PREdictive model for DISaster response configuration (PREDIS decision platform)

A research submitted for the degree of

Doctor of Philosophy

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JUNE 2015

ABSTRACT:

The extraordinary conditions of a disaster, require the mobilisation of all available resources, inducing the rush of humanitarian partners into the affected area. This phenomenon called the proliferation of actors, causes serious problems during the disaster response phase including the oversupply, duplicated efforts, lack of planning. The aim of this research is to provide a solution to reduce the partner proliferation problem. To that end the main research question is put forward as "How to reduce the proliferation of partners in a disaster response"? Panel analysis of the historic record of 4,252 natural onset disasters between 1980 to 2013 via regression analysis, MA and AHP gives rise to the formation of a predictive decision-making platform called PREDIS. It is capable of predicting the human impact of the disaster (fatality, injured, homeless) of up to 3% of errors and enables the decision makers to estimate the required needs for each disaster and prioritises them based on the disaster type and socio-economics of the affected country. It further renders it possible to rank and optimise the desired partners based on the decision maker's preferences. Verification of the PREDIS through a simulation game design using a sample group of decision makers, show that this technique enables the user to decide within one hour after the disaster strike using the widely available data at the time of the disaster. It also enables non-experts to decide almost identically to experts in terms of the similarity of the choices and the speed of the decision.The lack of an extensive database for the potential humanitarian partners from which to choose, is the limitation of this research in addition to the lack of standardised set of minimum requirements for the suitable partners.The model is also as strong as its data feed which is inconsistent in various humanitarian sources.

Keywords:Decision-making,VO,Disaster, AHP, MAUT,Simulation game,Proliferation of

partners, Collaborative networks.

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“The present is the past rolled up for action, and the past is the present unrolled for understanding…History smiles at all attempts to force its flow into theoretical patterns or logical grooves; it plays havoc with our generalizations, breaks all our rules; history is baroque”.

(Durant and Durant, Philosophy of history)

“If you take into account the conflagrations and earthquakes, which devouring or overwhelming whole cities, destroy the inhabitants by thousands; in a word, if you add together all the dangers with which these causes are always threatening us, you will see how dearly nature makes us pay for the contempt with which we have treated her lesson”.

(Jean-Jacques Rousseau, A discourse on inequality)

ACKNOWLEDGEMENT

First of all, I long to thank all the giants that every researcher has to stand upon their shoulders to see further. I also would like to extend my sincerest thanks and appreciation to those patient souls who helped me further this end.

I would like to extend my gratitude to all of the faculty and staff in the Brunel business school. I would first like to recognize Dr. Ramzi El-Haddadeh and Dr. Emel Aktas, my advisors, for their time and kind guidance, sharing their vast knowledge, and all the scientific and emotional support they spared me in the completion of this research. They walked me through the whole process, and without their consistent instructions, and constructive criticises, this research would have failed to reach the present form. Thanks are also extended to all the members of the Brunel Doctoral cohort who have contributed immensely to my personal and professional time at Brunel.

Gratitude is extended to Dr. Emma Ball from Middlesex University and Prof. David Greenberg from New York University for their guidance in the statistical aspects of the research. My special thanks go to Prof. Jay W. Forrester from Massachuset Institute of Technology, Prof. Mike Lewis from the University of Bath, Dr.Tal Ben-Zvi from Stevens Institute of Technology, Dr. Marco Greco from University of Cassino and Southern Lazio and Dr. Manuel Gentile from Palermo Institute for Educational Technologies for their guidance towards the simulation game conducted in the research. The advice provided by these individuals proved invaluable to my research.

Appreciation is also expressed to Prof. Andy Neely from Cambridge University, Prof. Umit Bititci from Heriot-Watt University, Prof. Gerald Midgley from university of Hull, Dr.

Ricardo Rodriguez-Ulloa from Pontifical Catholic University of Chile, Dr.Antonis Bikakis from University college London and Dr. Roman Belavkin from Middlesex University for their constructive insights which indirectly contributed to the development of the research.

