Science, 27, 1612-1630.

CHIU, Y.-C. & ZHENG, H. 2007. Real-time mobilization decisions for multi-priority emergency response resources and evacuation groups: Model formulation and solution. Transportation Research Part E: Logistics and Transportation Review, 43, 710-736.

CHOPRA, S. & MEINDL, P. 2007. Supply chain management. Strategy, planning & operation, Springer.

CHRISTOPHER, M. & TATHAM, P. 2014. Humanitarian logistics: Meeting the challenge of preparing for and responding to disasters, Kogan Page Publishers.

CHUDAK, F. A. & SHMOYS, D. B. 2003. Improved approximation algorithms for the uncapacitated facility location problem. SIAM Journal on Computing, 33, 1-25.

CLAY WHYBARK, D. 2007. Issues in managing disaster relief inventories. International Journal of Production Economics, 108, 228-235.

COBURN, A. & SPENCE, R. 2003. Earthquake protection, John Wiley & Sons.

COMFORT, L. K., KO, K. & ZAGORECKI, A. 2004. Coordination in rapidly evolving disaster response systems the role of information. American Behavioral Scientist, 48, 295-313.

CORNUÉJOLS, G., NEMHAUSER, G. L. & WOLSEY, L. A. 1983. The uncapacitated facility location problem. DTIC Document.

COUTINHO-RODRIGUES, J., TRALHÃO, L. & ALÇADA-ALMEIDA, L. 2012. Solving a location-routing problem with a multiobjective approach: the design of urban evacuation plans. Journal of Transport Geography, 22, 206-218.

CRET, L., YAMAZAKI, F., NAGATA, S. & KATAYAMA, T. 1993. Earthquake damage estimation and decision analysis for emergency shut-off of city gas networks using fuzzy set theory. Structural safety, 12, 1-19.

CROOKS, A. T. & WISE, S. 2013. GIS and agent-based models for humanitarian assistance. Computers, Environment and Urban Systems, 41, 100-111.

CROSON, R., SCHULTZ, K., SIEMSEN, E. & YEO, M. 2013. Behavioral operations: the state of the field. Journal of Operations Management, 31, 1-5.

CUI, T., OUYANG, Y. & SHEN, Z.-J. M. 2010. Reliable facility location design under the risk of disruptions. Operations research, 58, 998-1011.

CURNIN, S., OWEN, C., PATON, D., TRIST, C. & PARSONS, D. 2015. Role Clarity, Swift Trust and Multi-Agency Coordination. Journal of Contingencies and Crisis Management, 23, 29-35.

DALAL, J., MOHAPATRA, P. K. & MITRA, G. C. 2007. Locating cyclone shelters: a case. Disaster Prevention and Management: An International Journal, 16, 235-244.

DARCY, J. & HOFMANN, C.-A. 2003. Humanitarian needs assessment and decision-making, HPG.

DAS, R. & HANAOKA, S. 2014. An agent-based model for resource allocation during relief distribution. Journal of Humanitarian Logistics and Supply Chain Management, 4, 265-285.

DAVID, N., CALDAS, J. C. & COELHO, H. 2010. Epistemological perspectives on simulation III. Journal of Artificial Societies and Social Simulation, 13, 14.

DAVIDSON, A. L. 2006. Key performance indicators in humanitarian logistics. (Doctoral dissertation) Massachusetts Institute of Technology.

DAVIDSSON, P. 2001. Multi agent based simulation: beyond social simulation, Springer.

DAVIS, L. B., SAMANLIOGLU, F., QU, X. & ROOT, S. 2013. Inventory planning and coordination in disaster relief efforts. International Journal of Production Economics, 141, 561-573.

DAYA KAUL, M. & AYAZ, L. S. 2009. Disaster Management In India.

DE ANGELIS, V., MECOLI, M., NIKOI, C. & STORCHI, G. 2007. Multiperiod integrated routing and scheduling of World Food Programme cargo planes in Angola. Computers & Operations Research, 34, 1601-1615.

DE VERICOURT, F., JAIN, K., BEARDEN, J. N. & FILIPOWICZ, A. 2013. Sex, risk and the newsvendor. Journal of Operations Management, 31, 86-92.

DECKER, M. 2013. Last Mile Logistics for Disaster Relief Supply Chain Management: Challenges and Opportunities for Humanitarian Aid and Emergency Relief, Anchor Academic Publishing (aap_verlag).

DEKLE, J., LAVIERI, M. S., MARTIN, E., EMIR-FARINAS, H. & FRANCIS, R. L. 2005. A Florida county locates disaster recovery centers. Interfaces, 35, 133-139.

DOEBELIN, E. 1998. System dynamics: Modeling, analysis, simulation, design, CRC Press.

DOERNER, K. F., GUTJAHR, W. J. & NOLZ, P. C. 2009. Multi-criteria location planning for public facilities in tsunami-prone coastal areas. Or Spectrum, 31, 651-678.

DÖYEN, A., ARAS, N. & BARBAROSOĞLU, G. 2012. A two-echelon stochastic facility location model for humanitarian relief logistics. Optimization Letters, 6, 1123-1145.

DRABEK, T. E. & HOETMER, G. J. 1991. Emergency management: Principles and practice for local government, International city management association Washington, DC.

DRABEK, T. E. & MCENTIRE, D. A. 2003. Emergent phenomena and the sociology of disaster: lessons, trends and opportunities from the research literature. Disaster Prevention and Management: An International Journal, 12, 97-112.

DROGOUL, A., VANBERGUE, D. & MEURISSE, T. 2003. Multi-agent based simulation: Where are the agents? Multi-agent-based simulation II. Springer.

DURAN, S., GUTIERREZ, M. A. & KESKINOCAK, P. 2011. Pre-positioning of emergency items for CARE international. Interfaces, 41, 223-237.

EASTERBY-SMITH, M., THORPE, R. & JACKSON, P. R. 2008. Management research, Sage.

EASTERBY-SMITH, M., THORPE, R. & JACKSON, P. R. 2012. Management research, Sage.

EBERHARD, M. O., BALDRIDGE, S., MARSHALL, J., MOONEY, W. & RIX, G. J. 2010. The MW 7.0 Haiti earthquake of January 12, 2010: USGS/EERI advance reconnaissance team report. US Geological Survey Open-File Report, 1048, 58.

EDRISSI, A., POORZAHEDY, H., NASSIRI, H. & NOURINEJAD, M. 2013. A multi-agent optimization formulation of earthquake disaster prevention and management. European Journal of Operational Research, 229, 261-275.

EHRING, T., RAZIK, S. & EMMELKAMP, P. M. 2011. Prevalence and predictors of posttraumatic stress disorder, anxiety, depression, and burnout in Pakistani earthquake recovery workers. Psychiatry research, 185, 161-166.

EIDINGER, J. 2001a. Gujarat (Kutch) India Earthquake of January 26, 2001, Lifeline Performance. TCLEE Monograph, 19.

EIDINGER, J. M. 2001b .Gujarat (Kutch) India M7. 7 earthquake of January 26, 2001 and Napa M5. 2 earthquake of Sept. 3, 2000.. ASCE.

EISENHARDT, K. M. 1989. Building theories from case study research. Academy of management review, 14, 532-550.

EL-ANWAR, O., EL-RAYES, K. & ELNASHAI, A. 2009. Maximizing temporary housing safety after natural disasters. Journal of Infrastructure Systems, 16, 138-148.

ELDER, M. D. 1992. Visual interactive modelling: some guidelines for its implementation and some aspects of its potential impact on operational research. University of Strathclyde.

EM-DAT. The International Disaster Database: Centre for research of the epidemiology of disasters- CRED [Online]. [Accessed 17/11/ 2015].

EMDAT 2016. The International Disaster Database. Centre for Research on the Epidemiology of DIsasters.

ERGUN, Ö., GUI, L., HEIER STAMM, J. L., KESKINOCAK, P. & SWANN, J. 2014. Improving humanitarian operations through technology-enabled collaboration. Production and Operations Management, 23, 1002-1014.

ERTEM, M. A., BUYURGAN, N. & ROSSETTI, M. D. 2010. Multiple-buyer procurement auctions framework for humanitarian supply chain management. International Journal of Physical Distribution & Logistics Management, 40, 202-227.

FALASCA, M. & ZOBEL, C. W. 2011. A two-stage procurement model for humanitarian relief supply chains. Journal of Humanitarian Logistics and Supply Chain Management, 1, 151-169.

FERRIS, E. 2010. Earthquakes and floods: comparing Haiti and Pakistan. Brookings Institution, 26.

FIEDRICH, F., GEHBAUER, F. & RICKERS, U. 2000. Optimized resource allocation for emergency response after earthquake disasters. Safety Science, 35, 41-57.

FINK, A. 2013. Conducting research literature reviews: from the Internet to paper, Sage Publications.

FISHMAN, G. S. 1978. Principles of discrete event simulation, Wiley.

FORRESTER, J. W. 1958. Industrial dynamics: a major breakthrough for decision makers. Harvard business review, 36, 37-66.

FORRESTER, J. W. 1995. The beginning of system dynamics. McKinsey Quarterly, 4-17.

GALINDO, G. & BATTA, R. 2013. Review of recent developments in OR/MS research in disaster operations management. European Journal of Operational Research, 230, 201-211.

GEVAERS, R., VAN DE VOORDE, E. & VANELSLANDER, T. 2011. Characteristics and typology of last-mile logistics from an innovation perspective in an urban context. City distribution and urban freight transport: multiples perspectives, 56-71.

GILBERT, G. N. 2008. Agent-based models, Sage.

GINO, F. & PISANO, G. 2008. Toward a theory of behavioral operations. Manufacturing & Service Operations Management, 10, 676-691.

GLEICK, J. 1997. Chaos: Making a new science, Random House.

GLENN RICHEY JR, R., KOVÁCS, G. & SPENS, K. 2009. Identifying challenges in humanitarian logistics. International Journal of Physical Distribution & Logistics Management, 39, 506-528.

GONG, Q. & BATTA, R. 2007. Allocation and reallocation of ambulances to casualty clusters in a disaster relief operation. IIE Transactions, 39, 27-39.

GÖRMEZ, N., KÖKSALAN, M. & SALMAN, F. 2011. Locating disaster response facilities in Istanbul. Journal of the Operational Research Society, 62, 1239-1252.

GOSWAMI, H., DEVI, M., RAMBABU, S., BARBARA, A. & PRAKASH, K. 2014. An analysis of the relation between precipitation and earthquake in the Indian region. Indian Journal of Radio & Space Physics, 43, 41-47.

GRALLA, E., GOENTZEL, J. & FINE, C. 2014. Assessing Trade-offs among Multiple Objectives for Humanitarian Aid Delivery Using Expert Preferences. Production and Operations Management, 23, 978-989.

GUHA-SAPIR, D., HOYOIS, P., BELOW, R. & CENTRE 2014. Annual Disaster Statistical Review 2013 the numbers and trends. EMDAT: Centre for Research on the Epidemiology of Disasters (CRED).

GUMMESSON, E. 2000. Qualitative methods in management research, Sage.

HADDOW, G. D., BULLOCK, J. A. & COPPOLA, D. P. 2011. Introduction to Emergency Management (4th Edition). Elsevier.

HAGHANI, A. & OH, S.-C. 1996. Formulation and solution of a multi-commodity, multi-modal network flow model for disaster relief operations. Transportation Research Part A: Policy and Practice, 30, 231-250.

HALE, T. & MOBERG, C. R. 2005. Improving supply chain disaster preparedness: A decision process for secure site location. International Journal of Physical Distribution & Logistics Management, 35, 195-207.

HAMZA-LUP, G. L., HUA, K. A., LE, M. & PENG, R. 2008. Dynamic plan generation and real-time management techniques for traffic evacuation. IEEE Transactions on Intelligent Transportation Systems, 9, 615-624.

HAN, Y., GUAN, X. & SHI, L. 2011. Optimization based method for supply location selection and routing in large-scale emergency material delivery. Automation Science and Engineering, IEEE Transactions on, 8, 683-693.

HEALY, M. & PERRY, C. 2000. Comprehensive criteria to judge validity and reliability of qualitative research within the realism paradigm. Qualitative market research: An international journal, 3, 118-126.

HEASLIP, G. & BARBER, E. 2014. Using the military in disaster relief: systemising challenges and opportunities. Journal of Humanitarian Logistics and Supply Chain Management, 4, 60-81.

HELBING, D. 2012. Agent-based modeling. Social self-organization. Springer.

HOLGUÍN-VERAS, J., PÉREZ, N., JALLER, M., VAN WASSENHOVE, L. N. & AROS-VERA, F. 2013. On the appropriate objective function for post-disaster humanitarian logistics models. Journal of Operations Management, 31, 262-280.

HOLLOCKS, B. 2006. Forty years of discrete-event simulation—a personal reflection. Journal of the Operational Research Society, 57, 1383-1399.

HOME-AFFAIRS, M. O. 2007. National disaster management guidelines management of earthquakes. In: AUTHORITY, N. D. M. (ed.). Government of India.

HOME-AFFAIRS, M. O. 2011. Disaster management in India. In: INDIA, G. O. (ed.).

HORNER, M. & DOWNS, J. 2007. Testing a flexible geographic information system-based network flow model for routing hurricane disaster relief goods. Transportation Research Record: Journal of the transportation research board, 47-54.

HORNER, M. W. & DOWNS, J. A. 2010. Optimizing hurricane disaster relief goods distribution: model development and application with respect to planning strategies. Disasters, 34, 821-844.

HORNER, M. W. & WIDENER, M. J. 2011. The effects of transportation network failure on people's accessibility to hurricane disaster relief goods: a modeling approach and application to a Florida case study. Natural hazards, 59, 1619-1634.

HU, Z.-H. 2011. A container multimodal transportation scheduling approach based on immune affinity model for emergency relief. Expert Systems with Applications, 38, 2632-2639.

HUANG, K., JIANG, Y., YUAN, Y. & ZHAO, L. 2015. Modeling multiple humanitarian objectives in emergency response to large-scale disasters. Transportation Research Part E: Logistics and Transportation Review, 75, 1-17.

HUANG, R., KIM, S. & MENEZES, M. B. 2010. Facility location for large-scale emergencies. Annals of Operations Research, 181, 271-286.

HWANG, H. S. 1999. A food distribution model for famine relief. Computers & industrial engineering, 37, 335-338.

ICHOUA, S. 2010. Humanitarian logistics network design for an effective disaster response.

IFRC. 2011. Thai Red Cross supports migrant families following floods in Bangkok [Online]. International Federation of Red Cross [Accessed 25th January 2016].

IMD, I. M. D. 2011. RE: Report on Earthquake Sikkim Nepal Border-2011.

INDIA, T. O. 2011. Relief, rescue operations on after Sikkim earthquake [Online]. reliefweb. [Accessed 03/12/15 2015].

INDIA.GOV.IN. 2015. National Portal of India. India at a Glance. Retrieved , [Online]. Available: http://india.gov.in/india-glance/profile [Accessed 10/04/2015 2015].

INDRANIL CHAKRABORTY, D. S. G., DEBASISH BHATTACHARYA & ANJAN BORA. 2011. Earthquake induced landslides in the Sikkim-Darjeeling Himalayas [Online]. ngineering Geology Division, Geological Survey of India, Eastern Region, Kolkata. [Accessed 03/12/2015 2015].

JAHRE, M., JENSEN, L. M. & LISTOU, T. 2009. Theory development in humanitarian logistics: a framework and three cases. Management Research News, 32, 1008-1023.

JAHRE, M., PERSSON, G., KOVÁCS, G. & SPENS, K. M. 2007. Humanitarian logistics in disaster relief operations. International Journal of Physical Distribution & Logistics Management, 37, 99-114.

JALLER, M., UKKUSURI, S. & HOLGUIN-VERAS, J. A stochastic inventory model for fixed lifetime goods for disaster planning. Transportation Research Board 87th Annual Meeting, Washington DC, USA, 2008.

JIA, H., ORDÓÑEZ, F. & DESSOUKY, M. 2007a. A modeling framework for facility location of medical services for large-scale emergencies. IIE transactions, 39, 41-55.

JIA, H., ORDÓÑEZ, F. & DESSOUKY, M. M. 2007b. Solution approaches for facility location of medical supplies for large-scale emergencies. Computers & Industrial Engineering, 52, 257-276.

JIANMING, Z., JUN, H., DEGANG, L. & JIYE, H. Connected distribution center location problem under traffic network in emergency management. Fifth International Joint Conference on Computational Sciences and Optimization (CSO), 2012 23-26 June 2012 2012. 160-163.

JORDAN, H. T., BRACKBILL, R. M., CONE, J. E., DEBCHOUDHURY, I., FARFEL, M. R., GREENE, C. M., HADLER, J. L., KENNEDY, J., LI, J., LIFF, J., STAYNER, L. & STELLMAN, S. D. 2011. Mortality among survivors of the Sept 11, 2001, World Trade Center disaster: results from the World Trade Center Health Registry cohort. Lancet, 378, 879-887.

JULCA, A. 2012. Natural Disasters with Un-Natural Effects: Why? Journal of Economic Issues, 46, 499-510.

KAPUCU, N. 2008. Collaborative emergency management: better community organising, better public preparedness and response. Disasters, 32, 239-262.

KEHLER, N. 2004. Coordinating humanitarian assistance: A comparative analysis of three cases. United Nations.

KIM, S. K. & DSHALALOW, J. H. 2002. Stochastic disaster recovery systems with external resources. Mathematical and Computer Modelling, 36, 1235-1257.

KIMMS, A. & MAASSEN, K.-C. 2011. Optimization and simulation of traffic flows in the case of evacuating urban areas. OR spectrum, 33, 571-593.

KIMMS, A. & MAASSEN, K.-C. 2012. Cell-transmission-based evacuation planning with rescue teams. Journal of Heuristics, 18, 435-471.

KLEIN, H. K. & HIRSCHHEIM, R. A. 1987. A Comparative Framework of Data Modelling Paradigms and Approaches. The Computer Journal, 30, 8-15.

KNOTT, R. 1987. The logistics of bulk relief supplies. Disasters, 11, 113-115.

KNOTT, R. 1988. Vehicle Scheduling for Emergency Relief Management: A Knowledge-Based Approach. Disasters, 12, 285-293.

KONGSOMSAKSAKUL, S., YANG, C. & CHEN, A. 2005. Shelter location-allocation model for flood evacuation planning. Journal of the Eastern Asia Society for Transportation Studies, 6, 4237-4252.

KOTHARI, C. R. 2004. Research methodology. [electronic resource] : methods & techniques, New Delhi : New Age International (P) Ltd., Publishers, 2004. 2nd rev. ed.

KOTZAB, H., SEURING, S., MÜLLER, M. & REINER, G. 2006. Research methodologies in supply chain management, Springer Science & Business Media.

KOVÁCS, G. & SPENS, K. M. 2011. Humanitarian logistics and supply chain management: the start of a new journal. Journal of humanitarian logistics and supply chain management, 1, 5-14.

KUHN, T. 1962. The nature and necessity of scientific revolutions, na.

KUNZ, N. & REINER, G. 2012. A meta-analysis of humanitarian logistics research. Journal of Humanitarian Logistics and Supply Chain Management, 2, 116-147.

KUNZ, N., REINER, G. & GOLD, S. 2014. Investing in disaster management capabilities versus pre-positioning inventory: a new approach to disaster preparedness. International Journal of Production Economics, 157, 261-272.

LAKSHMI NARAYANAN, R. G. & IBE, O. C. 2012. A joint network for disaster recovery and search and rescue operations. Computer Networks, 56, 3347-3373.

LEE, E. K., CHEN, C.-H., PIETZ, F. & BENECKE, B. 2009a. Modeling and optimizing the public-health infrastructure for emergency response. Interfaces, 39, 476-490.

LEE, N. & LINGS, I. 2008. Doing business research: a guide to theory and practice, Sage.

LEE, Y. M., GHOSH, S. & ETTL, M. Simulating distribution of emergency relief supplies for disaster response operations. Simulation Conference (WSC), Proceedings of the 2009 Winter, 2009b. IEEE, 2797-2808.

LESEURE, M., HUDSON-SMITH, M., CHANDES, J. & PACHÉ, G. 2010. Investigating humanitarian logistics issues: from operations management to strategic action. Journal of Manufacturing Technology Management, 21, 320-340.

LI, A. C., NOZICK, L., XU, N. & DAVIDSON, R. 2012. Shelter location and transportation planning under hurricane conditions. Transportation Research Part E: Logistics and Transportation Review, 48, 715-729.