Obviously my deepest gratitude and special recognition goes out to my family, for their support, encouragement and patience during my long pursuit of the intellectual enlightenment! To my extremely supportive husband who provided constant encouragement during the entire process, without whom understanding and comprises I couldn’t have done this. To my parents for their long-life untiring encouragements and to my parents in law, for their unconditional emotional and financial support.

Thank you.

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June 2015

AUTHOR'S DECLARATION

The work in this research is based on a research carried out at the Brunel university business school, London. No part of this research has been submitted elsewhere for any other degree or qualification and it is all the author's original work unless referenced to the contrary in the text. However some of the material contained here has been presented in the form of the following:

Hasani, S., El-Haddadeh, R. and Aktas, E. 2015. "Evaluation of the PREDIS model: A simulation game design" paper presented at YounOR19, 2015, Birmingham, 22-24 September. Aston university: ORSociety.

Hasani, S., El-Haddadeh, R. and Aktas, E. 2015. "PREdictive model for DISaster response configuration" paper presented at YounOR19, 2015, Birmingham, 22-24 September. Aston university: ORSociety.

Hasani, S., El-Haddadeh, R. and Aktas, E. 2015. "A conceptual model for re-structuring the disaster relief operation". In: N. Altay, M. Haveelkorn and C. Zobel, ed., Advances in Managing Humanitarian Operations, 1st ed. Spring Verlag.

Hasani, S., El-Haddadeh, R. and Aktas, E. 2015. " Performance determinants in Virtual Organisations" In IJMR, under review.

Hasani, S. , El-Haddadeh, R. and Aktas, E. 2014. A disaster severity assessment decision support tool for reducing the risk of failure in the response operations. In: BREBBIA, C.Eds. 2014. Risk Analysis IX. UK: Wessex Institute of Technology, Vol.47

Hasani, S., El-Haddadeh, R. and Aktas, E. 2014. "Partner configuration in short term collaboration: A Taxonomy of literature between 1994 to 2013", paper presented at BAM 2014, Belfast, 9-11 September. Northern Ireland: British Academy of Management.

Hasani, S. , El-Haddadeh, R. and Aktas, E. 2014. A disaster severity assessment decision support tool for reducing the risk of failure in the response operations. paper presented at risk analysis, 2014, New Forest, 4-6 June, WIT.

Hasani, S, 2013 " Performance determinants in Virtual Organisations" poster presented at Brunel University, Student research conference, 2013, London, 29-30 April 2013.

ACRONYMS

ACO- Ant Colony Algorithm

AHP-Analytical Hierarchy Process

ANP-Analytical Network Process

DEA –Data Envelopment Analysis

DRI-Disaster Risk Index

DRN- Disaster Relief Networks

DSA-Disaster Severity Assessment

GA- Genetic Algorithm

HDI-Human Development Index

IASC- Inter-Agency Standing Committee

IFRC- International Federation of Red Cross and Red Crescent Societies

MADM- Multi Attribute Decision making

MAUT- Multi Attribute Utility Theory

MCDM-Multi Criteria Decision making

MIRA- Multi-cluster Initial Rapid Assessment

NGO- Non government organisation

NNA- Neural Network Analysis

OCHA- Office for the Coordination of Humanitarian Affairs

PSO- Particle Swarm Optimisation

TOPSIS- Technique for Order of Preference by Similarity to Ideal Solution

UN- United Nations

UNDP-United Nations Development Program

VBE-Virtual Breeding Environment

VIKOR- VlseKriterijumska Optimizacija I Kompromisno (Serbian name for multi-criteria optimization and compromise solution)