LI, L., JIN, M. & ZHANG, L. 2011. Sheltering network planning and management with a case in the Gulf Coast region. International Journal of Production Economics, 131, 431-440.

LI, X. & OUYANG, Y. 2010. A continuum approximation approach to reliable facility location design under correlated probabilistic disruptions. Transportation research part B: methodological, 44, 535-548.
LIBERATORE, F., ORTUÑO, M. T., TIRADO, G., VITORIANO, B. & SCAPARRA, M. P. 2014. A hierarchical compromise model for the joint optimization of recovery operations and distribution of emergency goods in Humanitarian Logistics. Computers & Operations Research, 42, 3-13.
LIN, Y.-H., BATTA, R., ROGERSON, P. A., BLATT, A. & FLANIGAN, M. 2011. A logistics model for emergency supply of critical items in the aftermath of a disaster. Socio-Economic Planning Sciences, 45, 132-145.
LINDELL, M. K. 2008. EMBLEM2: An empirically based large scale evacuation time estimate model. Transportation research part A: policy and practice, 42, 140-154.
LIU, H. X., BAN, J. X., MA, W. & MIRCHANDANI, P. B. 2007. Model reference adaptive control framework for real-time traffic management under emergency evacuation. Journal of Urban Planning and Development, 133, 43-50.
LIU, Y., ZHANG, T., LEI, H. & GUO, B. 2013. Stochastic programming approach for earthquake disaster relief mobilization with multiple objectives. Journal of Systems Engineering and Electronics, 24, 642-654.
LOCH, C. H. & WU, Y. 2007. Behavioral operations management, Now Publishers Inc.
LODREE JR, E. J. & TASKIN, S. 2008. An insurance risk management framework for disaster relief and supply chain disruption inventory planning. Journal of the Operational Research Society, 59, 674-684.
LONG, D. C. & WOOD, D. F. 1995. The logistics of famine relief. Journal of Business Logistics, 16, 213.
LONGHURST, R. 2003. Semi-structured interviews and focus groups. Key methods in geography, 117-132.
LOPEZ-PELAEZ, J. & PIGEON, P. 2011. Co-evolution between structural mitigation measures and urbanization in France and Colombia: A comparative analysis of disaster risk management policies based on disaster databases. HABITAT INTERNATIONAL, 35, 9.
LU, C.-C. 2013. Robust weighted vertex p-center model considering uncertain data: An application to emergency management. European Journal of Operational Research, 230, 113-121.
MACAL, C. M. & NORTH, M. J. Tutorial on agent-based modeling and simulation. Proceedings of the 37th conference on Winter simulation, 2005. Winter Simulation Conference, 2-15.

MALISZEWSKI, P. J. & HORNER, M. W. 2010. A spatial modeling framework for siting critical supply infrastructures*. The Professional Geographer, 62, 426-441.

MALISZEWSKI, P. J., KUBY, M. J. & HORNER, M. W. 2012. A comparison of multi-objective spatial dispersion models for managing critical assets in urban areas. Computers, Environment and Urban Systems, 36, 331-341.

MARKS, D. F. & YARDLEY, L. 2004. Research methods for clinical and health psychology, Sage.

MARTEL, A., BENMOUSSA, A., CHOUINARD, M., KLIBI, W. & KETTANI, O. 2013. Designing global supply networks for conflict or disaster support: the case of the Canadian Armed Forces. Journal of the Operational Research Society, 64, 577-596.

MARTIN, R. H. & RAFFO, D. 2000. A model of the software development process using both continuous and discrete models. Software Process: Improvement and Practice, 5, 147-157.

MARTINEZ, A. P., STAPLETON, O. & VAN WASSENHOVE, L. N. 2011. Last Mile Vehicle Fleet Management in Humanitarian Operations: A Case-Based Approach. working paper, INSEAD publication.

MCCONNAN, I. 1998. Humanitarian charter and minimum standards in disaster response, The Sphere Project.

MENTZER, J. T. & KAHN, K. B. 1995. A framework of logistics research. Journal of Business Logistics, 16, 231.

MENTZER, J. T. & KONRAD, B. P. 1991. An efficiency/effectiveness approach to logistics performance analysis. Journal of business logistics, 12, 33.

METE, H. O. & ZABINSKY, Z. B. 2010. Stochastic optimization of medical supply location and distribution in disaster management. International Journal of Production Economics, 126, 76-84.

MEYERSON, D., WEICK, K. E. & KRAMER, R. M. 1996. Swift Trust and Temporary Group. Trust in Organisations. Sage, Thousand Oaks.

MORITZ, B. B., HILL, A. V. & DONOHUE, K. L. 2013. Individual differences in the newsvendor problem: Behavior and cognitive reflection. Journal of Operations Management, 31, 72-85.

MYERS, M. D. 2013. Qualitative research in business and management, Sage.

NAGARAJAN, M., SHAW, D. & ALBORES, P. 2010. Informal dissemination scenarios and the effectiveness of evacuation warning dissemination of households—A Simulation study. Procedia Engineering, 3, 139-152.

NAJAFI, M., ESHGHI, K. & DULLAERT, W. 2013. A multi-objective robust optimization model for logistics planning in the earthquake response phase. Transportation Research Part E: Logistics and Transportation Review, 49, 217-249.

NAJI-AZIMI, Z., RENAUD, J., RUIZ, A. & SALARI, M. 2012. A covering tour approach to the location of satellite distribution centers to supply humanitarian aid. European Journal of Operational Research, 222, 596-605.

NETLOGO. 2014. https://ccl.northwestern.edu/netlogo/ [Online]. [Accessed 2014].

NG, M., PARK, J. & WALLER, S. T. 2010. A hybrid bilevel model for the optimal shelter assignment in emergency evacuations. Computer-Aided Civil and Infrastructure Engineering, 25, 547-556.

NIGAM, V. & JETHOO, A. 2013. Response Time Reduction in" Response and Relief" Phase of Earthquake using Dijkstra's Algorithm. Disaster advances, 6, 80-87.

NIKOLOPOULOS, C. V. & TZANETIS, D. E. 2003. A model for housing allocation of a homeless population due to a natural disaster. Nonlinear Analysis: Real World Applications, 4, 561-579.

NILSSON, S., SJÖBERG, M. & LARSSON, G. 2010. A civil contingencies agency management system for disaster aid: a theoretical model. International Journal of Organizational Analysis, 18, 412-429.

NOLZ, P. C., SEMET, F. & DOERNER, K. F. 2011. Risk approaches for delivering disaster relief supplies. OR spectrum, 33, 543-569.

NORTH, M. J. & MACAL, C. M. 2007. Managing business complexity: discovering strategic solutions with agent-based modeling and simulation, Oxford University Press.

NOYAN, N. 2012. Risk-averse two-stage stochastic programming with an application to disaster management. Computers & Operations Research, 39, 541-559.

OHNAKA, M. 2013. The physics of rock failure and earthquakes, Cambridge University Press.

OLORUNTOBA, R. 2010. An analysis of the Cyclone Larry emergency relief chain: Some key success factors. International Journal of Production Economics, 126, 85-101.

OLORUNTOBA, R. & GRAY, R. 2006. Humanitarian aid: an agile supply chain? Supply Chain Management: an international journal, 11, 115-120.

ONGHENA, E. 2008. Integrators: werkwijze, strategieën en toekomst. Universiteit Antwerpen.

ORTUÑO, M., CRISTÓBAL, P., FERRER, J., MARTÍN-CAMPO, F., MUÑOZ, S., TIRADO, G. & VITORIANO, B. 2013. Decision aid models and systems for humanitarian logistics. A survey. Decision aid models for disaster management and emergencies. Springer.

ORTUÑO, M., TIRADO, G. & VITORIANO, B. 2011. A lexicographical goal programming based decision support system for logistics of Humanitarian Aid. Top, 19, 464-479.

OWEN, C., ALBORES, P., GREASLEY, A. & LOVE, D. 2010. Simulation in the supply chain context: matching the simulation tool to the problem.

OWEN, C. D. 2013. Selection of simulation tools for improving supply chain perfromance. Doctor of Business Administration, Aston University.

OXENDINE, C., SONWALKAR, M. & WATERS, N. 2012. A Multi-Objective, Multi-Criteria Approach to Improve Situational Awareness in Emergency Evacuation Routing Using Mobile Phone Data. Transactions in GIS, 16, 375-396.

OZBAY, K. & OZGUVEN, E. 2007. Stochastic humanitarian inventory control model for disaster planning. Transportation Research Record: Journal of the Transportation Research Board, 63-75.

OZDAMAR, L. 2011. Planning helicopter logistics in disaster relief. OR spectrum, 33, 655-672.

ÖZDAMAR, L. & DEMIR, O. 2012. A hierarchical clustering and routing procedure for large scale disaster relief logistics planning. Transportation Research Part E: Logistics and Transportation Review, 48, 591-602.

ÖZDAMAR, L., EKINCI, E. & KÜÇÜKYAZICI, B. 2004. Emergency logistics planning in natural disasters. Annals of operations research, 129, 217-245.

OZDAMAR, L. & YI, W. 2008. Greedy neighborhood search for disaster relief and evacuation logistics. IEEE Intelligent Systems, 23, 14-23.

OZGUVEN, E. & OZBAY, K. 2012. Case study-based evaluation of stochastic multicommodity emergency inventory management model. Transportation Research Record: Journal of the Transportation Research Board, 12-24.

OZGUVEN, E. E. & OZBAY, K. 2013. A secure and efficient inventory management system for disasters. Transportation research part C: emerging technologies, 29, 171-196.

PATTERSON, M. E. & WILLIAMS, D. R. 1998. Paradigms and problems: The practice of social science in natural resource management.

PEEK, L. 2008. Children and disasters: Understanding vulnerability, developing capacities, and promoting resilience-an introduction. Children Youth and Environments, 18, 1-29.

PENG, M., PENG, Y. & CHEN, H. 2014. Post-seismic supply chain risk management: A system dynamics disruption analysis approach for inventory and logistics planning. Computers & Operations Research, 42, 14-24.

PERRY, M. 2007. Natural disaster management planning: a study of logistics managers responding to the tsunami. International Journal of Physical Distribution & Logistics Management, 37, 409-433.

PERRY, M. R. 2006. Humanitarian relief challenges in the wake of the South East Asian tsunami disaster, Dept. of Management, Monash University.

PIDD, M. 1998. Computer simulation in management science.

PIDD, M. 2003. Tools for Thinking: Modelling in Management Science. 2003. John W iley & Sons, Chichester.

PIDD, M. 2009. Tools for Thinking: Modelling in Management Science. 2003. John W iley & Sons, Chichester.

PRAMOD.K.MISHRA 2004. The Kutch Earthquake 2001. Ministry of Home Affairs, Govt. of India: National Institute of Disaster Management.

PRICE, G. & BHATT, M. 2009. The role of the affected state in humanitarian action: A case study on India. HPG working paper. Humanitarian Policy Group, Overseas Development Institute, London.

RADWAN, A., HOBEIKA, A. & SIVASAILAM, D. 1985. Computer simulation model for rural network evacuation under natural disasters. ITE journal, 55, 25-30.

RAJENDRAN, K., RAJENDRAN, C., THULASIRAMAN, N., ANDREWS, R. & SHERPA, N. 2011. The 18 September 2011, North Sikkim earthquake. Current Science (Bangalore), 101, 1475-1479.

RATH, S. & GUTJAHR, W. J. 2014. A math-heuristic for the warehouse location–routing problem in disaster relief. Computers & Operations Research, 42, 25-39.

RATHI, A. K., CHURCH, R. L. & SOLANKI, R. S. 1992. Allocating resources to support a multicommodity flow with time windows. Logistics and Transportation Review, 28, 167.

RATICK, S., MEACHAM, B. & AOYAMA, Y. 2008. Locating backup facilities to enhance supply chain disaster resilience. Growth and Change, 39, 642-666.

RAUTELA, P. January 2012. Sikkim Earthquake of 18th September, 2011. Disaster Mitigation and Management Centre (An autonomous institution of the Department of Disaster Management, Government of Uttarakhand) Uttarakhand Secretariat.

RAWLS, C. G. & TURNQUIST, M. A. 2010. Pre-positioning of emergency supplies for disaster response. Transportation research part B: Methodological, 44, 521-534.

RAWLS, C. G. & TURNQUIST, M. A. 2011. Pre-positioning planning for emergency response with service quality constraints. OR spectrum, 33, 481-498.

RAWLS, C. G. & TURNQUIST, M. A. 2012. Pre-positioning and dynamic delivery planning for short-term response following a natural disaster. Socio-Economic Planning Sciences, 46, 46-54.

REFUGEES, U. N. H. C. F. 1999. Handbook for emergencies. UNHCR Geneva.

REINDORP, N. 2002. Trends and challenges in the UN humanitarian system. The new Humanitarianisms: a review of Trends in Global Humanitarian Action. HPG Report, 11.

REPORT, I. N. 2011. INTERIM REPORT ON : EARTH QUAKE IN SIKKIM 2011. Church's Auxiliary for Social Action.

REY, F. 2001. The complex nature of actors in humanitarian action and the challenge of coordination. Reflections on Humanitarian Action: Principles, Ethics and Contradictions. TNI/Pluto Press with Humanitarian Studies Unit and ECHO (European Commission Humanitarian Office), London.

RICHARDSON, D., DE LEEUW, S. & VIS, I. F. 2010. Conceptualising inventory prepositioning in the humanitarian sector. Collaborative Networks for a Sustainable World. Springer.

RIDLEY, D. 2012. The literature review: A step-by-step guide for students, Sage.

RIEDL, D. F., KAUFMANN, L., ZIMMERMANN, C. & PEROLS, J. L. 2013. Reducing uncertainty in supplier selection decisions: Antecedents and outcomes of procedural rationality. Journal of Operations Management, 31, 24-36.

ROBINSON, S. 2014. Simulation: the practice of model development and use, Palgrave Macmillan.

RODRÍGUEZ-ESPÍNDOLA, O., ALBORES, P. & BREWSTER, C. 2017. Disaster preparedness in humanitarian logistics: A collaborative approach for resource management in floods. European Journal of Operational Research.

ROTTKEMPER, B., FISCHER, K., BLECKEN, A. & DANNE, C. 2011. Inventory relocation for overlapping disaster settings in humanitarian operations. OR spectrum, 33, 721-749.

RUBIN, H. J. & RUBIN, I. S. 2011. Qualitative interviewing: The art of hearing data, Sage.

SAARC. 2015. India disaster knowledge network [Online]. Available: http://www.saarc-sadkn.org/countries/india/disaster_profile.aspx [Accessed 10.04.2015 2015].

SANTOS, J. R., ORSI, M. J. & BOND, E. J. 2009. Pandemic Recovery Analysis Using the Dynamic Inoperability Input-Output Model. Risk Analysis: An International Journal, 29, 1743-1758.

SARAF, A. & CHOUDHURY, S. 2005. Cover: NOAA-AVHRR detects thermal anomaly associated with the 26 January 2001 Bhuj earthquake, Gujarat, India. International Journal of Remote Sensing, 26, 1065-1073.

SAUNDERS, M., LEWIS, P. & THORNHILL, A. 2009. Research methods for business students. [electronic resource], New York : Prentice Hall, c2009. 5th ed.

SAUNDERS, M., LEWIS, P. & THORNHILL, A. 2012. Research methods for business students. [electronic resource], Harlow, England ; New York : Pearson, 2012.6th ed.

SAVOIU, G. 2011. The holistic concepts of disaster management and social cohesion-statistics and method. Scientific Bulletin, 3.

SCHEER, S. J., VARELA, V. & EFTYCHIDIS, G. 2012. A generic framework for tsunami evacuation planning. Physics and Chemistry of the Earth, Parts A/B/C, 49, 79-91.

SCHWANINGER, M. 2006. System dynamics and the evolution of the systems movement. Systems Research and Behavioral Science, 23, 583.

SHAW, R., SHIWAKU HIROHIDE KOBAYASHI, K. & KOBAYASHI, M. 2004. Linking experience, education, perception and earthquake preparedness. Disaster Prevention and Management: An International Journal, 13, 39-49.

SHEN, Z.-J. M., PANNALA, J., RAI, R. & TSOI, T. S. 2008. Modeling transportation networks during disruptions and emergency evacuations. University of California Transportation Center.

SHEN, Z., ORDÓNEZ, F. & DESSOUKY, M. M. 2009. The stochastic vehicle routing problem for minimum unmet demand. Optimization and logistics challenges in the enterprise. Springer.

SHEU, J.-B. 2007a. Challenges of emergency logistics management. Transportation research part E: logistics and transportation review, 43, 655-659.

SHEU, J.-B. 2007b. An emergency logistics distribution approach for quick response to urgent relief demand in disasters. Transportation Research Part E: Logistics and Transportation Review, 43, 687-709.

SHEU, J.-B. 2010. Dynamic relief-demand management for emergency logistics operations under large-scale disasters. Transportation Research Part E: Logistics and Transportation Review, 46, 1-17.

SHEU, J.-B. 2014. Post-disaster relief–service centralized logistics distribution with survivor resilience maximization. Transportation research part B: methodological, 68, 288-314.

SHIOMI, Y., SETO, Y. & UNO, N. 2011. Model for location of medical facility and evaluation of vulnerability and accessibility of road network. Transportation Research Record: Journal of the Transportation Research Board, 41-48.

SIKKIM, C. O. I. 2011. District census handbook: North, West, South and East districts village and town wise primary census apstract (PCA)) Directorate of census operations Sikkim.

SNYDER, L. V. & DASKIN, M. S. 2005. Reliability models for facility location: the expected failure cost case. Transportation Science, 39, 400-416.

SOCIETIES, I. F. O. R. C. A. R. C. 2001. Relief Web: India/Gujarat: Earthquake Appeal No. 04/2001 Situation Report [Online]. [Accessed 10/01/2016].

SOCIETIES, I. F. O. R. C. A. R. C. 2012. DREF Final Report India: Sikkim Earthquake. International Federation of Red Cross and Red Crescent Societies.

SONG, B., HAO, S., MURAKAMI, S. & SADOHARA, S. 1996. Comprehensive evaluation method on earthquake damage using fuzzy theory. Journal of urban planning and development, 122, 1-17.

STELLMAN, J. M., SMITH, R. P., KATZ, C. L., SHARMA, V., CHARNEY, D. S., HERBERT, R., MOLINE, J., LUFT, B. J., MARKOWITZ, S. & UDASIN, I. 2008. Environmental medicine -neurobehavioural disease-Enduring Mental Health Morbidity and Social Function Impairment in World Trade Center Rescue, Recovery, and Cleanup Workers: The Psychological Dimension of an Environmental Health Disaster. Environmental health perspectives (Online), 116, 1248.

STERMAN, J. D. 2000. Business dynamics: systems thinking and modeling for a complex world, Irwin/McGraw-Hill Boston.

STERMAN, J. D. 2002. All models are wrong: reflections on becoming a systems scientist. System Dynamics Review, 18, 501-531.

SUZUKI, Y. 2012. Disaster-Relief Logistics With Limited Fuel Supply. Journal of Business Logistics, 33, 145-157.

SWEETSER, A. A comparison of system dynamics (SD) and discrete event simulation (DES). 17th International Conference of the System Dynamics Society, 1999. 20-23.

SWISS, R. 2016. Natural Catastrophes and man-made disasters in 2015. Sigma. Zurich: Swiss Re.

TAKO, A. A. 2008. Development and use of simulation models in Operational Research: a comparison of discrete-event simulation and system dynamics. University of Warwick.

TAKO, A. A. & ROBINSON, S. 2009. Comparing discrete-event simulation and system dynamics: users' perceptions. Journal of the operational research society, 60, 296-312.

TASKIN, S. & LODREE, E. J. 2010. Inventory decisions for emergency supplies based on hurricane count predictions. International Journal of Production Economics, 126, 66-75.

TASKIN, S. & LODREE JR, E. J. 2011. A Bayesian decision model with hurricane forecast updates for emergency supplies inventory management. Journal of the Operational Research Society, 62, 1098-1108.

TATHAM, P. & HOUGHTON, L. 2011. The wicked problem of humanitarian logistics and disaster relief aid. Journal of Humanitarian Logistics and Supply Chain Management, 1, 15-31.

TATHAM, P. & KOVÁCS, G. 2010. The application of "swift trust" to humanitarian logistics. International Journal of Production Economics, 126, 35-45.