VO- Virtual Organisation

MA- Moving Average

NRMSE- Normalised Root Mean Square Error

1 INTRODUCTION

Many cases of failure have been reported in disaster response operations due to the challenges faced by humanitarian partners including large-scale disasters such as the Haiti Earthquake in 2010 and the Indian Ocean Tsunami in 2004. One of these challenges is the proliferation problem in the disaster response network. The proliferation of actors is the product of the extreme requirements of a disaster where all available sources are mobilised (Tierney and Trainor, 2004); so any available partner is encouraged to participate. This reactionary response (Rolland et al., 2010) suddenly stretches the response budget in the public sector (UN, Red Cross, governments) and multiplies the funds raised by the private sector (such as NGOs). These additional financial resources exceed the capacity of an overstretched humanitarian network, which struggles to channel the funding in an effective manner. The result is the emergence of inexperienced actors in the relief operation, such as companies joining in the activities outside their area of expertise with an attempt to improve their public image (Telford et al., 2006; Careem et al., 2010). It also brings in partners who range from competent to incompetent, reputable to disreputable, opportunistic to committed, and well established to just-formed, in addition to individuals and tourists who are eager to help. This oversupply of uncoordinated and inexperienced partners is referred to as the proliferation of actors (Inomata, 2006). The actors enter the disaster-effected area in a chaotic pattern (Comfort, 2007), which contributes, to the proliferation problem.

The proliferation of actors is of special importance because the existence of various partners with different mandates, agendas, and levels of professionalism, expertise, and resources presents a major challenge to operational coordination. It also poses various threats to ethical and socio-economic aspects in the affected area such as creating armed forces

(Metcalfe, 2012), allegations of financial fraud and ethical misconduct of aid workers (Odihpn.org, 2014; Volbrun, 2012; Edition.CNN.com, 2014). These issues signal a necessity to deal with the proliferation problem with a wider approach than existing guidelines such as resource scheduling techniques (Rolland et al., 2010), reputation management systems for the efficient selection of partners (Javaid, 2013) and diagnosing the severity of the disaster (Hasani et al., 2014).

Although all types of dysfunctions in disaster situations have counterproductive effects on the entire disaster management operation and add negative value to the system (Telford et al., 2006), the proliferation problem in particular damages the quality of response (Reineck, 2010). This threatens the reputation of humanitarian aid organisations (Reineck, 2010), and can destroy trust in the long-term. Entrance of inexperienced actors increases the load on the affected populations, local authorities, and coordination structures for information or services. It also increases the costs due to duplicate offices and overheads and leads to a counterproductive duplication and confusion of effort. In this situation the partners may compete over donations, funding, facilities and publicity instead of taking advantage of each other’s capabilities (Kent, 2004; Telford et al., 2006; Balcik et al., 2010). To help answer the following question “how to quickly configure a response network in the early hours after the disaster has struck in order to avoid the rush of inexperienced, and unsuitable partners into the area”, the present study first articulates the challenges associated with the proliferation of partners and then synthesises a series of solutions based on existing literature.

1.1 BACKGROUND

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Disasters are defined as intense forms of collective stress caused by a disaster agent (Britton, 1986) and resulting in *'a disruption that physically affects a system as a whole and threatens its priorities and goals'* (Van Wassenhove, 2005, p.476). The intense negative impacts of a disaster on people, goods, services, and the environment make the community incapable of coping (Kovacs and Spense, 2009) and in need of assistance from government and international agencies.

Disasters have negative impacts on human, social, and economic environments which are impossible to eliminate, but can be minimised with effective disaster management (Moe and Pathranarakul, 2006). However, experiences in the Haiti Earthquake in 2010 and the Indian Ocean Tsunami in 2004 reveal various failures. For example, 2,500 people died of cholera in Haiti in the presence of 12,000 humanitarian organisations (Karunakara, 2010). This was partly associated with the lack of safe drinking water and the fact that seven months after the disaster 30% of camps did not have any kind of toilet (Heikkinen, 2012). This occurred in the context of donations of 1,482 USD per capita (Metcalf et al., 2011), which exceeded the general GDP of the country (669 USD per capita) in that year (World Bank, 2014). During the Indian Ocean Tsunami, competition among aid workers to spend huge private donations led to a misallocation of resources and duplication of activities (Wright, 2005). These negative impacts can be reduced if the partners are carefully selected according to the requirements of each particular disaster. This can be addressed by dealing with the partner proliferation problem, which will be discussed in the next section.

There are various challenges facing this process such as mass scale effects in large geographical areas and on the population, and severe damages to people and property. In addition, the involvement of multiple parties, the time pressure for rescue and decision making, severe resource shortages, and vast unpredictability are amongst the challenges facing the humanitarian operation logistics (Jiang et al, 2012). Various scholars emphasise deficiencies in preparedness and planning, and inadequacy of prepared rescuers (Benjamin et al., 2011; Kovacs and Spens, 2009). Others point out the proliferation of actors in the disaster situation (Reinecke, 2010; Telford et al., 2006; Balcik et al., 2010). The majority of these challenges are faced due to the lack of various criteria including the standards and indicators; the weak collaboration, and the inadequate infrastructure (Kovacs and Spens, 2009). In addition to the uncertainty in demand and supply, and the difficulty of inventory forecasting (Balcik et al., 2010) associated with the opportunistic behaviour of partners (Pettit and Beresford, 2009) together with high employee turn-over (Reinecke, 2010; Telford et al., 2006) complicate the situation. The low recognition of the role of logistics (Kovacs and Spens, 2009) specifically in humanitarian operations could further enhance the problem.

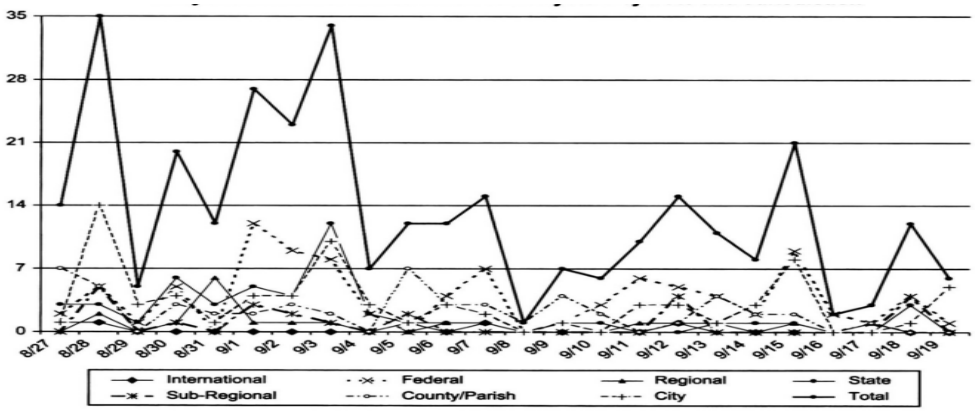
Nevertheless, despite the awareness of practitioners and scholars of the complications, the extent of the negative effect of these challenges on the disaster operation is understudied. In addition, the efforts to provide specific guidelines to tackle these challenges are limited to a few studies. For example, Farazmand (2007, 2009) introduces the concept of surprise management as a solution to the challenges facing humanitarian operations. He basically draws upon the failure of the response operation during Hurricane Katrina and suggests engagement of citizens and adaptive collaboration. However, this solution lacks adoptable guidelines or a framework to which the practitioners could refer and operationalise surprise management. Clearer frameworks, however, are provided in the work of Rolland et al. (2010) who provide resource scheduling decision support for the response and recovery phases, and Javaid (2013) who develops a reputation management system for the efficient selection of partners. Finally, the authors of this study proposed in an earlier paper a decision support system for diagnosing the severity of the disaster using the limited data available in the early hours (Hasani et al., 2014).

1.2 RESEARCH PROBLEM

As has been explained previously, there are many problems associated with the disaster response operations. The present research addresses the partner proliferation problem in disaster response networks as one of the most recurring problems in humanitarian operations. The existing experiences of failure in disaster management operations in large-scale disasters, signals the necessity to investigate an effective disaster relief management, which is successful in minimising the negative effects of the disasters (Moe and Pathranakul, 2006) specifically with the focus on reducing the problem of partner proliferation. This phenomenon has counterproductive effects on the whole disaster relief operation, will add negative value to the system (Telford and Cosgrave, 2006), and damages the quality of response (Reineck, 2010).