TATHAM, P., PETTIT, S., BANOMYONG, R. & SOPADANG, A. 2010a. Using Monte Carlo simulation to refine emergency logistics response models: a case study. International Journal of Physical Distribution & Logistics Management, 40, 709-721.

TATHAM, P., PETTIT, S., JAHRE, M. & JENSEN, L.-M. 2010b. Coordination in humanitarian logistics through clusters. International Journal of Physical Distribution & Logistics Management, 40, 657-674.

TATHAM, P., PETTIT, S., NOLZ, P. C., DOERNER, K. F. & HARTL, R. F. 2010c. Water distribution in disaster relief. International Journal of Physical Distribution & Logistics Management, 40, 693-708.

TATHAM, P., PETTIT, S., SCHULZ, S. F. & BLECKEN, A. 2010d. Horizontal cooperation in disaster relief logistics: benefits and impediments. International Journal of Physical Distribution & Logistics Management, 40, 636-656.

TATHAM, P. H., SPENS, K. M., TAYLOR, D., JAHRE, M., JENSEN, L.-M. & LISTOU, T. 2009. Theory development in humanitarian logistics: a framework and three cases. Management Research News, 32, 1008-1023.

TAYLOR, S. & ROBINSON, S. 2006. So where to next? A survey of the future for discrete-event simulation. Journal of Simulation, 1, 1-6.

TENNIS, J. T. 2008. Epistemology, theory, and methodology in knowledge organization: toward a classification, metatheory, and research framework. Knowledge organization, 35, 102-112.

THÉRIEN, J.-P. & LLOYD, C. 2000. Development assistance on the brink. Third World Quarterly, 21, 21-38.

THOMAS, A. S. & KOPCZAK, L. R. 2005. From logistics to supply chain management: the path forward in the humanitarian sector. Fritz Institute, 15, 1-15.

TIRADO, G., MARTÍN-CAMPO, F. J., VITORIANO, B. & ORTUÑO, M. T. 2014. A lexicographical dynamic flow model for relief operations. International Journal of Computational Intelligence Systems, 7, 45-57.

TRICOIRE, F., GRAF, A. & GUTJAHR, W. J. 2012. The bi-objective stochastic covering tour problem. Computers & Operations Research, 39, 1582-1592.

TUĞBA TURĞUT, B., TAŞ, G., HEREKOĞLU, A., TOZAN, H. & VAYVAY, O. 2011. A fuzzy AHP based decision support system for disaster center location selection and a case study for Istanbul. Disaster Prevention and Management: An International Journal, 20, 499-520.

TZENG, G.-H., CHENG, H.-J. & HUANG, T. D. 2007. Multi-objective optimal planning for designing relief delivery systems. Transportation Research Part E: Logistics and Transportation Review, 43, 673-686.

UDDIN, N. & ANG, A. H.-S. 2009. Disaster risk assessment and mitigation [electronic resource] : arrival of tsunami wave in Thailand / edited by Nasim Uddin, Alfredo Ang, Reston, VA : American Society of Civil Engineers, c2009.

UKKUSURI, S. & YUSHIMITO, W. 2008. Location routing approach for the humanitarian prepositioning problem. Transportation Research Record: Journal of the Transportation Research Board, 18-25.

UN 2015. U.N study: Natural disasters caused 600,000 deaths over 20 years. In: CHAN, M. (ed.). Time.

USGS. 1906. "The Great 1906 San Francisco earthquake of 1906". [Online]. United States Geological Survey. [Accessed.8/10/2015 2015].

USGS. 1946. "Historic Earthquakes — 1946 Anchorage Earthquake" [Online]. United States Geological Survey. [Accessed 08/10/2015 2015].

VAN TEIJLINGEN, E. 2014. Semi-structured interviews.

VAN WASSENHOVE, L. N. 2006. Humanitarian aid logistics: supply chain management in high gear. Journal of the Operational research Society, 57, 475-489.

VAN WYK, E., BEAN, W. & YADAVALLI, V. 2011. Modelling of uncertainty in minimising the cost of inventory for disaster relief. South African Journal of Industrial Engineering, 22, 1-12.

VITORIANO, B., ORTUÑO, M. T., TIRADO, G. & MONTERO, J. 2011. A multi-criteria optimization model for humanitarian aid distribution. Journal of Global Optimization, 51, 189-208.

VITORIANO, B., RODRÍGUEZ, J. T., TIRADO, G., MARTÍN-CAMPO, F. J., ORTUÑO, M. T. & MONTERO, J. 2015. Intelligent decision-making models for disaster management. Human and Ecological Risk Assessment: An International Journal, 21, 1341-1360.

VOSS, C., TSIKRIKTSIS, N. & FROHLICH, M. 2002. Case research in operations management. International journal of operations & production management, 22, 195-219.

WACHTENDORF, T. & KENDRA, J. M. 2004. Considering convergence, coordination, and social capital in disasters.

WANG, X. & WANG, H. 2008. Designing Optimal Emergency Logistics Networks with Time Delay and Demand Uncertainty. POMS 19th Annual Conference. La Jolla, California, U.S.A.

WASSENHOVE, V. 2006. Blackett Memorial Lecture Humanitarian Aid Logistics: Supply Chain Management in High Gear. Retrieved June 13, 2010.

WESTHOFF, W. W., LOPEZ, G. E., ZAPATA, L. B., WILKE CORVIN, J. A., ALLEN, P. & MCDERMOTT, R. J. 2008. Reproductive Health Education and Services Needs of Internally Displaced Persons and Refugees following Disaster. American Journal of Health Education, 39, 95-103.

WHO 2002. Disasters & emergencies definitions. WHO: Panafrican Emergency Training Centre, Addis Ababa Updated March 2002 by EHA.

WHYBARK, D. C. 2007. Issues in managing disaster relief inventories. International Journal of Production Economics, 108, 228-235.

WHYBARK, D. C., MELNYK, S. A., DAY, J. & DAVIS, E. 2010. Disaster relief supply chain management: new realities, management challenges, emerging opportunities. Decision Line, 41, 4-7.

WIDENER, M. J. & HORNER, M. W. 2011. A hierarchical approach to modeling hurricane disaster relief goods distribution. Journal of Transport Geography, 19, 821-828.

WILENSKY, U. A. S., W. 2003. NetLogo HubNet Root Beer Game model. http://ccl.northwestern.edu/netlogo/models/HubNetRootBeerGame. [Online]. [Accessed 10/01/2016].

WINSTON, W. L. 2004. Operations research : applications and algorithms, London : Brooks/Cole : Thomson, 2004. 4th ed.

WISNER, B. & ADAMS, J. 2002. Environmental health in emergencies and disasters: a practical guide, World health organization.

WORLD-BANK. 2016. Country profile: India [Online]. Available: http://data.worldbank.org/country/india [Accessed 15/03/2017 2017].

WU, L., TAN, Q. & ZHANG, Y. 2013. Delivery time reliability model of logistics network. Mathematical Problems in Engineering, 2013.

WYSS, M. 2001. Why is earthquake prediction research not progressing faster? Tectonophysics, 338, 217-223.

YAMADA, T. 1996. A network flow approach to a city emergency evacuation planning. International Journal of Systems Science, 27, 931-936.

YAN, S. & SHIH, Y.-L. 2009. Optimal scheduling of emergency roadway repair and subsequent relief distribution. Computers & Operations Research, 36, 2049-2065.

YAZICI, M. & OZBAY, K. 2007. Impact of probabilistic road capacity constraints on the spatial distribution of hurricane evacuation shelter capacities. Transportation Research Record: Journal of the Transportation Research Board, 55-62.

YI, D., FUREN, X. & ZHENMING, W. 2012. Wenchuan Earthquake Surface Fault Rupture and Disaster: A Lesson on Seismic Hazard Assessment and Mitigation. International Journal of Geophysics.

YI, W. & KUMAR, A. 2007. Ant colony optimization for disaster relief operations. Transportation Research Part E: Logistics and Transportation Review, 43, 660-672.

YI, W. & ÖZDAMAR, L. 2007. A dynamic logistics coordination model for evacuation and support in disaster response activities. European Journal of Operational Research, 179, 1177-1193.

YIN, R. K. 2013. Case study research: Design and methods, Sage publications.

YUSHIMITO, W. F., JALLER, M. & UKKUSURI, S. 2012. A Voronoi-based heuristic algorithm for locating distribution centers in disasters. Networks and Spatial Economics, 12, 21-39.

ZHANG, X., ZHANG, Z., ZHANG, Y., WEI, D. & DENG, Y. 2013. Route selection for emergency logistics management: a bio-inspired algorithm. Safety science, 54, 87-91.

ZHAO, P., GUO, B. & WANG, P.-Z. The optimization analysis of urban disaster hedge places based on multi-objective programming. Control and Decision Conference (CCDC), 2012 24th Chinese, 2012. IEEE, 2415-2419.

ZHENG, Y., CHEN, S. & LING, H. 2013. Efficient multi-objective tabu search for emergency equipment maintenance scheduling in disaster rescue. Optimization Letters, 7, 89-100.

ZHU, J., HUANG, J., LIU, D. & HAN, J. Connected distribution center location problem under traffic network in emergency management. Computational Sciences and Optimization (CSO), 2012 Fifth International Joint Conference on, 2012. IEEE, 160-163.

Appendix

Appendix 1: Preliminary literature search

Table A 1.1: Preliminary literature search

Date	Name of the journal	Keywords	Number of articles	Number of relevant articles	Reason for relevancy
20.04.2013	Science Direct	humanitarian supply chain	1609	380	Natural disaster, humanitarian supply chain, united nations, emergency, disaster and others
23.04.2013	EBSCO	humanitarian supply chain	1430	287	emergency, disaster, natural disaster, relief chain operation, response operation and others
25.04.2013	JSTOR	humanitarian supply chain	1000	348	natural disaster, relief chain operation, NGOs and others
27.04.2013	Elsevier Science	humanitarian supply chain	1267	254	natural disaster, relief chain operation, NGOs, supply chain during disaster and others
28.04.2013	Web of Science	humanitarian supply chain	342	180	excluding the health care in humanitarian supply chain
22.05.2013	Science Direct	relief distribution	8677	500	food aid, natural disaster, earthquake, response operation and others
23.05.2013	EBSCO	relief distribution	5434	465	natural disaster, NGOs, aid distribution, supply and demand of relief

Table A 1.1 Continued....

Date	**Name of the journal**	**Keywords**	**Number of articles**	**Number of relevant articles**	**Reason for relevancy**
25.05.2013	JSTOR	relief distribution	2966	489	post disaster, natural disaster, aid distribution, response operation, aid supply chain
28.05.2013	Elsevier Science	relief distribution	9434	434	aid and relief, post-disaster distribution, relief operation and others
30.05.2013	Web of Science	relief distribution	969	343	earthquake, flood, natural disaster, aid distribution, response and relief operation, others
03.06.2013	Science Direct	emergency logistics	18245	767	disaster inventory, disaster facility location, disaster shelter location, natural disaster, relocation and transportation and others
05.06.2013	EBSCO	emergency logistics	15456	632	humanitarian logistics, emergency transportation, inventory during a disaster, supply and demand during a disaster
10.06.2013	JSTOR	emergency logistics	21234	540	emergency logistical decisions, natural disaster, NGOs and others
13.07.2013	Elsevier Science	emergency logistics	9564	355	inventory management during an emergency situation, relief distribution, affected population relocation, transportation, shelter location, distribution centre location and others
17.07.2013	Web of Science	emergency logistics	8567	570	natural disaster, pre-positioning of relief, relief distribution, transportation and others

Table A 1.1 Continued....

Date	Name of the journal	Keywords	Number of articles	Number of relevant articles	Reason for relevancy
20.07.2013	Science Direct	relief chain operation	7564	400	aid distribution, relief, relief supply, natural disaster and others
26.07.2013	EBSCO	relief chain operation	3657	288	food aid, earthquake, post-disaster distribution, humanitarian supply chain and others
29.07.2013	JSTOR	relief chain operation	8356	378	emergency logistics, aid supply, relief demand and others
04.08.2013	Elsevier Science	relief chain operation	6789	230	relief operation, emergency situation, emergency logistics and others
05.08.2013	Web of Science	relief chain operation	568	187	natural disaster, relief supply, response operation and others
07.08.2013	Science Direct	last mile relief distribution	145	89	relief distribution, aid operation, distribution during an emergency situation and others
08.08.2013	EBSCO	last mile relief distribution	87	23	aid operation, food distribution, emergency situation, the final distribution of relief and others

Table A 1.1 Continued....

Date	**Name of the journal**	**Keywords**	**Number of articles**	**Number of relevant articles**	**Reason for relevancy**
09.08.2013	JSTOR	last mile relief distribution	540	67	relief pre-positioning, shelter location and distribution,
10.08.2013	Elsevier science	last mile relief distribution	212	100	aid supply, response operation during disaster and others
11.08.2013	Web of Science	last mile relief distribution	45	10	final distribution, local level distribution, natural disaster and others

Appendix 2: The sample of literature analysis:

Table A 2.1: Paper specification:

Paper number	Year	Author	First Author	Second Author	Third Author	Fourth Author	Fifth Author	Title	Journal	Type
1	2002	BARBAROSOGLU, G., ÖZDAMAR, L. & ÇEVIK, A.	Bogazici University, Turkey	Yeditepe University, Turkey	Yeditepe University, Turkey	N/A	N/A	An interactive approach for hierarchical analysis of helicopter logistics in disaster relief operations	European Journal of Operational Research	Science
2	2004	ÖZDAMAR, L., EKINCI, E. & KÜÇÜKYAZICI, B.	Nanyang Technological University, Singapore	Turkish Armed Forces, Turkey	Yeditepe University, turkey	N/A	N/A	Emergency logistics planning in natural disasters	Annals of Operations Research	Science

Table A 2.1 Continued....

Paper number	Year	Author	First Author	Second Author	Third Author	Fourth Author	Fifth Author	Title	Journal	Type
3	2005	DEKLE, J., LAVIERI, M. S., MARTIN, E., EMIR-FARINAS, H. & FRANCIS, R. L.	Union County High School, USA	University of British Columbia, Canada	Gainesville Regional Utilities, USA	IBM Software Group, USA	University of Florida, USA	A Florida County Locates Disaster Recovery Centers	Interfaces	Science
4	2006	BEAMON, B. M. & KOTLEBA, S. A.	University of Washington, USA	University of Washington, USA	N/A	N/A	N/A	Inventory management support systems for emergency humanitarian relief operations in South Sudan	International Journal of Logistics: Research and Applications	Social
5	2007	CHANG, M. S., TSENG, Y. L. & CHEN, J. W.	Chung Yuan Christian	National Central	Chung Hua University, Taiwan	N/A	N/A	A scenario planning approach for	Transportation Research Part E: Logistics	Science

Table A 2.1 Continued....

Paper number	Year	Author	First Author	Second Author	Third Author	Fourth Author	Fifth Author	Title	Journal	Type
			University, Taiwan	University, Taiwan				the flood emergency logistics preparation problem under uncertainty	and Transportation Review	
6	2008	BALCIK, B., BEAMON, B. M. & SMILOWITZ, K.	University of Washington, USA	University of Washington, USA	Northwestern University, USA	N/A	N/A	Last mile distribution in humanitarian relief	Journal of Intelligent Transportation Systems: Technology, Planning, and Operations	Science
7	2009	DOERNER, K. F., GUTJAHR, W. J. & NOLZ, P. C.	University of Vienna, Austria	University of Vienna, Austria	University of Vienna, Austria	N/A	N/A	Multi-criteria location planning for	OR Spectrum	Science

Table A 2.1 Continued....

Paper number	Year	Author	First Author	Second Author	Third Author	Fourth Author	Fifth Author	Title	Journal	Type
								public facilities in tsunami-prone coastal areas		
8	2010	TASKIN, S. & LODREE JR, E. J.	ASELSAN, Turkey	The University of Alabama, USA	N/A	N/A	N/A	Inventory decisions for emergency supplies based on hurricane count predictions	International Journal of Production Economics	Science
9	2011	ADIDA, E., DELAURENTIS, P.-C. C. & LAWLEY, M. A.	University of Illinois, USA	IU Center for Health Services & Outcomes	Biomedical Engineering, Purdue University, US	N/A	N/A	Hospital stockpiling for disaster planning	IIE Transactions	Science

Table A 2.1 Continued....

Paper number	Year	Author	First Author	Second Author	Third Author	Fourth Author	Fifth Author	Title	Journal	Type
				Research, USA						
10	2012	YUSHIMITO, W. F., JALLER, M. & UKKUSURI, S.	Rensselaer Polytechnic Institute, USA	Rensselaer Polytechnic Institute, USA	Purdue University, USA	N/A	N/A	A Voronoi-Based Heuristic Algorithm for Locating Distribution Centers in Disasters	Networks and Spatial Economics	Science
11	2013	BERMAN, O., HAJIZADEH, I. & KRASS, D.	University of Toronto, Canada	University of Toronto, Canada	University of Toronto, Canada	N/A	N/A	The maximum covering problem with travel time uncertainty	IIE Transactions	Science

Table A 2.1 Continued....

Paper number	Year	Author	First Author	Second Author	Third Author	Fourth Author	Fifth Author	Title	Journal	Type
12	2014	PENG, M., PENG, Y. & CHEN, H.	University of Electronic Science and Technology of China, China	University of Electronic Science and Technology of China, China	University of Electronic Science and Technology of China, China	N/A	N/A	Post-seismic supply chain risk management : A system dynamics disruption analysis approach for inventory and logistics planning	Computers and Operations Research	Science

Table A 2.2: Disaster types and phases of disaster

Paper number	Paper	Disaster type	Preparedness phase	Response phase
1	2002	Any type	No	Yes
2	2004	Any type	No	Yes
3	2005	Any type	Yes	No
4	2006	Any type	No	Yes
5	2007	Floods	Yes	No
6	2008	Any type	No	Yes
7	2009	Tsunami	Yes	No
8	2010	Hurricane	No	Yes
9	2011	Any type	Yes	No
10	2012	Any type	Yes	No
11	2013	Any type	Yes	No
12	2014	Earthquake	No	Yes

Table A 2.3: Objective function and types of objectives

Paper number	Objective	Type of objective	Levels
1	Minimize cost on the top level and minimize the maximum tour duration among all helicopters	Bi-level	2
2	Minimize unsatisfied demand trough the planning horizon	Mono-objective	1
3	Minimize number of recovery facilities needed	Mono-objective two stage	1
4	Minimize total cost per unit of replenishment	NA	NA
5	Minimize cost and shipment distance	Two-stage	1
6	Minimize cost and penalties	Mono-objective	1
7	Maximize coverage, minimize risk and minimize cost	Multi-objective	1
8	Minimize the expected total cost	Multi-stage	1
9	Minimize cost avoiding shortages	Mono-objective	1
10	Minimize the urgency of the relief demand while maximizing coverage	Mono-objective	1
11	Maximize coverage over all scenarios	NA	NA
12	NA		

Table A 2.4: Identified emergency logistical activities

Paper number	Facility location	Stock pre-positioning (relief items)	Routing	Casualty transportation	relief distribution	Resource and inventory management	Number of topics
1	No	No	No	Yes	Yes	No	2
2	No	No	No	No	Yes	No	1
3	Yes	No	No	No	No	No	1
4	No	No	Yes	No	No	Yes	2
5	Yes	Yes	No	No	Yes	Yes	3
6	No	No	Yes	No	Yes	No	2
7	Yes	No	No	No	No	No	1
8	No	No	No	No	No	Yes	1
9	No	Yes	No	No	No	No	1
10	Yes	No	No	No	No	No	1
11	Yes	No	No	No	No	No	1
12	No	No	No	No	No	Yes	1

Table A 2.5: Model analysis

Paper number	Cost Efficiency or cost in terms of distance and/or time)	Time (delays)	Distance	Coverage	Service (maximize fill rate, demand satisfaction, minimize unmet demand)	Number of facilities	Personnel	Vehicles	Efficiency	Effectiveness
1	Yes	Yes	No	No	No	No	No	No	Yes	Yes
2	No	No	No	No	Yes	No	No	No	No	Yes
3	No	No	No	No	No	Yes	No	No	Yes	No
4	Yes	No	No	No	No	No	No	No	Yes	No
5	Yes	No	Yes	No	No	No	No	No	Yes	Yes
6	Yes	No	No	No	No	No	No	No	Yes	No
7	Yes	No	No	Yes	No	No	No	No	Yes	Yes
8	Yes	No	No	No	No	No	No	No	Yes	No
9	Yes	No	No	No	No	No	No	No	Yes	No
10	No	No	No	No	No	No	No	No	No	Yes
11	No	No	No	No	No	No	No	No	No	No
12	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Table A 2.6: Modelling techniques and solution techniques

Paper number	**Modelling technique**	**Solution technique**	**Application**
1	Optimisation	GAMS XA solver and future research: Iterative coordination heuristic	Case study
2	Optimisation	Lagrangean relaxation for a tailored algorithm	Numerical examples and case study
3	Optimisation	Excel	Case study
4	Optimisation and simulation	Arena for simulation	Case study
5	Optimisation and GIS	Sample average approximation using Lingo	Case study
6	Optimisation	Cplex in GAMS	Numerical examples
7	Optimisation	Heuristic approach based on the NSGA-II	Case study
8	Optimisation	Excel Solver and the simultaneous backward reduction algorithm	Numerical Examples
9	Optimisation and Game Theory	NA	Numerical examples
10	Optimisation	Nelder-Mead based solution of the sub-problem within a Heuristic based on Voronoi diagrams	Numerical experiments and case study
11	Optimisation	Cplex, Greedy heuristic and Lagrangian heuristic according to the case	Numerical examples and case study
12	Simulation (System Dynamics)	NA	Numerical examples

Table A 2.7: Validation technique

Paper number	VALIDATION METHOD	Different type of model (or approaches)	Classic model	Other solution methods (algorithms or solvers) for performance	Sensitivity analysis or scenario analysis	Historical data or current system	Model with and without a feature (sequential vs combined)	Number of validation methods
1	N/A	No	No	No	No	No	No	0
2	Comparison between the results of the algorithm and GAMS, and also comparison of the algorithm on the case study to a greedy heuristic	No	No	Yes	No	No	No	1
3	N/A	No	No	No	No	No	No	0
4	Simulation over several instances	No	No	No	Yes	No	No	1
5	Comparison between the stochastic model and the equivalent deterministic model and sensitivity analysis	Yes	No	No	Yes	No	No	2

Table A 2.7 Continued....