The proliferation of actors is induced due to the extreme requirements of the disaster which forces to mobilise and recover all the available sources (Tierney and Trainor, 2004) and therefore all available partners are encouraged to participate. The negative effect of this reactionary response (Rolland et al., 2010) is twofold. First, the mandatory growth in the relief budget in the public sector (UN, Red Cross and governments) as well as the fund raising by the private sector (such as NGOs) exceeds the absorption capacity of an overstretched humanitarian industry. This pushes the inexperienced actors including the public image seeking companies into activities outside their area of expertise (Telford et al., 2006; Careem et al., 2010). This situation leads to the oversupply of uncoordinated and inexperienced partners (Inomata, 2006). This rush of all available partners creates a range of partners from competent and incompetent, reputable and disreputable, opportunistic and committed, well established and just-formed in addition to individuals, tourists and also companies which aim to generate a favourable public image, to increase their long-term profit. They enter the disaster-effected area in a chaotic pattern and cause the proliferation problem (Figure **1-1**). This as mentioned before, results in the budget stretch leading to the oversupply of a range of heterogeneous uncoordinated and inexperienced partners (Inomata, 2006).

Figure 1-1 Partner's entry pattern into the affected area of Hurricane Katrina



Source: Comfort (2007)

Figure **1-1** shows the chaotic pattern of partners' rushing into the affected area of Hurricane Katrina.

This increases the load on the affected populations, local authorities, and coordination structures for information or services. It also increases the costs due to replicated offices and overheads, produces a counterproductive duplication and confusion of efforts, and leads to competition between agencies for donations, facilities, and publicity.

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The second negative effect of proliferation is the increase in the risks of inappropriate aid, due to the time pressure of competition and the rush for publicity. This increases the risk to the quality of the response and reputation of the humanitarian community through the actions of inexperienced or irresponsible agencies and damages the quality of the responses (Reineck, 2010). The damage is enhanced by the fact that this wasted effort could be used instead to take advantage of the capabilities of the partners within the network and creates competition between the agencies over funding (Kent, 2004; Telford and Cosgrave, 2006; Balcik et al., 2010).

The study suggests that one of the reasons for failure in disaster relief network lies in the incompatibility of the disaster relief situation with the existing collaborative structures used for managing the response operation. The uncertainty and the lack of information (Tomasini and van Wassenhove, 2009), together with damaged infrastructure (Jiang et al., 2012), unequal and ineffective distribution of demand and supply and their respective fluctuations (Comfort et al., 2004, Tierney and Trainor, 2004), unsteady flow of the financial resources obtained by fund-raising from occasional donors (Oloruntoba and Gray, 2006) all make the planning and long-term outlook almost impossible. Also long-term approaches in practice are usually profit-based whilst in disaster situations the non-financial factors such as the time value of commodities are much greater than the costs associated (Oloruntoba and Gray, 2006; Pettit and Beresford, 2009), which make the conventional profit-based values less accurate. Therefore, due to the lack of control and information in disaster situations, the existing structures such as supply chains or project-based collaborations might fall short in practice because these structures require a certain amount of knowledge about the supply, demand, timing, costs, etc. which are generally unknown in disaster situations.

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To that end, this research proposes restructuring the relief network to accommodate the characteristics of the disaster situation with a non-financial short-term outlook, which has the capability to work with the minimum data available and without much pre-planning. The current study builds upon empirical research carried out in the field of decision making in disaster response operations as a response to Altay and Green's (2006) call stating that an optimal network structure to assist in resolution of disasters is yet to be developed. Dealing with the proliferation problem in a disaster situation falls under the heading of decision making under uncertainty. The author argues that in the response network based on the principles of Resource dependency theory (Pfeffer and Salancik, 1978) and the "uncertainty" situation the humanitarian network can reduce the uncertainty and improve access to the communal resources of other humanitarian partners through collaboration. Just like commercial firms engaging in collaboration to reduce the uncertainty (Eisenhardt and Schoonhoven, 1996, Hillman, 2009) by gaining access to other firms' resources.