Paper number	VALIDATION METHOD	Different type of model (or approaches)	Classic model	Other solution methods (algorithms or solvers) for performance	Sensitivity analysis or scenario analysis	Historical data or current system	Model with and without a feature (sequential vs combined)	Number of validation methods
6	Comparison between different instances	No	No	No	Yes	No	No	1
7	Comparison between the results of the heuristic and a decomposition technique	No	No	Yes	No	No	No	1
8	Comparison to traditional approaches and different instances	No	No	No	Yes	No	No	1
9	Comparison centralized vs decentralised model, sensitivity analysis	Yes	No	No	Yes	No	No	2
10	Comparison between the results of the heuristics and Baron	No	No	Yes	No	No	No	1

Table A 2.7 Continued....

Paper number	VALIDATION METHOD	Different type of model (or approaches)	Classic model	Other solution methods (algorithms or solvers) for performance	Sensitivity analysis or scenario analysis	Historical data or current system	Model with and without a feature (sequential vs combined)	Number of validation methods
11	Comparison between the results of the heuristics and Baron	No	No	Yes	No	No	No	1
12	Analysis of scenarios and sensitivity analysis	No	No	No	Yes	No	No	1

Appendix 3: Ethical approval report

Aston University Ethics Committee
Aston University
Aston Triangle
Birmingham
B4 7ET
Telephone +44 (0)121 204 3000
Fax +44 (0)121 204 3696

Chairperson: Ms Nichola Seare

Secretary: Mr John Walter

30th May 2014

Dr Elizabeth Bridges

School of Life and Health Sciences

Dear Liz

Study Title: 'Decision support system for last mile relief distribution in India'

REC Reference: Ethics Application A-2014

Protocol Number:

Confirmation of ethical opinion

On behalf of the Committee, I am pleased to confirm a favourable ethical opinion for the above research on the basis described in the application form, protocol and supporting documentation as revised.

The project is approved until the completion date provided it is commenced within two years of the date of this letter and you are required to notify the Committee when the project is completed.

Approved documents

The final list of documents reviewed and approved by the Committee is as follows:

Document	Version	EC Review Date
University Ethics Application Form	One	17/03/2014
Appendix 1: Consent form	One	17/03/2014
Appendix 2: Letter to make the initial contact with people from the Organisations	One	17/03/2014
University Ethics Application Form	Two	20/03/2014
Appendix 1: Consent form	Two	20/03/2014
Appendix 2: Letter to make the initial contact with people from the Organisations	Two	20/03/2014
University Ethics Application Form	Three	27/05/2014

Appendix 1: Consent form	Three	27/05/2014
Appendix 2: Letter to make the initial contact with people from the Organisations	Three	27/05/2014

Statement of compliance

The Committee operates in accordance with the Aston University Ethics policy and procedures:

http://www1.aston.ac.uk/registry/for-staff/regsandpolicies/ethics-policy-and-procedures/

Reporting Requirements

The details of the investigation will be placed on file. You should notify the Secretary of the University Ethics Committee of any adverse events which occur in connection with this study and/or which may alter its ethical consideration, and/or any difficulties experienced by the volunteer subjects.

If you intend to make any future protocol amendments these must be approved by the Ethics Committee prior to implementation. You should also seek approval for any extension of the approved completion date.

Membership

The members of the University Ethics Committee present at the meeting are listed below:

- Professor Richard Booth, Professor of Occupational Health & Safety, Aston University
- Ms Nichola Seare, AHRIC Director, Aston University
- Mr John Walter, Director of Governance, Aston University

REC reference: **Ethics Application A-2014** **Please quote this number on all correspondence**

With the Committee's best wishes for the success of the project

Yours sincerely

J.G. Walter

Secretary of the Ethics Committee

Email: j.g.walter@aston.ac.uk

Appendix 4: Letter to make the initial contact with people from the Organisations

Title: Decision support system for last mile relief distribution in India

Dear Sir/Madam,

I am Priyanka Roy, a second-year PhD student at Aston Business School, Aston University, Birmingham, UK. I am working with operation and information management group. My two supervisors are Dr Pavel Albores (Lecturer) and Dr Christopher Brewster (Lecturer). My project is to build a holistic and integrated logistics model for the last mile relief distribution.

About the project

Earthquakes, Tsunamis, Floods, Hurricanes, Draughts, Terrorist attack; Famine etc. are few names of (natural and manmade) disaster. After an earthquake, the disaster affected people need emergency relief in the form of food, water, medicine, shelters etc. The purpose of disaster relief operation is to rapidly respond with emergency supplies to the affected people during a disaster. Therefore disaster relief distribution operation is always an obvious action, which is performed after a disaster. Last mile relief distribution is the final stage of relief distribution. It refers to supply the relief items from the local distribution centres to the disaster affected people. We will investigate the responsible drivers which affect the operational perspective of the final relief distribution (or last mile relief distribution). Therefore the objective of this project is to create a framework of responsible behavioural factors which affect the performance of last mile relief distribution of NGOs and Government Organisations for the quick and efficient response to the last mile relief distribution operation. The project will examine:

- Identify the theoretical and practical factors which are affecting the final relief distribution performance
- Verify and validate the responsible factors as behavioural factors
- Analyse and justify that the behavioural factors are affecting the emergency logistics field as well as the final relief distribution
- Analyse and justify that coordination is the most important behavioural factor for Indian context
- Integrate coordination into the Indian last mile relief distribution system
- Demonstrate and justify that coordination have a substantial impact on last mile relief distribution performance

We would be very grateful if we could have access to your organisation. In particular, we would like to interview some of your colleagues and if possible have access to some of the data concerning relief distribution decisions. Thus in particular:

1. We would like to interview some of your colleagues (basically those who are involved in the logistics operations e.g. warehouse managers, logistics officers, field officer; relief officer etc.).
2. We would be grateful for access to data concerning the logistics (reports, spreadsheets or other data).
3. We would be grateful if we could attend a couple of internal and external meetings to understand the logistics strategies and logistics processes.
4. We would like to visit some local warehouses in order to obtain a better understanding of inventory management.
5. If it were possible, we would like to visit a disaster affected area.

In return we will make available the results of our research, and provide you with:

1. The logistics model for rapid relief distribution operation.
2. An evaluation of the current strategies of your organisation about relief distribution.
3. Highlight potential areas for improvement in the relief distribution processes.

For more details please contact:

Priyanka Roy,

Aston Business School, UK.

roypl@aston.ac.uk

Tel: +44 (0)121 204 5319).

Best regards

Priyanka Roy

PhD Student

Mobile: +44(0) 7735349022

Address:

Operation and Information Management Group,

Aston Business School

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Birmingham

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United Kingdom

Appendix 5: Information sheet for participants

Project Title: Factors for last mile relief distribution performance in Indian context

Invitation: You are being invited to take part in a research study. The title of the research project is mentioned above and the details of the research project mentioned below. Before you decide it is important for you to understand why the research is being done and what it will involve. Please take the time to read the information carefully.

The purpose of the study: Quick response to the disaster is the key to reduce human casualties. The purpose of this research is to explore the factors, which affect the last mile (final) relief performance for earthquakes in India. More particularly, the objective of this research as follows:

5. Identify the theoretical and practical factors which affect the last mile relief distribution performance;
6. Classify, verify and validate those factors;
7. Identify the major factors for Indian last mile relief distribution, particularly focused on earthquakes;
8. Evaluate the impact of these major factors on Indian last mile relief distribution system performance.

Why have I been chosen: This study will review the emergency logistical decisions during a response operation. The researcher would like to know about the final distribution policy to provide relief goods to the affected people in India. The study will ask about the logistical decisions taken during the final relief distribution time in India. The logistical manager, warehouse manager, relief distribution personnel will be interviewed for this research. Therefore your working experience and knowledge will help the researcher to understand the insight of the relief distribution logistical operation in a practical sense.

What will happen to me if I take part: The duration of the interview will be 45 minutes to 1 hour per participant. You will be interviewed on semi-structured questions, which are prepared by the researcher. The total interview will be voice recorded and this will be called as 'collected data' by the researcher. The interview will take place at your office with prior permission from the responsible authorities. The date and time for this interview will be selected according to your favourable choices. You will be able to withdraw your name as a participant any time before, during and after the interview. Your name can not be withdrawn after the publication of the result in public domain. Your identity will not be disclosed under any circumstances. The collected data will help the researcher to understand the logistical decisions making procedure during the relief distribution time in the response phase.

Are there any potential risks in taking part in the study: The interviews will be carried out in the offices of the relief agency and not in the disaster-affected places. Hence there is no risk or hazard. The researcher does not foresee any ethical issues arising from this.

Do I have to take part: You may choose not to participate in this research, or refuse to answer any question, retract any comment or the full interview up to the point at which the data has been anonymised.

Expenses and Payments: The participation in this research is totally voluntary. Therefore there will be no expenses and payments are involved.

Will my taking part in this study be kept confidential: The identifiable information (original identities) will be stored safely in a separate password protected file for 5 years, as part of the requirement for the academic audit of research. The recordings will be kept under lock and the digital files will be password-protected. The researcher will not disclose any name in the research output.

What will happen to the result of the research study: The researcher will seek to present the results in the academic conferences and in academic publications.

Who is organising and funding the research: The research is funded by Aston business School, Aston University, Birmingham.

The researcher can be contacted at the following address:

Priyanka Roy

PhD Student

Mobile: +44(0) 7735349022

Address:

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This doctoral research is being supervised by

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Who has reviewed the study: The research has been reviewed by Aston University's Ethics Committee.

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Appendix 6: Interview Transcripts

Transcript 1: GCS- Practitioner17 (50-minute long interview):

- Please describe your role in the relief organisation /governmental organisation?

I'm a civil-military coordination (CIMIC) officer within the Canadian Army. My job is to understand the civilian environment where the Canadian troops are deployed, that means the host country population and the international community. I need to try to minimise the impact of the military operations on the civilian populations and also to identify the gaps in the international community activities which could have an impact on the military mission. By example, if the international community isn't able to reach a community and this community spread a disease that's could also spread on the military troop so we will discuss with the international community the possibility that the military troops give the education and the treatment to this community.

- Have you participated in any earthquake disaster relief aid operation? How many? Can you please name them? Selecting one of the operations (please state which one) please explain your participation in that operation? (For example, how do you know about the disaster? What was your role? When did you reach that area? What were the decisions you have to take before reaching that area? What information was available to you? Etc.)

I was deployed in Bosnia and Herzegovina in 2002 as Operation Officer for Psychological operations in Banja Luka.

I was deployed in Afghanistan, Kabul in 2004 as Operation Officer for Civil-military Cooperation (CIMIC) platoon working at the tactical level to support the interim Afghan government and prepare the election.

I was deployed in Afghanistan in 2007, covering the 4 provinces in the South as Provincial Reconstruction Team (PRT) engagement team. I was trying to connect the Afghan National Plan with the development plan of the 4 provinces (Kandahar, Uruzgan, Helmand and Zabul)

I was deployed in Sudan, Khartoum in 2009 as Civil-military cooperation officer at UNMIS HQ. We were 2 CIMIC officers at the HQ and we were trying to support the 6 areas of operations, which means train persons in each area about the CIMIC job and coordinate with the UN agencies as civil affairs, political affairs, child protection, gender unit and Reintegration Unit to identify areas where UN military troops could support them.

I was deployed in Port Au Prince, Haiti in 2010 as Civil-military officer Staff Officer at MINUSTAH HQ. We were 10 CIMIC officers. My task was to identify gaps in the cholera responses, TOMAS hurricane response and election in order to identify the impacts on the security situation and propose action to the military commander. As for the election we identify the lack of information in the IDP's camps and how to vote and we were expecting civilian unrest on the election day so we require to the Haitian organisation in charge of the election to do an information campaign in the IDP's camps, they didn't so we have to adjust the security plan during the election in order to focus on the IDP's camps.

- What are the key factors which affect the earthquake response operation?

Key factors;

- Accurate assessment of the situation
- Prioritisation of the needs
- Understanding of the cultural aspects where the disaster occurs
- Engaging the host country population in the response
- Communicate the plan to the host country population.
- How they related to the disaster phase
- During disaster response phase, the understanding of the situation and where the needs are, are crucial in order to make a distribution plan. The problem is often the barrier language, the non-sharing of information among the organisations, the population who request more than they need and the facts that organisations are limited to reach some communities because of the roads conditions or the security situations.

Also, the population would be more willing to wait if the plan was communicated to them, the fact they don't understand what is going on makes them more worries. The communication plan is as important as the distribution plan.

- How do you manage the whole logistics processes during a disaster?

I can't answer to this one because I have no idea. The only think I can tell is within UN Missions or where the military are deployed we are often supporting request at last minutes from the INGO's to move supplies. In Haiti, during the preparation phase before TOMAS hurricane, the logistic cluster identified just one day before the hurricane the location of their prepositioning position and required to the military component support. That was very difficult to provide as it was last minute. During the hurricane, the INGO's had to stay at home in security until the hurricane passed same for the camp coordinator, the military units were the only one patrolling but they didn't have the equipment to distribute to the population in needs as tents. Everything the military units are distributing is at the expense of the military personnel like the medical supplies each country sending troop to give the military medical officer medical supplies for the troop not for the population. When the military provides medical support or other support it's the military commander, who takes the risk and assesses that the military will not need it until the next military re-supply.

In Haiti, we have the Joint Operation Tasking Centre (JOTC) where all request in support to the UN mission (police, military and civilian component) is screen by this centre. In this centre, we have Haitian representatives, clusters representatives and military and police representatives. It's working well during disaster and was set up after the earthquake of 2010 when they had more than one military chain of command (UN chain of command, US, Canada, France… because each of them have military troops deployed under different command).

- How do you manage the logistic processes in last mile relief distribution (for example managing the relief from the local or field warehouse or distribution centre to the disaster affected area)?

For this one, I can't help you. The only thing I can say is when I am doing the project as CIMIC, I have to apply the Canadian rules and use Canadian code of conduct and mandates even if the project that I am doing is in Afghanistan. We are selecting the survival buildings after the earthquake and then making a joint decision on a criteria tables that we are establishing based on what we want to achieve. Different organisation have different relief items. So they choose the community according to their capacity. And from the central warehouse, the supply of individual agency's relief supposed to arrive at the local level. If any agency needs more relief they need to order from their central warehouse. And the relief will come according to that agency's replenishment policy. Prepositioning gives us the opportunity to reach a population that is cut from distribution road as in Haiti, we knew which road would be impracticable after a hurricane so we send the material to be able to respond on a local basis. This material was under the responsibility of the local authorities. We did the same in Afghanistan but the pre-positioning point was sometimes destroyed or stolen.

I will send you the link of UN Joint logistic centre SOP so you will understand which services they are offering. Also, they are lobbying on the behalf of the organisations to the local authorities to ease the customs process or at other authorities like American army in Haiti to ease the process for the supply fight to come in, same in Sudan.

Usually, we are using the military patrol to fill in need assessment and we trained them before about indicator. We try to use the same form that the local authorities and INGO's. We give the information to OCHA or local authorities and we are looking with them where they need help to fill in the gaps.

What I saw in Haiti for the cholera response is that it is difficult to get what we need in the local market and we have often to look for international suppliers. The UN clusters have warehouses like in Panama where they call first to get re-supply and I guess is the task of theses warehouses to find other supplies.

- Rank the factors which will affect the last mile relief distribution (final relief distribution) from local distribution centre to the disaster affected area? Please add any other factors you consider as important (1 is the factor with the highest impact)

Names of the factors	**Rank**
Coordination	1
Funds	3
Logistics	1
Need assessment	1
Volunteers	3
Safety and security	2
Involvement of local community member	2
Others (…Trust between the organisation and among the organisation and the affected community………)	2
Others (.........Culture issues of the affected community....)	2

- For the distribution procedures, which are the main issues you need to think?

For me, the first criteria will be the security as when a distribution occurs it is really easy to lost control, during relief distribution, which will create stolen of relief materials and a total cause of the whole situation. In Haiti, the INGO's were proceeding at the distribution in 2 different days; the first day they were distribution coupon numbers and on the day of the distribution, only the ticket holder allowed in the distribution area.

- For the set-up of the distribution centres, which are the main issues you need to think?

I have attached a world vision document which could help you for this question. I also attached a document (called reception centre) that we are using to set up a disarmament centre which could make you think about some points as it's a similar concept.

- Could you please explain the distribution procedure during earthquake relief distribution?

- Security situation and security plan at least inform local police and look how to request help
- Location, outside of crow areas in order to avoid
- Communication plan with the local population and local authorities
- Criteria on which the distribution will be held, like after the earthquake in Haiti, the distribution was only among women
- Time required for the distribution as if the person needs to wait for a while they will need water and toilets during the distribution
- Control mechanism during the distribution, the easier way is to require local worker to do the control and give them more than the others as payment
- Moment of the day for the distribution

Usually, we always make a recce the day before of the distribution points; even in Haiti after the earthquake, we were doing it the night before.

- How do you measure the success of your distribution operation?

The success rate depends that what is the need of the community and the fulfilment of those needs. In which level the organisation are able to fulfil the need of the affected community.

- Could you please explain the distribution procedure during earthquake relief distribution?

I will send you some information about this question.

1. What is the most vulnerable situation during distribution in response phase?

I think it is to control the population during the distribution and to avoid to be attacked on road to the distribution points. That is happening often for the military and civilian convoy.

2. What are your strategies to identify eligible recipients?

For TOMAS, the hurricane was on Saturday morning, in the late afternoon, the clusters send 2 teams to do a rapid assessment and send 2 other teams the day after to do a complete assessment. The result of the assessment was discussed among the leaders of each cluster during the Intercluster meeting at the EJOC and there they were deciding who will intervene. I will send you a ppt that we used in Haiti to explain the needs assessment and a ppt explaining the organisations. (called Natural disaster preparedness DPC COUN). In Haiti, they were trying to follow the indication of the Haitian authorities to determine the needs and the prioritisation for the distribution and I think that was going well. In Afghanistan, we tried to do it but the provincial governors were requiring directly to the military units in their areas instead informing the national government and that was a big point of friction.

3. Do you have any strategy for the recipients' registration?

In this case, we are taking the local council's help. They have all the information about the specific community and census report. Some of the organisation are asking a signature when the affected community are receiving the relief items.

Transcript 2: GCS- Practitioner3: (45 minutes long interview):

- Please describe your role in the relief organisation /governmental organisation?

I am a physician. I did my postgraduate in public health and studied disaster management at health sector level mostly response. For last 20 years, I am working in risk reduction and disaster management. I am working in Haiti. Mostly my experience is in Haiti.

- What are the key factors which affect the earthquake response operation?

Several key factors are affecting the disaster response phase. They are as follows:

The level of preparation: If people do not have has a good level of preparation it is very difficult to cope up in the case of disaster. At that time we synchronise or try to do everything it is almost impossible. We have to remember when the disaster strike that the community almost isolated from the world for a specific time that can be 6 hours, can be 1 day, 2 days etc. We have to prepare the community to do that to organise themselves for response phase to be the first responder, also be able to evaluate the situation and ask for what are the needs? That preparation is very important in the case of disaster.

Good response plan: If the people don't have a good level of preparation it is very difficult to cope up with that situation. This is not only the planning it is also working together that can be volunteers or disaster response people. Suppose if you never working as a firefighter, during the emergency time you are calling for such rescue operation. It is very difficult to establish to contact with that person and the confidence on what you are going to do and the confidence for himself how you are acting. Sometimes in the case of emergency you have to act quickly, you have to speak first. If the person does not learn your language and understands what you are acting for, then it is very difficult for that person to perform. In addition to that, if that person or agency cannot work properly, it is hard to work as a team and delaying the response according to the demand. Not only people of the community, all the agency should work together.

Coordination: Coordination is the very important situation. Then another factor is having background data. Like you have agility situation by the time to evaluate the situation you have to quickly react and say what is my need and by the time the disaster is seen on TV you have to act fast. If you want to mobilise especially the international money and resources.

Known data: If you have data and scenario available, when the disaster strike, you have something to begin. You have some information to act quickly for first 48 hours through the scenario. From that you can extrapolate, you can do estimation, use your knowledge that you have and you can make a good projection. Then you can continue to collect the information, which will be more accurate. You can continue to collect the information and still in disaster preparation I will say that a very important factor is to understand the needs to begin your work in the field of disaster.

- How do you manage the whole logistics processes during a disaster?

You have to be prepared. You cannot expect to do something if you are not well prepared or exercised yourself. We have to learn about the specific situation of the country, the specific norm of the country. We need to know the specific law of the country. Sometimes you have time (like a hurricane) to adapt your plan. In the case of an earthquake, it happens suddenly. Nobody can say what is going to happen? If you don't know what are you going to do? How can your feet that situation? After the earthquake, one of the common situation is the difficulty in organising the things (plans, process). The shocks in first 6 hours are very difficult. After that, what to do? The basic needs we have to do is difficult to organise. The volunteers need to adopt the plan during a response. If you have a good plan everybody should know the plan. A clear understanding of the policy is very important.

What do you want to do? What do you expect the policymakers to do? When you have the rough idea what strategy you want to make it? What can be applied at that level? Then we are talking about coordination. For the supply, first of all, we go to the community and tell them "what do you have? What do you need?" Then they told us, "we have nothing and we need everything". That is the situation. Do we need to identify the community resources? For an example, if they are really very poor and they have only one donkey, they can use that for any purpose. Here I want to mean that even they are poor they still have some resources. First, we have to identify what the community have? One of the thing we need to follow additional resources in value and they begin to be positive about the capacity to answer. What are the additional resources and by working for them we have to decide what the additional resources they need? On the basis of their answer, you are going to analyse their needs and find out about the community. There are some challenges can occur during a disaster. Suppose there are 1000 of NGOs are distributing relief to some specific community but there are other communities who did not get any relief after the disaster. You need to cover all the affected community, not the specific community. Now looking at the pattern you have to think what types of mobilisation you have to do. If you are unable to fulfil that mobilisation then you have to contact at the regional level or the national level or the international level. Then when you know what they need and you can go to find the proper partner. In the Haiti case, there are a good number of NGOs involved. When you know the NGOs, you know what they have and propose them to work with the community in a process. Let's see you have a partner who is specialisation in educational support and you propose them for logistics support that partner may want to work for you but it depends on their capacity. They may help. The capacity and the mission segment that exceeds what you have to do? You have to learn about your partner then you have to ask them what they can do? That's why you do active mobilisation. You can ask some country for money, some country for goods and what types of goods they are willing to give you that you have to find. You have to find out. If you have time in your planning process, you will invite all of your partners to the central level to be there. This is the part of your planning process and where you want to add/ what you want to add? At what level you want to add? For an example in Haiti everybody wants to give shelter but that time you don't need shelter you need water sanitation and if you know your partner, you can tell your partner to work on sanitation and you can start negotiation and convince them to work on that matter. Needs assessment is very important: We have several ways to do that. I am going to look at the figure to the need assessment and response. Needs assessments: go first. 2nd we have to ask for. There is a strategy to do that.

- How do you manage the logistic processes in last mile relief distribution (for example managing the relief from the local or field warehouse or distribution centre to the disaster affected area)?

In Haiti earthquake 2010 the final distribution centres are setup into the survival buildings for example office or school. First, a thorough needs assessment was conducted and the basis of those needs assessment the NGOs are supplying the relief. But every NGO has their own capacity and specific relief items. So their central warehouse sends them the relief items and they have their specific community to supply the relief. The relief was supplied according to the needs of the affected people. During relief distribution operation the suitable knowledge of responders is also necessary. For example how to manage the distribution planning, exact knowledge of logistical issues, proper use of technologies and understanding the previous data.

- Rank the factors which will affect the last mile relief distribution (final relief distribution) from local distribution centre to the disaster affected area? Please add any other factors you consider as important (1 is the factor with the highest impact)

Names of the factors	Rank
Coordination	1
Funds	4
Logistics	1
Need assessment	1
Volunteers	2
Safety and security	1
Involvement of local community member	1
Others (…Availability of relief items for the exact timing ………)	2
Others (.........Reduce the competing attitude of the involved NGOs....)	2

- Could you please explain the distribution procedure during earthquake relief distribution?

That depends on what type of things you going to distribute and your specific strategy. You need to have a clear strategic view of the distribution procedure. You need good preparation for distribution. You need a large place, where in and out should be happening very quickly. Easy to handle the task for the people. If you want to distribute successfully, you need a good strategy and good security measure. If you are sometimes cannot wait for the resources from the outside of the country, then we have to do all the methodical procedures, which can take the time and a lot of people's involvement. If the people are waiting more than 2 hours in the queue they begin to start fighting. You have to take special measure. How many people can I distribute at one time? How many people do I need for that? You have to be on time. People should not come before you, that is good for the dignity and then begin the distribution procedure.

- Before starting the distribution procedure what are the issues you need to think about?

The key issues:

How many people are you going to have?

How many resources do you need to distribute?

Where are you going to distribute?

The best place is where the one people can get in and one people can get out.

Security need not only for the distribution but also the served people can get home safely that also needed.

- What is the most vulnerable situation during distribution in response phase?

Distribution is not an easy job. We need a lot of security for everything. Need protection for the young girls and woman. In the planning process, most difficult time is when you are going to stop the distribution. You have to think about the parameters that in that point you will stop the distribution. You have to think about the exact quantity and quality of relief items. Always need to remember that the affected people are the needy population, they cannot wait for a long time. If they are not getting the relief on the exact time, they might die. So the availability of adequate relief items is necessary. And if one NGO is running out of resources, the other NGO can cooperate and work as a partner to supply the relief to the affected community on time.

- How do you measure your success of the work (evaluate your work) for the particular earthquake disaster?

After a disaster, it is necessary to understand the affected people are getting proper food, water, medicine and other necessary relief items according to their needs. The success measure will be satisfied if all the affected population are served with their necessary items and on time.

- Do you have any strategy for the recipients' registration?

Yes, the recipients are identified by the local council or local community.

Transcript 3: GCS- Practitioner6 (34-minute long interview):

4. Please describe your role in the relief organisation /governmental organisation?

I am working in UN OCHA. I am working in OCHA as an information management officer for 7 years.

ABOUT OCHA

OCHA has 4 broad mandates they are: humanitarian advocacy, coordination, resource mobilisation, information management. IM (information management) is a core mandate for OCHA. The main aim of information management is to support the other three mandates, implement the information management strategy in the field and to support the other mandates in the field. In order to do that we have different tools. Our main product is our website. Everybody can access it. You know generally humanitarian work divided into separate clusters. The humanitarian filed categories into different clusters. We support those clusters. In OCHA we help the clusters. Most of the time the cluster will have the capacity to upload the information to the website, sometimes they don't have the capacity. So in that point OCHA help them. If you look at the humanitarian response agencies usually carry out their own mandates, like WFP food distribution, WHO medicine distribution but nobody wants to do coordination. Coordination no one wants to do. OCHA bring everyone to work together. Coordinated information for clusters as well as OCHA has been coordinated by the general assembly try to solve the problem. In any emergency, the emergency response coordinator is the primary coordination.

- Did you participate in any humanitarian relief aid operation? How many? Which are they?

Iraq during the war time, tsunami response Indonesia 205, earthquake Indonesia 2006, flood Indonesia 2007, Peru earthquake 2008.

5. What are the key factors which affect the disaster response phase? How they related to the disaster response phase?

Most important factors are coordination. The biggest problem we have the big chaos. People are trying to make the sense of what happening. Otherwise we help the agencies to make the sense, otherwise, people go out and do whatever they want to do without really understanding the gaps and overlaps. It is important to make sure that the response coordinated and people are talking to each other. As an agency, you will go to the same place where WFP do some food distribution and you might miss other areas where there is a need of food that is the lack of coordination.

- How do you manage the whole logistics processes during a disaster?

Usually, the agency coordinates with each other. They will know like disaster risk reduction. If there is a predictable disaster, WFP will arrange preposition system. But if this is a natural and sudden onset disaster, then they cannot do prepositioning. But most of this country like Kenya...floods, drought, Chronic disaster the agency know what they need. Need assessment is the first step of any disaster. Once you have that kind of disaster WFP food, WHO medicine etc. It will help cluster and come together and share their capacities. If OCHA wants to request assistance then they need to go through the appropriate Cluster, i.e., logistic/transport requests to the Logs Cluster, medical requests to the Health Cluster etc. Whenever possible, such requests should be fulfilled at the Cluster level, either by way of mutual support from other Cluster members or by the allocation of resources available at the Cluster level.

If the request cannot be met at the Cluster level and no civilian means of accomplishing the task are available and the Cluster agrees that the request is valid in terms of sectoral priorities and plans.

In Haiti there are three clusters:

a. Transport/Logistics Support (using existing Logs Cluster form);
b. Escort/Area Security Support
c. Infrastructure/Technical Support

The Transport/Logistics Support the requesting process. If the logistics cluster coordinator is unable to provide transport/logistics support, the request will be forwarded by the logistics cluster to the higher authority for action. For security and infrastructure/technical requests, the requesting organisation must complete a form and have it signed by the relevant cluster leader. For example, support for a health activity must be approved by the health cluster coordinator, for an education activity by the education cluster coordinator. This step is to ensure the activity being supported fits within the overall cluster strategy and priorities. The completed form, with the signature of the cluster coordinator, should be brought to the joint office reception for logging and further action. The joint office of coordination is located on the log base near the cluster briefing area. Where there are two requests concerning a single event, e.g., a request for transport and escorts or security, then two separate request forms are required. The two forms must be cross-referenced, and delivered to the office together, once endorsed by the appropriate cluster(s). This is to avoid the case where security assistance is stood up for a task which the military or police is otherwise unable to support.

6. How do you manage the logistic processes in last mile relief distribution (for example managing the relief from the local or field warehouse or distribution centre to the disaster affected area)?

In the local level, a thorough needs assessment is conducted to understand the need of the affected community. After the needs assessment, the NGOs need to utilise the resources and information. A common situational awareness of the prevailing security and humanitarian situation is created through locally. The OCHA will coordinate the procedures for requesting military or police assistance in support of humanitarian relief operations, which will coordinate the procedures for requesting military or police assistance in support of humanitarian relief operations. As a matter of principle, military assets will only be used as a last resort.

The key aspects of final relief distribution are:

a. A more effective, efficient and coordinated utilisation of military, police and relief;
b. A single point of contact for requests for military or police assistance;
c. Priorities set by the humanitarian coordination mechanism, e.g., the clusters, Humanitarian Country Team (HCT);
d. Sharing knowledge and information among the active organisation is necessary;
e. Correct use of resources/relief is necessary;
f. As during earthquake the affected area have minimum amount of survival building, so though the organisation have sufficient relief but in the local area it is hard to store;
g. Distribution procedure have to be well organised;

7. Rank the factors which will affect the last mile relief distribution (final relief distribution) from local distribution centre to the disaster affected area? Please add any other factors you consider as important (1 is the factor with the highest impact)

Names of the factors	Rank
Coordination	1
Funds	3
Logistics	1
Need assessment	2
Volunteers	3
Safety and security	2
Involvement of local community member	3
Others (…knowledge sharing………)	3
Others (....Reduce competing attitude of the active organisation.........)	3

- For the set-up of the distribution centres, which are the main issues you need to think?

For the distribution centre we need to really identify the needs and for that need, assessment is very important. Suppose there are 10,000 people affected in a place and 500 people affected in another place. So distribution centres should be near to the 10,000 people's area. The distribution centres have to be where there is a need. There are a lot of other issues such as security issues (for that may be population affected), food drop, depends on different sectors and different disaster. More like subject knowledge, in terms of what type of things the affected people need.
In briefly the set-up of the distribution centres depend on:
What is the disaster? Exactly what the affected people need? Where can they manage good security? It depends on different types of disasters and different types of the sector.

- How do you measure the success of your distribution operation?

If the whole distribution procedure successfully complete, that is the success rate of our distribution procedure. Mainly all the affected people need to be served equally. There should not be more suffering because of the relief, as they already lost everything during the disaster.

- Could you please explain the distribution procedure during earthquake relief distribution?

I will send you some internal document to understand the procedure.

- What is the most vulnerable situation during distribution in response phase?

The key issues are "are you really serving the right people, right needs and right items". As disaster situation is a very chaotic situation. Well planning is necessary. There are some incidents happen where some of the community get 2 or 3 times relief items, on the other hand, the other community gets nothing. That's why well-organised planning and communication with the other organisation is necessary. For the volunteer selection, the agency always has the right people. The selection depends on more on skill.

- Before starting the distribution procedure what are the issues you need to think about?

Need assessment is the most vulnerable situation. Need assessment is the first step for disaster relief operation. What are the needs? What are the gaps? These two questions are very important. Needs assessment is an on-going process. Needs change so far. 1st 72 hours all saving life. After three days of 1-month emergency response, after 3 -12 months is recovery, reconstruction and after 12 months risk reduction. The demand of resource is very important during the response. The distribution procedure should not be stopped for any reason, as then there will be more chaos happen. The affected people will not understand that the specific organisation does not have enough relief, they will think that there is some discrimination happening. So in that problematic situation, the other agencies need to help that specific agency by reducing their competing attitude and sharing the resources.
A lot of people ask for maps, human directory etc. to understand the effect of the disaster. Some agencies don't have mapping capacity, then the other agencies help them. The time limit is another very important issue for disaster response. For flood, it always needs contingency planning and clusters. What is our plan? What is our strategy? etc.

- What are your strategies to identify eligible recipients?

A clear need assessment and the local government's help.

- Do you have any strategy for the recipients' registration?

Yes, during the relief distribution, the volunteers ask the affected community for signature or some other documents. But during a disaster they may lose their important document, in that case, some photographs are taken also by the volunteers during relief distribution.

Transcript 4: ICS- Practitioner1: (30-minute long interview):

- Please describe your role in the relief organisation/governmental organisation?

Name of the organisation: National Institute of Disaster Management (Government of India)

Have you participated in any disaster relief aid operation? How many? Can you please name them? Selecting one of the operations (please state which one) please explain your participation in that operation? (For example, how do you know about the disaster? What was your role? When did you reach that area? What were the decisions you have to take before reaching that area? What information was available to you? Etc.)

I was working as a special secretary in the very disaster prone state of India that is Bihar. In Bihar flood is the common disaster, drought is also common there. I worked there during flood situation in 2007, 2009 and 2010. So during this flood situation, I was working at the state level. We are providing instructions, we are providing guidance and we are providing monetary assistance and facilitating the relief, what this is carried out by the district magistrate of District and by the other forces.

- Could you please explain the whole logistics process?

As I serve during the flood, I can give you an example of the logistics process during the flood. In every year flood is coming due to the month of July and August. So before that monsoon season, all the district magistrates are being instructed to procure necessary relief materials like the food grains, We are looking at to repair all the roads, we have to arrange all the shelters, we have to arrange all the important kits etc.

- Can you please explain about earthquake response operation?

For earthquakes, depending on their magnitude, the scale of response and the corresponding role players will be identified and mobilised at the district, state or national levels. Systems will be institutionalised by the DMAs, at various levels, for coordination between the various agencies like central government ministries and departments, state governments, district administration and other stakeholders for an effective post-earthquake response. Most vulnerable and poor community migrated and live in the unsafe lands and risky shelters, so after an earthquake, they are the most affected community. But after an earthquake, they lost everything. So a continuous demand always occurs. The severity of an earthquake is often underestimated, immediately after its occurrence. The preliminary assessment of severity of the earthquake is based on its magnitude and depth collected from online seismological instruments. Field observation data, once available, will be used to make an accurate assessment. Immediately following the occurrence of an earthquake, the IMD will disseminate the details of its magnitude and epicentre to all agencies concerned. This will help the state governments to undertake their response appropriately.

- Can you please explain the relief operation during an earthquake?

Trained community level teams will assist in planning and set up emergency shelters, distributing relief among the affected people, identifying missing people, and addressing the needs of education, healthcare, water supply and sanitation, food etc., of the affected community. Members of these teams will be made aware of the specific requirements of the disaster affected communities. These teams will also assist the government in identifying the most vulnerable people who may need special assistance following an earthquake.

- Rank the factors which will affect the last mile relief distribution (final relief distribution) from local distribution centre to the disaster affected area? Please add any other factors you consider as important (1 is the factor with the highest impact)

Names of the factors	**Rank**
Coordination	1
Funds	1
Logistics	2
Need assessment	2
Volunteers	3
Safety and security	4
Involvement of local community member	5
Others (....culture issue.......)	
Others (.............)	

- Regarding the logistical factors that affect the last mile relief distribution (final relief distribution), can you explain how the decisions made?

Specialised heavy earthmoving equipment and search and rescue equipment are required immediately following an earthquake to clear debris and to carry out search and rescue of trapped people from collapsed structures. State governments will compile a list of such equipment and identify suppliers of such specialised equipment and enter into long-term agreements for their mobilisation and deployment in the event of an earthquake. The IDRN, which is a web-based resource inventory of information on emergency equipment and response personnel available in every district, will be revised and updated frequently. The setting up of relief camps for the people whose houses have been damaged by an earthquake and the provision of basic amenities in such camps involve complex logistics of mobilising relief supplies, tents, water supply and sanitation systems, transport and communication systems, and medical supplies. The DM plans at the state and district levels will address this issue in detail.

- Could you please explain the distribution procedure during disaster relief distribution?

After the disaster, the affected people must be looked after for their safety, security and the wellbeing and provided food, water, shelter, clothing, medical care etc. So as to ensure that the affected people live with dignity. State governments shall be responsible for providing prompt and adequate relief assistance to the victims of disasters. Where necessary free distributions of food shall be made to those who need the food most. The food distribution will be discontinued as soon as possible. Wherever possible dry rations shall be provided for home cooking. A community kitchen for mass feeding shall be organised only for an initial short period following a major disaster, particularly where affected people do not have the means to cook. While providing food assistance, local food practices shall be kept in mind and commodities being provided must be carefully chosen, in consultation with the affected population. Foods must be of good quality, safe to consume and appropriate and acceptable to recipients. Rations for general food distributions shall be adopted to bridge the gap between the affected population's requirements and their own food resources. Food distributed should be of appropriate quality and fit for human consumption.

- What is the most vulnerable situation during distribution in response phase?

The disaster affected people can get the sufficient relief according to their needs. The availability of resources, safety and security, correct need assessment, well-organised distribution planning.

- Before starting the distribution procedure what are the issues you need to think about?

We need to make sure about enough relief items, clear needs assessment analysis, clear communication with the affected community.

- What are your strategies to identify eligible recipients?

We have the census report for every single city, municipality, and village. We use that to identify the eligible recipients.