The problem with collaboration is that the collaborative empowerment happens through synergy (Lasker et al., 2001) and the success of collaboration is influenced by interaction of contributors (Westphal et al., 2010) and the overall performance is not necessarily equal to the integrated performance of all participants. Therefore, sometimes the act of collaboration fails to guarantee the success of a collaborative network (Bamford et al., 2004; Bullinger et al., 2003; Dürmüller 2002 cited by Westphal et al., 2008). In fact, the failures pf collaborations are more common than successes (Lewis, 1990; Elmuti and Kathawala, 2001; Zineldin and Bredenlow, 2003 cited by Bititci et al., 2008). The examples of failure in collaboration in a disaster response network are the Haiti Earthquake in 2010 and the Indian Ocean Tsunami in 2004 and they reveal various failures. For example, as mentioned previously 2,500 people died of cholera in Haiti in the presence of 12,000 humanitarian organisations (Karunakara, 2010). This was partly associated with the lack of safe drinking water and the fact that seven months after the disaster 30% of camps did not have any kind of toilet (Heikkinen, 2012). This occurred in the context of donations of 1,482 USD per capita (Metcalf et al., 2011), which exceeded the general GDP of the country (669 USD per capita) in that year (World Bank, 2014). During the Indian Ocean Tsunami, competition among aid workers to spend huge private donations led to a misallocation of resources and duplication of activities (Wright, 2005). These negative impacts can be reduced if the partners are carefully selected according to the requirements of each particular disaster to make sure the interaction between heterogeneous partners does not have a counterproductive effect. To that end, an efficient operation needs to be supported with a suitable selection of partners who work together efficiently and guarantee the success of collaboration. Based on the argument above, the research focuses on the partner selection in disaster situations as a solution to the partner proliferation problem.

However although a huge body of literature exist on the "how to restructure the selected partners", these approaches face a serious problem of duplication of efforts and the counterproductive effect of the operations during the disaster response operation. The existing research on this area mainly focuses on preparation, mitigation, and recovery phases by suggesting various long-term collaborative structures such as supply chains (Maon et al., 2009; Ebig and Tandler, 2009; Tatham and Spens, 2011; Weber et al., 1991; Holt, 1998; Degraeve et al., 2000; De Boer et al., 2001; Wu and Barnes, 2011). The problem arises from the high state of uncertainty in the response phase due to the temporary and urgent nature of the aid required, and the chaotic nature of disaster strike. This uncertainty affects the available data required for planning (Wassenhove, 2005), the stream of financial resources (Oloruntoba and Gray, 2006) and unknown and fluctuating, supply and demand (Comfort, 2004; Tierney and Trainer, 2004; Wassenhove, 2005). All the arguments above raise the suspicion that long-term collaboration may not be the optimal structure for disaster relief networks in all cases.

With this in mind, scholars have recently started to employ the temporary organisational structure (Simpson and Hancock, 2009; Moe and Pathranakul, 2006; Camarinha-Matos and Afsarmanesh, 2008a, 2008b; Nolte and Boegnick, 2012). This research follows the initiation suggested by Noran (2011) where a short-term structure is suggested for the response phase from the disaster life cycle and also a long-term structure is suggested for the mitigation, preparation, and recovery in a disaster life cycle. The research then argues that the most suitable structure for a disaster response is Virtual organisation (Grabowski and Roberts, 2011; Javaid et al., 2013) as a temporary form of alliances (Jones and Bowie, 1998) from independent and heterogeneous enterprises (Camarinha-Matos and Afsarmanesh, 2006; Romero, 2009). Moreover, the research has developed a decision making framework (PREDIS) for selecting suitable partners by reviewing the records of natural onset disasters, which have happened worldwide since 1980, and their data are available in various humanitarian databases (Emdat.be, 2014; Munichre.com, 2014; ReliefWeb, 2014; Gdacs.org, 2014). PREDIS ultimately deals with the proliferation problem by ranking and selecting the most suitable partners based on the principals of the Decision theory and Resource-based theory.