- Do you have any strategy for the recipients' registration?

We ask the recipients for the signature or their left thump impression.

Transcript 5: ICS- Practitioner12: (40-minute long interview):

- Please describe your role in the relief organisation/governmental organisation?

C.E.O and head of the National NGO

- Have you participated in any earthquake disaster relief aid operation? How many? Can you please name them? Selecting one of the operations (please state which one) please explain your participation in that operation? (For example, how do you know about the disaster? What was your role? When did you reach that area? What were the decisions you have to take before reaching that area? What information was available to you? Etc.)

Yes. Gujrat earthquake 2001, Sikkim earthquake 2011, Orissa cyclone and many others.

- How do you manage the whole logistics processes during a disaster?

If you think about the whole supply chain like what we have to incorporate, then it comes to your warehouses, once it is in the central warehouse, it goes to the regional warehouse and then to the wholesaler and then to the retailer and from retailer, it goes to the consumer. When there is a variation in the demand you know the wolvi effect. So if there is a minor change in demand, the whole inventory levels have greater impact and ease you as you know away from customer move towards the manufacturing unit. But here if you compare the same supply chain with humanitarian supply chain, the demands keep on fluctuating. So you can understand how the inventories are build up at various levels. In the humanitarian supply chain, it is not only the manufacturer who is supplying the goods to the central warehouse, here come the donors also those who donate goods. So when there is a disaster immediately the suppliers to the warehouses are shoots up at the same time despatches also shoots up. So you have to really handle huge loads of received goods and despatches and at the same time, you have to manage what space you have? How are you moving to store the supplied goods within the warehouse? How you are going to retrieve it again managing various methods FIFO and water to manage the supply. So there is a tremendous pressure to the warehouse manager when he is going through this disaster response phase. When these goods are despatch to the field I am just going to add some few levels in between with this question. In the field, you may have your temporary warehouses where all these goods are coming. So there you may not have all those goods handling facilities storage space all those issues are there which we face generally. In the warehouse's procedure you may plan beforehand this is what your pin card, stock card. This is how you are going to measure your laser whatever or you may use your software. But again in the moment of goods is so high and a variety of goods you have been receiving. So it definitely creates some chaos in the field. The energy what you can say that you are supposed to ensuring that the proper goods are received and proper goods are delivered to the people that are tremendous because you get a lot of unwanted supplies from many places. It is not systematic things that the standard package you get this thing and that is to be delivered to X, Y, Z location. So the packaging size, shape, weight everything keeps on changing. It depends on particular donors or suppliers. You may have your organisation's standard but whatever you are procuring or you are supplying from your own stocks that only have the standards. But if something is coming from other donor or supplier which you are trying to tap in this emergency phase, they will not be able to supply you in the standard format which you are expecting. So you should be in the position to handle those goods also. It also depends on the terranes like in India north side we all have hilly terranes, in between you have flat planes and then as you go to the south you have this sisho area. So challenges for each area, when you are trying to deliver are different. Every geographical area, every population have the challenge. There are several external and internal factors which are responsible for this.

- How do you manage the logistic processes in last mile relief distribution (for example managing the relief from the local or field warehouse or distribution centre to the disaster affected area)?

Like I can quote you the Sikkim earthquake where after the earthquake because of landslides some of the areas are not accessible at all. And when people try to transport the relief goods or even something like water purification units and all the useful necessary units it was very difficult. If you want to take it by helicopter also it was not possible because of the weather condition. It was the dense fog, then heavy rainfall. So these are the things which pose the actual challenges when you try to transport in terms of emergencies. But definitely, there are ways or you can say means you should use to transport these goods. It depends on particular actually situation. It is not a standard supply chain. It is a humanitarian supply chain and its need to be customised according to the situation. I think stress need to be given on coordination that is the most important thing actually. If you have some resources and I have some resources then if we come together, then I think we will be in better position in delivering goods.

- Rank the factors which will affect the last mile relief distribution (final relief distribution) from local distribution centre to the disaster affected area? Please add any other factors you consider as important (1 is the factor with the highest impact)

Names of the factors	**Rank**
Coordination	1
Funds	3
Logistics	1
Need assessment	2
Volunteers	1
Safety and security	2
Involvement of local community member	3
Others (……Trust……)	2
Others (.....Sharing knowledge........)	1

- For the set-up of the distribution centres, which are the main issues you need to think?

If you see the warehouses, there are permanent structures of warehouses that you need have before the disaster struck. In that warehouse you have your proper management system, inventory management system whatever it is, you are maintaining your stocks and all that. There is another warehousing that usually tries to have near the place of disaster. So that whatever the supplies are coming in those are stocks near that area and then you distribute those relief supplies. So when you are talking about efficiency as you move towards the disaster affected area the efficiency of the warehouse that you have near the disaster prone area and the efficiency of the warehouse which is far away from that affected area is totally different. Because a load of that temporary warehouse or newly establish warehouse is having that will be something different and people who are working in those warehouses they may not be work together before, they may not know each other. Therefore, to get that organise it take some time. Then many people start dumping the materials during the disaster time, which may or may not be used for the response. So that also creates another problem, actually for the warehouse manager. So that eats away all the facility that you are trying to have to handle the relief supplies efficiently. It definitely releases your efficiency. So there are many factors which contribute towards reducing the minimising of efficiency during a disaster.

- How do you measure the success of your distribution operation?

The primary success will be a measure that according to the needs you can satisfy the demand of the specific community. Correct use of proper distribution planning. For example, when I was in Pakistan flood there are already established field warehouse, from where we can cover the affected area. Therefore, no need to establish the field warehouse. But in Haiti everywhere was affected, therefore need to established field warehouse. The other issues are for the establishment of field warehouse need very big area, distance from the disaster affected area, condition of road network from the field warehouse, near from the water supply, safety and security issues.

- Could you please explain the distribution procedure during earthquake relief distribution?

Again it depends on the situation actually. Generally what we do we carry out assessment; we have our beneficiary identification criteria. We stock beneficiaries' item based on that criteria and in the coordination of local authority. Then goods are delivered, inform the beneficiaries that on such and such dates the such and such items will be handed over to them and they have to come with a coupon which we give them beforehand. As soon as they come the distribution point we hand over the particular relief supply to them and take their signature and for the verification, they return us these coupon/cards what we give them earlier. This is the process what we follow for distribution.

There is some forecasting method. It happens but not immediately follow the emergencies. As the time passes everything falls into places. And if the disaster is very big, then actually this demand forecasting can be done in a proper way. Otherwise, it is very difficult to forecast how much you require in which state because there are in the logistical challenge in between the supplies. So this person needs to demand anything from the field but how we can deliver these reliefs that are the challenge in the field. This demand forecasting we can start actually after considerable time only in the emergencies. The base is the needs assessment.

- What is the most vulnerable situation during distribution in response phase?

I think it is to control the population during the distribution and to avoid to be attacked on road to the distribution points. That is happening often for the military and civilian convoy. We need a lot of security for everything. Need protection for the young girls and woman. In the planning process, most difficult time is when you are going to stop the distribution. You have to think about the parameters that in that point you will stop the distribution.

- Before starting the distribution procedure what are the issues you need to think about?

The key issues:

- How many people are you distributing?
- How many resources do you need to distribute?
- Where are you going to distribute?
- The best place is where the one people can get in and one people can get out.
- Security is not only for the distribution but also the served people can get home safely that also needed.
- Communication plan with the local population and local authorities;
- Criteria on which the distribution will be held, like after the earthquake in Haiti, the distribution was only among women;
- Time required for the distribution as if the person needs to wait for a while they will need water and toilets during the distribution;
- Control mechanism during the distribution, the easier way is to require local worker to do the control and give them more than the others as payment;
- Moment of the day for the distribution;

What are your strategies to identify eligible recipients?

Needs assessment and local municipality's help.

- Do you have any strategy for the recipients' registration?

We have registration policy. It starts from the need assessments and also another registration happened before the distribution starts.

Appendix 7: The final themes of LMRD

Table A 7.1: Final themes of LMRD

<table>
<tr><th>Final codes</th><th>Identifying themes</th><th>Reviewing themes</th><th>Defining the themes</th></tr>
<tr><td>Relief</td><td rowspan="4">Decisions:
Facility; Inventory; Logistics; Shelter; Mutual aid; Allocation; Distribution; Transportation; Prioritisation; Demand; Minimum; Maximum; Logistics; Coverage; Volunteers; Warehouse; Distribution centre; Performance; Replenishment of items; Relief supply; Distance;</td><td rowspan="6">FACTORS:
Coordination::
Collaboration; Cooperation; Sharing; Joint Decisions; Risk sharing; Communication; Mutual aid;
Trust::
Active agencies; Disaster-affected population; Reliability; Necessity;
Needs assessment::
Situation; Needs; Feedback; Information; Analysis;
Culture Role::
Food; Clothes; Habits; Geographical region; Culture;
Correct knowledge::
Knowledge; Volunteers; Responders; Available data; Suitable;
Knowledge of local area::</td><td rowspan="6">FACTORS::
Coordination;
Trust;
Culture role;
Needs assessment feedback;
Current knowledge of the responders;
Minimising the competing attitude of the involved agencies;
Involvement of local community member;
Knowledge of local area;</td></tr>
<tr><td>Distribution</td></tr>
<tr><td>Cooperation</td></tr>
<tr><td>Fund</td></tr>
<tr><td>Logistics</td><td rowspan="2">Factors:
Cooperation;
Sharing;
Culture;
Trust;
Protocol;
Knowledge;</td></tr>
<tr><td>Time</td></tr>
</table>

Table A 7.1 Continued....

Final codes	Identifying themes	Reviewing themes	Defining the themes
	Needs assessment; Active organisations; Knowledge; Involvement; Geographical region; Competition between the agencies; Local community member; Safety; Situation; Security; Responsible; Collaboration;	Involvement; Local; Community member; Affected neighbourhood; Prioritisation; Vulnerable area; Involvement; Distribution Relief; **Competition between the agencies::** Active agencies; Joint Decisions; Minimise; Disaster-affected population; Service; Fund; Necessary; Demand; Distribution relief;	
Communication Risk	Prioritisation;	**PERFORMANCE MEASURE:** **Coverage::** Maximise; Relief distribution; Affected area; Demand satisfaction; Decision; Shortages of food, water and medicine; **Distance::** Affected area; Damages of road network; Efficiency; Maximise;	**PERFORMANCE MEASURES::** Maximise the coverage level; Minimise the time delay; Maximise the distance efficiency; Maximise the demand served; Prioritisation of service efficiency; Maximise the allocation efficiency;
Protocol Relief chain Mutual aid Important Minimum	**Performance:** Activity; Risk; Analysis; Relief chain; Last mile relief distribution; Final relief chain; Measure; Disaster-affected population; Involved agencies;		

Table A 7.1 Continued....

Final codes	Identifying themes	Reviewing themes	Defining the themes
	Environment; Behaviour; Information; Group; Service; Efficiency; Feedback;	Distribution relief; Availability; Facility; Shelter; Distribution centre; Relief supply; Information; **Time::** Relief supply; Demand satisfaction; Minimise; Delay; Distribution relief; Disaster-affected population; **Allocation::** Maximise; Facility; Relief items; Inventory; Volunteers; Vehicles; Decision; Measure; Efficiency; **Cost::** Fund; Minimise; Efficiency; Logistics; Decision; **Demand::** Maximise; Satisfaction; Efficiency; Distribution relief; Inventory; Shelter; Facility;	Maximise the cost efficiency; Minimise the risks;

Table A 7.1 Continued....

Final codes	Identifying themes	Reviewing themes	Defining the themes
		Disaster Affected community; Decision; **Service::** Disaster-affected population; Prioritisation; Efficiency; Needs; Distribution relief; **Risk::** Social; Environmental; Minimise; Disaster-affected population; Security; Reliability; Vulnerable area; Safety; Responders; Volunteers; Relief items; Shelter;	
Analysis			
Food			
Clothes			
Affected neighbourhood			
Demand			
Necessity			
Reliability			
Feedback			
Maximum			
Allocation			
Safety			
Security			
Joint decision			
Vulnerable area			
Facility			
Data			
Involvement			
Situation			
Transportation			
Inventory			

Table A 7.1 Continued....

Final codes	Identifying themes	Reviewing themes	Defining the themes
Responders			
Volunteers			
Final relief			
Understand			
Availability			
Warehouse			
Community			
Geographical region			
Collaboration			
Culture			
Local area			
Community members			
Habits			
Sharing knowledge			
Distance			
Capacity			
Factors			
Delay			
Shortage			
Volume			
Shelter			
Needs assessment			
Demand			
Damage of road network			
Trust			
Competition between the agencies			
Coverage level			
Efficiency			
Prioritisation			
Replenishment of items			
Distribution centre			
Measure			
Vehicle			
Information			
Needs			
Relief supply			

Table A 7.1 Continued....

Final codes	Identifying themes	Reviewing themes	Defining the themes
Local community member			
Responsible group			
LMRD			
Performance			
Disaster-affected population			
Earthquake			
Knowledge			

Appendix 8: Invitation letter from SAARC

SAARC

SAARC DISASTER MANAGEMENT CENTRE

NIDM Building, 5-B I.P. Estate, IIPA Campus, Mahatma Gandhi Road, New Delhi - 110002, India

Dr. O. P. Mishra, Head
Geological Disasters Division

No. 4980 /SDMC/Misc. Corr./2012
March 26, 2012

Dear Dr. Albores and Dr. Brewster,

I would like to appreciate your meticulous guidance and supervision of your research scholar, Mrs Priyanka Roy, who has been pursuing her higher study on "Disaster logistics modelling" leading to Ph.D degree from the Aston Business School, Birmingham, U. K. Ms. Roy had sent us her research proposal, which we found very interesting and educative indeed! She has expressed her desire to interact with our South Asia Association for Regional Cooperation (SAARC) Disaster Management Centre (SDMC), New Delhi to understand voluminous regional activities of SDMC, which are being carried out by the centre dedicatedly in the field of Disaster Management for the mutual benefit of SAARC Member Countries (Afghanistan, Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan, and Sri Lanka).

We would like to extend our invitation to Mrs. Priyanka Roy to visit our organisation and give a seminar about her work on disaster logistics modelling on any of days in the month of May, 2012. Mrs Roy may plan to take advantage of this invitation to observe our work and she can conduct interviews of officials and our staffs for the purposes of her thesis. SDMC may enrich its understanding on disaster logistics and last mile relief processes through interactions with your visiting researcher to our centre.

Unfortunately, while we welcome her visit, we are unable to cover the costs of her visit. Kindly arrange to provide her cost of visit to our Centre for better understanding of both institutions.

Thanking you with best regards!

Yours truly,

Mishra
26/03/2012

(O. P. MISHRA)

Copy for information to:

(i) Director, SDMC, New Delhi

(ii) Ms. Priyanka Roy, PhD Student, Operation & Information Management Centre, Aston Business School, Aston University, Birmingham, B4 7ET, United Kingdom.

Phone : 91-11-23702445, 23724085, Fax: 91-11-23702446, e-mail: dir.sdmc@gmail.com

Appendix 9: LMRD model coding without coordination

```
globals [
 demand-today        ;; the demand occurs at all retailers everyday
 colors              ;; colors for plot
 ]

breed [players player]

;; There are 2 types of directed links in the model
;; demand links for order placement, and supply links for shipment pipeline

directed-link-breed [supply-links supply-link]
supply-links-own [orders-filled pair-demand-link]

directed-link-breed [demand-links demand-link]
demand-links-own [orders-placed back-orders]

players-own [
 role        ;; 3 roles in the model: district warehouse, agency and responders
 base-stock       ;; we assume players are operating under base-stock policy
 on-hand
```

```
  backlog
  inventory-position    ;; inventory equals to on-hand inventory + pipeline inventory - back-
orders
  last-received
  pen-color
  cost
  id-number   ;; id-number is used to distinguish players with the same role
  demand-history   ;; a list consisting of the demands in a few past days
  revenue          ;; revenue from selling the products
  safety-factor        ;; parameter determining to what extent the player want to keep safety
inventory against demand uncertainty
  current-supplier
]

to setup
  ca
  set colors [5 15 25 35 45 55 65 75 85 95 105 115 125 135 67 117 28 18 37]  ;; a list of 20
colors
  set colors shuffle colors
  layout
  initialize
  resize-shape
  reset-plots
```

```
  reset-ticks
end


to go
  if ticks >= days-of-simulation [stop]
  set demand-today daily-demand          ;; generate today's demand
  place-order-to-up
  receive-order-from-up
  process-order-from-down
  summarize
  update-policy
  resize-shape
  tick
end


to update-policy               ;; the players can update their inventory policy according to their demand record
  ask players with [role = "agency"][
    set base-stock cal-base-stock-level demand-history lead-time-coordinationhub-agency
  ]
  ask players with [role = "responder"][
    set base-stock cal-base-stock-level demand-history lead-time-agency-responder
  ]
```

```
end


;; Inventory operations

;; ************************

to place-order-to-up

  ask players with [role = "agency"][

                                        ;; in this model, we assume all players are operating under base-stock policy

    let amount-to-order max list (base-stock - inventory-position) 0   ;; that is once the inventory position is below the base stock level,

                                        ;; we order the quantity equal to the difference between inventory position and base stock level

                                        ;; otherwise, don't place any order



    ask my-out-demand-links [set orders-placed 0]                ;; since in a network supply chain, a player can order from multiple upstream nodes

    ask who-to-order [set orders-placed amount-to-order]          ;; choose one node each time

  ]

  ask players with [role = "responder"][

                                     ;; in this model, we assume all players are operating under base-stock policy

    let amount-to-order max list (base-stock - inventory-position) 0   ;; that is once the inventory position is below the base stock level,

                                        ;; we order the quantity equal to the difference between inventory position and base stock level
```

```
                                        ;; otherwise, don't place any order
ask my-out-demand-links [set orders-placed amount-to-order]
 ]
end
to receive-order-from-up
 ask players [
  if role = "agency" or role = "responder" [
   set last-received sum [first orders-filled] of my-in-supply-links     ;; take out the first item in the supply-link pipeline
   ask my-in-supply-links [set orders-filled but-first orders-filled]     ;; remove it from the pipeline
   set on-hand on-hand + last-received                                    ;; add it to the current on-hand inventory

  ]
  if role = "coordinationhub" [set on-hand 3000]                           ;; we assume the supplier has unlimited supply
 ]
end
to process-order-from-down
 ask players [
  let new-orders 0                       ;; for distributors and suppliers, new orders equal to the sum of the orders-placed of all in-demand-links
```

if role = "agency" or role = "coordinationhub" [set new-orders sum [orders-placed] of my-in-demand-links]

if role = "responder" [set new-orders demand-today]

set demand-history lput new-orders demand-history ;; record the new-order in the demand history

set demand-history but-first demand-history ;; delete the earliest demand history on the record, in order to keep the record length the same

let orders-requested new-orders + backlog ;; besides new orders, back-orders also need to be satisfied

let orders-to-ship min list orders-requested on-hand ;; if there is sufficient inventory, ship the requested amount

;; if not sufficient inventory, ship whatever on-hand

if role = "agency" [set revenue revenue + 2 * orders-to-ship] ;; revenue for distributors is 2 for each unit shipped

if role = "responder" [set revenue revenue + 3 * orders-to-ship] ;; revenue for is 3 for each unit shipped

set backlog max list 0 (backlog - on-hand + new-orders) ;; the unsatisfied demand is counted as backlog (or back-orders)

let rest-amount orders-to-ship ;; allocate total shipping amount to each downstream node

```
foreach sort my-out-supply-links [ ?1 ->
  ask ?1 [                          ;; quota to each supply link is proportional the sum of back-orders and new orders of the pair demand link
    let quota sum [back-orders] of pair-demand-link + sum [orders-placed] of pair-demand-link
    let ship-to-this-link 0               ;; if no order, ship nothing, and put 0 in the supply link
    if orders-requested > 0 [             ;; if positive order, ship according to the quota
      set ship-to-this-link min list ceiling (quota * orders-to-ship / orders-requested) rest-amount
    ]                                     ;; note that we use ceiling to guarantee the integrity of the shipping quantity
    set rest-amount rest-amount - ship-to-this-link
    set orders-filled lput ship-to-this-link orders-filled   ;; put the ship quantity at the last place of the supply pipeline
    ask pair-demand-link [set back-orders max list 0 (quota - ship-to-this-link)]  ;; update the back-orders in the pair demand link
  ]
]
set on-hand on-hand - orders-to-ship   ;; reduce the shipped quantity from the on-hand inventory
]
end
to summarize
 ask players [
  let pipeline sum [sum orders-filled] of my-in-supply-links   ;; calculate the pipeline inventory (inventory in-transit) for each player
```

```
  set inventory-position on-hand + pipeline - backlog          ;; recalculate the inventory position

  let cost-add (0.5 * on-hand + 2 * backlog)                   ;; calculate inventory holding cost and
backlog penalty

  set cost cost + cost-add                                     ;; update the cost

 ]


 ask players with [role = "agency" or role = "responder"] [ ;; plots

  plot-on-hand-inventory

  plot-profit

 ]

end


;; ****************************

to-report y-locations [number]        ;; report a list of y-coordinates that would evenly distribute
the "number" players on y-axis

 let y-list []


 let interval round ((2 * (max-pycor - 3) + 1) / (number + 1))


 let current-pos (- max-pycor + 3 + interval)


 repeat number [

  set y-list lput current-pos y-list
```

```
  set current-pos current-pos + interval
 ]
 report y-list
end
to layout
 set-default-shape players "circle"
 set-default-shape links "arc"

 create-players 1 [
  setxy -12 12
  set color red
  set role "coordinationhub"
  set size 5
  set label "C-1"              ;; the size of the supplier won't be updated in the simulation
 ]
 create-players 1 [
  setxy -12 0
  set color red
  set role "coordinationhub"
  set size 5
  set label "C-2"
 ]
```

```
  create-players 1 [
  setxy -12 -12
  set color red
  set role "coordinationhub"
  set size 5
  set label "C-3"
  ]
 create-players 1 [
   setxy 0 0
   set color blue
   set role "agency"
 ]
 create-players 1 [
   setxy 0 9
   set color blue
   set role "agency"
 ]
create-players 1 [
   setxy 0 -9
   set color blue
   set role "agency"
 ]
```

```
create-players 1 [
    setxy 7 0
    set color green
    set role "responder"
]
create-players 1 [
    setxy 7 6
    set color green
    set role "responder"
]
create-players 1 [
    setxy 7 12
    set color green
    set role "responder"
]
create-players 1 [
    setxy 7 18
    set color green
    set role "responder"
]
create-players 1 [
```

```
    setxy 7 -7
    set color green
    set role "responder"
  ]
create-players 1 [
    setxy 7 -14
    set color green
    set role "responder"
  ]
let d-number 1
  foreach sort players with [role = "agency"][ ?1 ->   ;; assign each distributor an id-number, and
label them with the id-number
   ask ?1[
    set label word "A-" d-number
    set id-number d-number
    set d-number d-number + 1
   ]
  ]
let r-number 1
  foreach sort players with [role = "responder"][ ?1 ->    ;; assign each retailer an id-number,
and label them with the id-number
   ask ?1[
    set label word "R-" r-number
```

```
      set id-number r-number
      set r-number r-number + 1
    ]
  ]
let index 0
  foreach sort players with [role = "agency" or role = "responder"][ ?1 ->
    ask ?1[
      set pen-color item index colors    ;; assign each distributor and retailer a different plot pen color
      set index index + 1
    ]
  ]
ask player 4  [
    create-demand-link-to player 0    ;; create demand and supply links between distributors and retailers
    create-supply-link-from player 0
  ]

 ask player 3  [
    create-demand-link-to player 1    ;; create demand and supply links between distributors and retailers
    create-supply-link-from player 1
  ]
```

```
ask player 5  [
   create-demand-link-to player 2     ;; create demand and supply links between distributors and
retailers
   create-supply-link-from player 2
 ]

ask player 8  [
   create-demand-link-to player 4     ;; create demand and supply links between distributors and
retailers
   create-supply-link-from player 4
 ]
ask player 9  [
   create-demand-link-to player 4     ;; create demand and supply links between distributors and
retailers
   create-supply-link-from player 4
 ]
ask player 6  [
   create-demand-link-to player 3     ;; create demand and supply links between distributors and
retailers
   create-supply-link-from player 3
 ]
ask player 7  [
   create-demand-link-to player 3    ;; create demand and supply links between distributors and
retailers
```

```
   create-supply-link-from player 3

 ]


ask player 10  [

   create-demand-link-to player 5     ;; create demand and supply links between distributors and retailers

   create-supply-link-from player 5

 ]

ask player 11  [

   create-demand-link-to player 5    ;; create demand and supply links between distributors and retailers

   create-supply-link-from player 5

 ]

  ask supply-links [                              ;; define the pair demand link of each supply link, the link with the same ends

   set pair-demand-link demand-links with [end1 = [end2] of myself and end2 = [end1] of myself]

  ]

end

to initialize

ask players [

   if role = "agency" [

     set base-stock initial-stock-agency  ;; set the initial base-stock level and on-hand inventory to "initial-stock-distributor"
```

```
set on-hand initial-stock-agency

ask my-out-demand-links [

 set orders-placed 0

 set back-orders 0

 ]


;; create a list with all elements equal to 0, with the length equals to "lead-time-supplier-distributor"

;; representing the supply pipeline between the supplier and the distributor


ask my-in-supply-links [set orders-filled n-values lead-time-coordinationhub-agency [0]]

]

if role = "responder" [

 set base-stock initial-stock-responder

 set on-hand initial-stock-responder

ask my-out-demand-links [

 set orders-placed 0

 set back-orders random 0

 ]

;; create a list with all elements equal to 0, with the length equals to "lead-time-distributor-retailer"

;; representing the supply pipeline between the distributor and the retailer
```

```
    ask my-in-supply-links [set orders-filled n-values lead-time-agency-responder [0]]

   ]

   if role = "coordinationhub"[

    set on-hand 10000

   ]

   set backlog 0

   set inventory-position on-hand - backlog

  ]

ask players [    ;; randomly assign the safety-factor to players

   set cost 0      ;; the higher safety factor  means that the player is willing to keep higher safety
inventory against the demand uncertainty

   set revenue 0

   set safety-factor 1.5 + random-float 1

   set demand-history n-values record-length [""]  ;; set the demand history as a list with empty
elements, with the length equals to "record-length"

   ]

end

to resize-shape    ;; visualize the on-hand stock via size of the turtle

  ask players with [role = "agency" or role = "responder"][

   set size 0.5 * (sqrt on-hand)

  ]

end

to reset-plots          ;; clear all plots and create plot pens for each player
```

```
  clear-all-plots
  ask players with [role = "agency" or role = "responder"][
    create-plot-pens
  ]
end
to create-plot-pen [my-plot]
  set-current-plot my-plot
  create-temporary-plot-pen label  ;; name the plot pen with the player's label
  set-plot-pen-color pen-color
end
to create-plot-pens
  create-plot-pen "total profit"       ;; one plot for total profit
  create-plot-pen "on-hand inventory"  ;; one plot for on-hand inventory level
end
to plot-profit
  set-current-plot "total profit"
  set-current-plot-pen label
  plot revenue - cost
end
to plot-on-hand-inventory
set-current-plot "on-hand inventory"
set-current-plot-pen label
```

```
plot on-hand

end

;; Demand distribution generation

;; ************************************

to-report daily-demand              ;; we design three mechanisms for generating the daily demand, which can be chosen in the chooser

  if distribution = "deterministic"

  [report deterministic-demand]     ;; deterministic demand means the demand is constant, there is no uncertainty


  if distribution = "poisson"       ;; poisson demand means that the daily demand follows Poisson distribution

    [report random-poisson mean-for-poisson]


  if distribution = "normal"        ;; normal demand means that the daily demand follows truncated normal distribution (modified in this model)

    [report truncated-normal mean-for-normal std-for-normal lower-bound-for-normal upper-bound-for-normal]

end

to-report truncated-normal [mean-value std-value min-value max-value]      ;; there are 4 parameters for the truncated normal distribution

  let random-num random-normal mean-value std-value                      ;; we first generate a random-normal number according to the mean value and standard-deviation value

  ifelse random-num > max-value or random-num < min-value
```

[report round (min-value + random-float (max-value - min-value))] ;; if the value is beyond the min-value and max-value, report a random number within the range

[report round random-num] ;; if the value is within the min-value and max-value, report the rounding of this number

end

;; **

to-report cal-base-stock-level [demand-list delay] ;; calculate base-stock based on demand-history

let numbers filter is-number? demand-list ;; during the first few days, not all the elements in the demand history are numbers, but ""

let mean-value mean numbers ;; calculate mean value

let std 0

if length numbers >= 2[;; calculate the standard deviation of the demand history

set std standard-deviation numbers

] ;; according to inventory theories, the base-stock level is usually calculate according to mean and std and supply delays

report round (mean-value * (delay + 1) + safety-factor * std * (sqrt (delay + 1))) ;; "+1" because of the order processing delay

end

to-report who-to-order ;; report the demand link that has the lowest back-orders, so that the player will choose to order from this one

let min-back-order min [back-orders] of my-out-demand-links ;; find out the minimum back-order

let sorted-links [] ;; prepare an empty list

```
foreach sort my-out-demand-links [ ?1 ->          ;; if the back-orders of the demand links equals to the minimum back-order
  ask ?1 [                               ;; add the demand link to sorted-links list
    if back-orders = min-back-order [set sorted-links lput self sorted-links]
  ]
]
ifelse member? current-supplier sorted-links [    ;; if the current-supplier (actually the corresponding demand link) is among the demand links with the minimum back-order
  report current-supplier                  ;; choose the current supplier due to customer loyalty
][
let chosen-one one-of sorted-links              ;; if not, choose one from the demand links with the minimum back-order
set current-supplier chosen-one               ;; then transfer the supplier to this one
report chosen-one
]
end
```

Appendix 10: LMRD model coding partial coordination

```
globals [
  demand-today         ;; the demand occurs at all retailers everyday
  colors               ;; colors for plot
  ]

breed [players player]

;; There are 2 types of directed links in the model
;; demand links for order placement, and supply links for shipment pipeline

directed-link-breed [supply-links supply-link]
supply-links-own [orders-filled pair-demand-link]

directed-link-breed [demand-links demand-link]
demand-links-own [orders-placed back-orders]

players-own [
  role           ;; 3 roles in the model: coordination hub, agency, and responders
  base-stock     ;; we assume players are operating under base-stock policy
  on-hand
  backlog
```

```
  inventory-position    ;; inventory equals to on-hand inventory + pipeline inventory - back-orders
  last-received
  pen-color
  cost
  id-number        ;; id-number is used to distinguish players with the same role
  demand-history   ;; a list consisting of the demands in a few past days
  revenue          ;; revenue from selling the products
  safety-factor        ;; parameter determining to what extent the player want to keep safety inventory against demand uncertainty
  current-supplier
]

to setup
  ca
  set colors [5 15 25 35 45 55 65 75 85 95 105 115 125 135 67 117 28 18 37]  ;; a list of 20 colors
  set colors shuffle colors
  layout
  initialize
  resize-shape
  reset-plots
  reset-ticks
```

```
end

to go
  if ticks >= days-of-simulation [stop]
  set demand-today daily-demand          ;; generate today's demand
  place-order-to-up
  receive-order-from-up
  process-order-from-down
  summarize
  update-policy
  resize-shape
  tick
end

to update-policy                ;; the players can update their inventory policy according to their demand record
  ask players with [role = "agency"][
    set base-stock cal-base-stock-level demand-history lead-time-coordinationhub-agency
  ]
  ask players with [role = "responder"][
    set base-stock cal-base-stock-level demand-history lead-time-agency-responder
  ]
end
```

```
;; Inventory operations

;; *************************

to place-order-to-up

 ask players with [role = "agency"][

                                    ;; in this model, we assume all players are operating under base-stock policy

   let amount-to-order max list (base-stock - inventory-position) 0   ;; that is once the inventory position is below the base stock level,

                                    ;; we order the quantity equal to the difference between inventory position and base stock level

                                    ;; otherwise, don't place any order



   ask my-out-demand-links [set orders-placed 0]              ;; since in a network supply chain, a player can order from multiple upstream nodes

   ask who-to-order [set orders-placed amount-to-order]       ;; choose one node each time

 ]

 ask players with [role = "responder"][

                                    ;; in this model, we assume all players are operating under base-stock policy

   let amount-to-order max list (base-stock - inventory-position) 0   ;; that is once the inventory position is below the base stock level,

                                    ;; we order the quantity equal to the difference between inventory position and base stock level

                                    ;; otherwise, don't place any order
```

```
  ask my-out-demand-links [set orders-placed amount-to-order]

 ]

end

to receive-order-from-up

 ask players [

  if role = "agency" or role = "responder" [

   set last-received sum [first orders-filled] of my-in-supply-links     ;; take out the first item in the supply-link pipeline

   ask my-in-supply-links [set orders-filled but-first orders-filled]     ;; remove it from the pipeline

   set on-hand on-hand + last-received     ;; add it to the current on-hand inventory



  ]

  if role = "coordinationhub" [set on-hand 3000]     ;; we assume the supplier has unlimited supply

 ]

End

to process-order-from-down

 ask players [

  let new-orders 0     ;; for distributors and suppliers, new orders equal to the sum of the orders-placed of all in-demand-links
```

if role = "agency" or role = "coordinationhub" [set new-orders sum [orders-placed] of my-in-demand-links]

if role = "responder" [set new-orders demand-today]

set demand-history lput new-orders demand-history ;; record the new-order in the demand history

set demand-history but-first demand-history ;; delete the earliest demand history on the record, in order to keep the record length the same

let orders-requested new-orders + backlog ;; besides new orders, back-orders also need to be satisfied

let orders-to-ship min list orders-requested on-hand ;; if there is sufficient inventory, ship the requested amount

;; if not sufficient inventory, ship whatever on-hand

if role = "agency" [set revenue revenue + 2 * orders-to-ship] ;; revenue for distributors is 2 for each unit shipped

if role = "responder" [set revenue revenue + 3 * orders-to-ship] ;; revenue for is 3 for each unit shipped

set backlog max list 0 (backlog - on-hand + new-orders) ;; the unsatisfied demand is counted as backlog (or back-orders)

let rest-amount orders-to-ship ;; allocate total shipping amount to each downstream node

foreach sort my-out-supply-links [?1 ->

ask ?1 [;; quota to each supply link is proportional the sum of back-orders and new orders of the pair demand link

let quota sum [back-orders] of pair-demand-link + sum [orders-placed] of pair-demand-link

let ship-to-this-link 0 ;; if no order, ship nothing, and put 0 in the supply link

```
if orders-requested > 0 [              ;; if positive order, ship according to the quota
  set ship-to-this-link min list ceiling (quota * orders-to-ship / orders-requested) rest-amount
  ]                                    ;; note that we use ceiling to guarantee the integrity of the shipping quantity
  set rest-amount rest-amount - ship-to-this-link
  set orders-filled lput ship-to-this-link orders-filled   ;; put the ship quantity at the last place of the supply pipeline
  ask pair-demand-link [set back-orders max list 0 (quota - ship-to-this-link)]  ;; update the back-orders in the pair demand link
  ]
 ]
set on-hand on-hand - orders-to-ship   ;; reduce the shipped quantity from the on-hand inventory
 ]
end
to summarize
 ask players [
  let pipeline sum [sum orders-filled] of my-in-supply-links   ;; calculate the pipeline inventory (inventory in-transit) for each player
  set inventory-position on-hand + pipeline - backlog          ;; recalculate the inventory position
  let cost-add (0.5 * on-hand + 2 * backlog)                   ;; calculate inventory holding cost and backlog penalty
  set cost cost + cost-add                                     ;; update the cost
 ]
```

```
ask players with [role = "agency" or role = "responder"] [  ;; plots
   plot-on-hand-inventory
   plot-profit
 ]
end
;; ****************************
to-report y-locations [number]        ;; report a list of y-coordinates that would evenly distribute the "number" players on y-axis
 let y-list []
let interval round ((2 * (max-pycor - 3) + 1) / (number + 1))
let current-pos (- max-pycor + 3 + interval)
repeat number [
   set y-list lput current-pos y-list
   set current-pos current-pos + interval
 ]
 report y-list
end
to layout
 set-default-shape players "circle"
 set-default-shape links "arc"
create-players 1 [
   setxy -10 0
   set color red
```

```
  set role "coordinationhub"
  set size 5
  set label "C-1"              ;; the size of the supplier won't be updated in the simulation
 ]
create-players 1 [
    setxy 0 0
    set color blue
    set role "agency"
 ]
create-players 1 [
    setxy 0 9
    set color blue
    set role "agency"
 ]
create-players 1 [
    setxy 0 -9
    set color blue
    set role "agency"
 ]
create-players 1 [
    setxy 7 0
    set color green
```

```
    set role "responder"
  ]
  create-players 1 [
    setxy 7 6
    set color green
    set role "responder"
  ]
  create-players 1 [
    setxy 7 12
    set color green
    set role "responder"
  ]
  create-players 1 [
    setxy 7 18
    set color green
    set role "responder"
  ]
  create-players 1 [
    setxy 7 -7
    set color green
    set role "responder"
  ]
```

```
create-players 1 [
    setxy 7 -14
    set color green
    set role "responder"
  ]
let d-number 1
  foreach sort players with [role = "agency"][ ?1 ->   ;; assign each distributor an id-number, and label them with the id-number
   ask ?1[
    set label word "A-" d-number
    set id-number d-number
    set d-number d-number + 1
   ]
  ]
let r-number 1
  foreach sort players with [role = "responder"][ ?1 ->    ;; assign each retailer an id-number, and label them with the id-number
   ask ?1[
    set label word "R-" r-number
    set id-number r-number
    set r-number r-number + 1
   ]
  ]
```

```
 let index 0
  foreach sort players with [role = "agency" or role = "responder"][ ?1 ->
    ask ?1[
      set pen-color item index colors    ;; assign each distributor and retailer a different plot pen color
      set index index + 1
    ]
  ]
ask player 7  [
    create-demand-link-to player 2    ;; create demand and supply links between distributors and retailers
    create-supply-link-from player 2
 ]
ask player 6   [
    create-demand-link-to player 2    ;; create demand and supply links between distributors and retailers
    create-supply-link-from player 2
 ]
ask player 5  [
    create-demand-link-to player 1    ;; create demand and supply links between distributors and retailers
    create-supply-link-from player 1
 ]
ask player 4  [
```

```
   create-demand-link-to player 1     ;; create demand and supply links between distributors and retailers
   create-supply-link-from player 1
 ]
ask player 8  [
   create-demand-link-to player 3     ;; create demand and supply links between distributors and retailers
   create-supply-link-from player 3
 ]
ask player 9 [
   create-demand-link-to player 3     ;; create demand and supply links between distributors and retailers
   create-supply-link-from player 3
 ]
ask players with [role = "agency"] [
   create-demand-links-to players with [role = "coordinationhub"]          ;; create demand and supply links between supplier and distributors
   create-supply-links-from players with [role = "coordinationhub"]
  ]
ask supply-links [                              ;; define the pair demand link of each supply link, the link with the same ends
   set pair-demand-link demand-links with [end1 = [end2] of myself and end2 = [end1] of myself]
  ]
```

```
end

to initialize

ask players [

  if role = "agency" [

    set base-stock initial-stock-agency  ;; set the initial base-stock level and on-hand inventory to "initial-stock-distributor"

    set on-hand initial-stock-agency

    ask my-out-demand-links [

      set orders-placed 0

      set back-orders 0

      ]

 ;; create a list with all elements equal to 0, with the length equals to "lead-time-supplier-distributor"

 ;; representing the supply pipeline between the supplier and the distributor

ask my-in-supply-links [set orders-filled n-values lead-time-coordinationhub-agency [0]]

  ]

  if role = "responder" [

    set base-stock initial-stock-responder

    set on-hand initial-stock-responder

 ask my-out-demand-links [

      set orders-placed 0

      set back-orders random 0

      ]
```

```
;; create a list with all elements equal to 0, with the length equals to "lead-time-distributor-retailer"
 ;; representing the supply pipeline between the distributor and the retailer
ask my-in-supply-links [set orders-filled n-values lead-time-agency-responder [0]]
   ]
   if role = "coordinationhub"[
     set on-hand 3000
   ]
   set backlog 0
   set inventory-position on-hand - backlog
  ]
ask players [    ;; randomly assign the safety-factor to players
   set cost 0      ;; the higher safety factor  means that the player is willing to keep higher safety inventory against the demand uncertainty
   set revenue 0
   set safety-factor 1.5 + random-float 1
   set demand-history n-values record-length [""]  ;; set the demand history as a list with empty elements, with the length equals to "record-length"
   ]
end
to resize-shape    ;; visualize the on-hand stock via size of the turtle
  ask players with [role = "agency" or role = "responder"][
   set size 0.5 * (sqrt on-hand)
```

```
 ]
end
to reset-plots          ;; clear all plots and create plot pens for each player
  clear-all-plots
  ask players with [role = "agency" or role = "responder"][
    create-plot-pens
  ]
end
to create-plot-pen [my-plot]
  set-current-plot my-plot
  create-temporary-plot-pen label  ;; name the plot pen with the player's label
  set-plot-pen-color pen-color
end
to create-plot-pens
  create-plot-pen "total profit"       ;; one plot for total profit
  create-plot-pen "on-hand inventory"  ;; one plot for on-hand inventory level
end
to plot-profit
  set-current-plot "total profit"
  set-current-plot-pen label
  plot revenue - cost
end
```

```
to plot-on-hand-inventory

  set-current-plot "on-hand inventory"

  set-current-plot-pen label

  plot on-hand

end

;; Demand distribution generation

;; ***********************************

to-report daily-demand          ;; we design three mechanisms for generating the daily demand, which can be chosen in the chooser

  if distribution = "deterministic"

    [report deterministic-demand]    ;; deterministic demand means the demand is constant, there is no uncertainty


  if distribution = "poisson"       ;; poisson demand means that the daily demand follows Poisson distribution

    [report random-poisson mean-for-poisson]


  if distribution = "normal"        ;; normal demand means that the daily demand follows truncated normal distribution (modified in this model)

    [report truncated-normal mean-for-normal std-for-normal lower-bound-for-normal upper-bound-for-normal]

end

to-report truncated-normal [mean-value std-value min-value max-value]      ;; there are 4 parameters for the truncated normal distribution
```

```
  let random-num random-normal mean-value std-value                    ;; we first generate a
random-normal number according to the mean value and standard-deviation value

  ifelse random-num > max-value or random-num < min-value

  [report round (min-value + random-float (max-value - min-value))]     ;; if the value is beyond
the min-value and max-value, report a random number within the range

  [report round random-num]                                ;; if the value is within the min-value
and max-value, report the rounding of this number

end

;; ***************************************************************

to-report cal-base-stock-level [demand-list delay]     ;; calculate base-stock based on demand-
history

  let numbers filter is-number? demand-list          ;; during the first few days, not all the elements
in the demand history are numbers, but ""

  let mean-value mean numbers                        ;; calculate mean value


  let std 0

  if length numbers >= 2[                            ;; calculate the standard deviation of the demand
history

    set std standard-deviation numbers

  ]

                                         ;; according to inventory theories, the base-stock level is
usually calculate according to mean and std and supply delays

  report round (mean-value * (delay + 1) + safety-factor * std * (sqrt (delay + 1)))  ;; "+1"
because of the order processing delay

end
```

to-report who-to-order ;; report the demand link that has the lowest back-orders, so that the player will choose to order from this one

let min-back-order min [back-orders] of my-out-demand-links ;; find out the minimum back-order

let sorted-links [] ;; prepare an empty list

foreach sort my-out-demand-links [?1 -> ;; if the back-orders of the demand links equals to the minimum back-order

ask ?1 [;; add the demand link to sorted-links list

if back-orders = min-back-order [set sorted-links lput self sorted-links]

]

]

ifelse member? current-supplier sorted-links [;; if the current-supplier (actually the corresponding demand link) is among the demand links with the minimum back-order

report current-supplier ;; choose the current supplier due to customer loyalty

][

let chosen-one one-of sorted-links ;; if not, choose one from the demand links with the minimum back-order

set current-supplier chosen-one ;; then transfer the supplier to this one

report chosen-one

]

end

Appendix 11: LMRD model coding with coordination

globals [

demand-today ;; the demand occurs at all retailers everyday

```
  colors              ;; colors for plot
  ]

breed [players player]

;; There are 2 types of directed links in the model
;; demand links for order placement, and supply links for shipment pipeline

directed-link-breed [supply-links supply-link]
supply-links-own [orders-filled pair-demand-link]

directed-link-breed [demand-links demand-link]
demand-links-own [orders-placed back-orders]

players-own [
  role          ;; 3 roles in the model: coordination hub, agency and responders
  base-stock      ;; we assume players are operating under base-stock policy
  on-hand
  backlog
  inventory-position    ;; inventory equals to on-hand inventory + pipeline inventory - back-
orders
  last-received
  pen-color
```

```
  cost
  id-number        ;; id-number is used to distinguish players with the same role
  demand-history    ;; a list consisting of the demands in a few past days
  revenue          ;; revenue from selling the products
  safety-factor        ;; parameter determining to what extent the player want to keep safety
inventory against demand uncertainty
  current-supplier
]
to setup
  ca
  set colors [5 15 25 35 45 55 65 75 85 95 105 115 125 135 67 117 28 18 37]  ;; a list of 20
colors
  set colors shuffle colors
  layout
  initialize
  resize-shape
  reset-plots
  reset-ticks
end
to go
  if ticks >= days-of-simulation [stop]
  set demand-today daily-demand          ;; generate today's demand
  place-order-to-up
```

```
  receive-order-from-up
  process-order-from-down
  summarize
  update-policy
  resize-shape
  tick
end

to update-policy                ;; the players can update their inventory policy according to their
demand record
  ask players with [role = "agency"][
    set base-stock cal-base-stock-level demand-history lead-time-coordinationhub-agency
  ]
  ask players with [role = "responder"][
    set base-stock cal-base-stock-level demand-history lead-time-agency-responder
  ]
end

;; Inventory operations
;; *************************
to place-order-to-up
  ask players with [role = "agency" or role = "responder"][
                                              ;; in this model, we assume all players are
operating under base-stock policy
```

```
  let amount-to-order max list (base-stock - inventory-position) 0   ;; that is once the inventory
position is below the base stock level,
                                                   ;; we order the quantity equal to the difference
between inventory position and base stock level
                                                   ;; otherwise, don't place any order

  ask my-out-demand-links [set orders-placed 0]                ;; since in a network supply
chain, a player can order from multiple upstream nodes
  ask who-to-order [set orders-placed amount-to-order]          ;; choose one node each time
 ]
end
to receive-order-from-up
 ask players [
  if role = "agency" or role = "responder" [
   set last-received sum [first orders-filled] of my-in-supply-links     ;; take out the first item
in the supply-link pipeline
   ask my-in-supply-links [set orders-filled but-first orders-filled]     ;; remove it from the
pipeline
   set on-hand on-hand + last-received                          ;; add it to the current on-hand
inventory
  ]
  if role = "coordinationhub" [set on-hand 10000]                ;; we assume the supplier
has unlimited supply
 ]
end
```

to process-order-from-down

ask players [

let new-orders 0 ;; for distributors and suppliers, new orders equal to the sum of the orders-placed of all in-demand-links

if role = "agency" or role = "coordinationhub" [set new-orders sum [orders-placed] of my-in-demand-links]

if role = "responder" [set new-orders demand-today] ;; for retailers, new orders simply equal to today's demand

set demand-history lput new-orders demand-history ;; record the new-order in the demand history

set demand-history but-first demand-history ;; delete the earliest demand history on the record, in order to keep the record length the same

let orders-requested new-orders + backlog ;; besides new orders, back-orders also need to be satisfied

let orders-to-ship min list orders-requested on-hand ;; if there is sufficient inventory, ship the requested amount

;; if not sufficient inventory, ship whatever on-hand

if role = "agency" [set revenue revenue + 2 * orders-to-ship] ;; revenue for distributors is 2 for each unit shipped

if role = "responder" [set revenue revenue + 3 * orders-to-ship] ;; revenue for is 3 for each unit shipped

set backlog max list 0 (backlog - on-hand + new-orders) ;; the unsatisfied demand is counted as backlog (or back-orders)

```
let rest-amount orders-to-ship      ;; allocate total shipping amount to each downstream node

foreach sort my-out-supply-links [ ?1 ->

 ask ?1 [                          ;; quota to each supply link is proportional the sum of back-
orders and new orders of the pair demand link

  let quota sum [back-orders] of pair-demand-link + sum [orders-placed] of pair-demand-
link

  let ship-to-this-link 0              ;; if no order, ship nothing, and put 0 in the supply link

  if orders-requested > 0 [             ;; if positive order, ship according to the quota

   set ship-to-this-link min list ceiling (quota * orders-to-ship / orders-requested) rest-
amount

  ]                                ;; note that we use ceiling to guarantee the integrity of the
shipping quantity

  set rest-amount rest-amount - ship-to-this-link

  set orders-filled lput ship-to-this-link orders-filled   ;; put the ship quantity at the last place
of the supply pipeline

  ask pair-demand-link [set back-orders max list 0 (quota - ship-to-this-link)]  ;; update the
back-orders in the pair demand link

 ]

]

set on-hand on-hand - orders-to-ship   ;; reduce the shipped quantity from the on-hand inventory

]

end
```

```
to summarize
 ask players [
   let pipeline sum [sum orders-filled] of my-in-supply-links   ;; calculate the pipeline inventory (inventory in-transit) for each player
   set inventory-position on-hand + pipeline - backlog          ;; recalculate the inventory position
   let cost-add (0.5 * on-hand + 2 * backlog)                   ;; calculate inventory holding cost and backlog penalty
   set cost cost + cost-add                                     ;; update the cost
 ]
ask players with [role = "agency" or role = "responder"] [  ;; plots
   plot-on-hand-inventory
   plot-profit
 ]
end
;; ****************************
to-report y-locations [number]        ;; report a list of y-coordinates that would evenly distribute the "number" players on y-axis
 let y-list []
let interval round ((2 * (max-pycor - 3) + 1) / (number + 1))
let current-pos (- max-pycor + 3 + interval)
repeat number [
   set y-list lput current-pos y-list
   set current-pos current-pos + interval
```

```
 ]
 report y-list
end
to layout
 set-default-shape players "circle"
 set-default-shape links "arc"
 create-players 1 [
  setxy -10 0
  set color red
  set role "coordinationhub"
  set size 5                ;; the size of the supplier won't be updated in the simulation
 ]
ask patches with [pxcor = 0 and (member? pycor y-locations num-of-agencies)] [ ;; evenly layout the distributors in the middle
  sprout-players 1 [
   set color blue
   set role "agency"
  ]
 ]
ask patches with [pxcor = 10 and (member? pycor y-locations num-of-responders)] [ ;; evenly layout the retailers on the right
  sprout-players 1 [
   set color green
```

```
      set role "responder"
    ]
  ]
let d-number 1
  foreach sort players with [role = "agency"][ ?1 ->   ;; assign each distributor an id-number, and label them with the id-number
    ask ?1[
      set label word "A-" d-number
      set id-number d-number
      set d-number d-number + 1
    ]
  ]
let r-number 1
  foreach sort players with [role = "responder"][ ?1 ->     ;; assign each retailer an id-number, and label them with the id-number
    ask ?1[
      set label word "R-" r-number
      set id-number r-number
      set r-number r-number + 1
    ]
  ]
let index 0
  foreach sort players with [role = "agency" or role = "responder"][ ?1 ->
```

```
   ask ?1[
     set pen-color item index colors    ;; assign each distributor and retailer a different plot pen color
     set index index + 1
   ]
  ]
ask players with [role = "responder"] [
   create-demand-links-to players with [role = "agency"]     ;; create demand and supply links between distributors and retailers
   create-supply-links-from players with [role = "agency"]
  ]
  ask players with [role = "agency"] [
   create-demand-links-to players with [role = "coordinationhub"]        ;; create demand and supply links between supplier and distributors
   create-supply-links-from players with [role = "coordinationhub"]
  ]
ask supply-links [                              ;; define the pair demand link of each supply link, the link with the same ends
   set pair-demand-link demand-links with [end1 = [end2] of myself and end2 = [end1] of myself]
  ]
end
to initialize
ask players [
```

```
  if role = "agency" [
    set base-stock initial-stock-agency   ;; set the initial base-stock level and on-hand inventory to "initial-stock-distributor"
    set on-hand initial-stock-agency
    ask my-out-demand-links [
      set orders-placed 0
      set back-orders 0
      ]
;; create a list with all elements equal to 0, with the length equals to "lead-time-supplier-distributor"
;; representing the supply pipeline between the supplier and the distributor

    ask my-in-supply-links [set orders-filled n-values lead-time-coordinationhub-agency [0]]
  ]
  if role = "responder" [
    set base-stock initial-stock-responder
    set on-hand initial-stock-responder

    ask my-out-demand-links [
      set orders-placed 0
      set back-orders random 0
      ]
```

```
    ;; create a list with all elements equal to 0, with the length equals to "lead-time-distributor-retailer"

    ;; representing the supply pipeline between the distributor and the retailer


    ask my-in-supply-links [set orders-filled n-values lead-time-agency-responder [0]]

   ]

   if role = "coordinationhub"[

    set on-hand 3000

   ]

   set backlog 0

   set inventory-position on-hand - backlog

  ]

ask players [    ;; randomly assign the safety-factor to players

   set cost 0      ;; the higher safety factor  means that the player is willing to keep higher safety inventory against the demand uncertainty

   set revenue 0

   set safety-factor 1.5 + random-float 1

   set demand-history n-values record-length [""]  ;; set the demand history as a list with empty elements, with the length equals to "record-length"

   ]

end

to resize-shape    ;; visualize the on-hand stock via size of the turtle

  ask players with [role = "agency" or role = "responder"][
```

```
    set size 0.5 * (sqrt on-hand)
  ]
end
to reset-plots          ;; clear all plots and create plot pens for each player
  clear-all-plots
  ask players with [role = "agency" or role = "responder"][
    create-plot-pens
  ]
end
to create-plot-pen [my-plot]
  set-current-plot my-plot
  create-temporary-plot-pen label  ;; name the plot pen with the player's label
  set-plot-pen-color pen-color
end
to create-plot-pens
  create-plot-pen "total profit"       ;; one plot for total profit
  create-plot-pen "on-hand inventory"  ;; one plot for on-hand inventory level
end
to plot-profit
  set-current-plot "total profit"
  set-current-plot-pen label
  plot revenue - cost
```

```
end

to plot-on-hand-inventory
  set-current-plot "on-hand inventory"
  set-current-plot-pen label
  plot on-hand
end

;; Demand distribution generation
;; ****************************************

to-report daily-demand              ;; we design three mechanisms for generating the daily demand, which can be chosen in the chooser
  if distribution = "deterministic"
    [report deterministic-demand]   ;; deterministic demand means the demand is constant, there is no uncertainty

  if distribution = "poisson"       ;; poisson demand means that the daily demand follows Poisson distribution
    [report random-poisson mean-for-poisson]

  if distribution = "normal"        ;; normal demand means that the daily demand follows truncated normal distribution (modified in this model)
    [report truncated-normal mean-for-normal std-for-normal lower-bound-for-normal upper-bound-for-normal]
end
```

```
to-report truncated-normal [mean-value std-value min-value max-value]      ;; there are 4 parameters for the truncated normal distribution

  let random-num random-normal mean-value std-value                        ;; we first generate a random-normal number according to the mean value and standard-deviation value

  ifelse random-num > max-value or random-num < min-value

  [report round (min-value + random-float (max-value - min-value))]     ;; if the value is beyond the min-value and max-value, report a random number within the range

  [report round random-num]                                  ;; if the value is within the min-value and max-value, report the rounding of this number

end

;; ************************************************************

to-report cal-base-stock-level [demand-list delay]     ;; calculate base-stock based on demand-history

  let numbers filter is-number? demand-list          ;; during the first few days, not all the elements in the demand history are numbers, but ""

  let mean-value mean numbers                        ;; calculate mean value



  let std 0

  if length numbers >= 2[                            ;; calculate the standard deviation of the demand history

    set std standard-deviation numbers

  ]

                              ;; according to inventory theories, the base-stock level is usually calculate according to

mean and std and supply delays
```

```
 report round (mean-value * (delay + 1) + safety-factor * std * (sqrt (delay + 1)))  ;; "+1" because of the order processing delay

end

to-report who-to-order  ;; report the demand link that has the lowest back-orders, so that the player will choose to order from this one

 let min-back-order min [back-orders] of my-out-demand-links  ;; find out the minimum back-order

 let sorted-links []                    ;; prepare an empty list

 foreach sort my-out-demand-links [ ?1 ->          ;; if the back-orders of the demand links equals to the minimum back-order

   ask ?1 [                            ;; add the demand link to sorted-links list

     if back-orders = min-back-order [set sorted-links lput self sorted-links]

   ]

 ]

 ifelse member? current-supplier sorted-links [      ;; if the current-supplier (actually the corresponding demand link) is among the demand links with the minimum back-order

   report current-supplier                    ;; choose the current supplier due to customer loyalty

 ][

 let chosen-one one-of sorted-links              ;; if not, choose one from the demand links with the minimum back-order

 set current-supplier chosen-one              ;; then transfer the supplier to this one

 report chosen-one

 ]

end
```

Appendix 12: Sensitivity analysis results

Table A 12.1: 2 involved agencies financial efficiency

Involved agency	**Without coordination**	**With coordination**	**Gap in percentage between with and without coordinated model about cost efficiency**
Agency 1	-25212	-23144	8%
Agency 2	-24656	-23100	
Average cost efficiency in the system	-24934	-23122.1	

Table A 12.2: 3 involved agencies financial efficiency

Involved agency	**Without coordination**	**With coordination**	**Gap in percentage between with and without coordinated model about cost efficiency**
Agency 1	-22212	-22144	15%
Agency 2	-21656	-17400	
Agency 3	-21968	-17853	
Average cost efficiency in the system	-21945	-19133	

Table A 12.3: 4 involved agencies financial efficiency

Involved agency	Without coordination	With coordination	Gap in percentage between with and without coordinated model about cost efficiency
Agency 1	-19934	-17024	15%
Agency 2	-19003	-16509	
Agency 3	-18660	-16632	
Agency 4	-17660	-15368	
Average cost efficiency in the system	-18814.2	-16383.3	

Table A 12.4: 5 involved agencies financial efficiency

Involved agency	Without coordination	With coordination	Gap in percentage between with and without coordinated model about cost efficiency
Agency 1	-12086	-10049	16%
Agency 2	-12359	-10460	
Agency 3	-12115	-10216	
Agency 4	-12511	-10339	
Agency 5	-12041	-11766	
Average cost efficiency in the system	-12222.2	-10565.9	

Table A 12.5: 6 involved agencies financial efficiency

Involved agency	**Without coordination**	**With coordination**	**Gap in percentage between with and without coordinated model about cost efficiency**
Agency 1	-10086	-9048.6	17%
Agency 2	-11359	-9459.7	
Agency 3	-11115	-9216.4	
Agency 4	-11511	-9838.5	
Agency 5	-11041	-9766.1	
Agency 6	-10944	-9002	
Average cost efficiency in the system	-11009.2	-9388.55	

Table A 12.6: 7 involved agencies financial efficiency

Involved agency	**Without coordination**	**With coordination**	**Gap in percentage between with and without coordinated model about cost efficiency**
Agency 1	-9085.7	-8048.6	18%
Agency 2	-9359	-7459.7	
Agency 3	-10115	-8216.4	
Agency 4	-9511	-7838.5	
Agency 5	-10041	-9266.1	
Agency 6	-8944	-7002	
Agency 7	-9432	-8666	
Average cost efficiency in the system	-9498.16	-8071.04	

Appendix 13: Case study 1 result for Sanitation kits, kitchen kits or temporary shelter kits agency on-hand inventory for the individual agency

Table A 13.1: Case study 1 inventory

	With coordination	**Partial coordination**	**Without coordination**
Agency (Distribution centres) 1	6211	6343	6945
Agency (Distribution centres) 2	5995	6057	6389
Agency (Distribution centres) 3	5923	6990	6924
Average	6043	6463.34	6752.67

Appendix 14: Case study 1 result for Sanitation kits, kitchen kits or temporary shelter kits: agency cost efficiency for the individual agency

Table A 14.1: Case Study 1 cost efficiency

	With coordination	**Partial coordination**	**Without coordination**
Agency (Distribution centres) 1	-70634	-76835	-80388
Agency (Distribution centres) 2	-69463	-72346	-76220
Agency (Distribution centres) 3	-62337	-76896	-78522
Average	-67478	-75359	-78376.7