The significance of this research is that in addition to dealing with the primary problem of the research (proliferation problem), it provides a framework for prediction of the loss, estimation of the needs, and resource optimisation of the resource allocation to the needs during the disaster response operation. This framework is noteworthy because currently the first official report of the disaster effects is released 72 hours after the disaster strikes leading to a three-day gap between the decisions about the distribution of aid, and obtaining information about the actual needs amongst the affected population. The PREDIS framework in this sense is an attempt to cover this gap by using the data available at the time of the disaster striking. It also is the only framework of this type, which enables the non-experts to make decisions almost on a par with experts. This characteristic is also helpful because when a disaster strikes in many areas the people who decide about the allocation of the resources, are not trained in the field of decision making or logistics. Instead, they happen to be in the disaster-affected area before experts arrive, and this framework could help them to make decisions more efficiently.

1.3 MOTIVATION

In the light of the above argument the present research is a response to the call by Moe and Pathranakul (2006) who emphasised the necessity to minimise the negative effects of disasters and to Altay and Green (2006) who pointed out the lack of a network structure to facilitate the response phase of disasters. Although various papers have been published, especially in the past two years in response to these calls, the majority of them are concerned with the focus on the pre- and post-disaster phases including mitigation, recovery, and preparedness (Crawford et al., 2014; Doocy et al., 2014; Hardy et al., 2013; Malhotra and Vetkatesh, 2013; Karunasena, 2011). The articles focusing on the response phase using the collaborative partners are limited to the studies, which investigate how the partners who actually responded to the disaster are different from those who were planned to participate (Guo and Kapucu, 2015). This shows that emergency norms prevail the bureaucratic norms (Schneider, 2011), which is another confirmation of the issue that pre-planning, and long-term outlook in the response phase is difficult if not impossible. Basically the partners in the existing studies are important as a part of the collaborative structures. The significance of the partners in a disaster concept is in the fact that the performance of a disaster response is increasingly being assessed by comparisons between planned versus actual networks (Guo and Kapucu, 2015; Hu et al., 2014; Hu and Kapucu, 2014; Kapucu and Demiroz, 2011; Kapucu and Demiroz, 2011; Choi and Kim, 2007; Choi and Brower, 2006). However these articles mostly focus on reporting the discrepancies between the planned, and actual structures/partners without providing guideline for dealing with these differences. Meaning that a solution for how to control or reduce the discrepancies between the expected partners, and the actual proliferated partners is missing. There are some studies, which provide guidelines for scheduling and task allocation during the response phase (Fiedrich et al., 2000; Nourjou et al., 2014a, 2014b). However articles focusing on the response phase, and specifically addressing the proliferation problem in this phase are yet to be developed. These issues signal a necessity to deal with the proliferation problem with a wider approach than existing guidelines such as resource scheduling techniques (Rolland et al., 2010), reputation management system for the efficient selection of partners (Javaid, 2013), and diagnosing the severity of the disaster (Hasani et al., 2014).

Another motivation is the ethical aspect attached to the proliferation problem. The existence of various partners with different mandates, agendas, levels of professionalism and expertise, and resources presents a major challenge to operational coordination. It also poses various threats to ethical and socio-economic issues in the affected area. A number of these actors have moved beyond life-saving activities, and tried to make changes in the societal environment, and conflict resolution. For example, many of them have created their own armed security forces or are in close relations with military (Metcalfe, 2012). This also brings about various issues where a range of allegations of financial fraud, and ethical misconduct of aid workers are reported along, with sexual exploitation, abuse, and bullying (Odihpn.org, 2014; Volbrun, 2012; Edition.CNN.com, 2014). This signals a necessity to deal with the proliferation problem in a disaster response network concerning the ethical aspects and reduce the damage to the socio-economic structure of the affected areas. To that end, the present paper addresses the partner proliferation problem in disaster response networks as one of the most recurring problems in humanitarian operations.

1.4 RESEARCH QUESTIONS

As mentioned earlier the proliferation of partners is more problematic at the response phase because when the disaster strikes it paralyses the infrastructure and help is appreciated from any sources possible. However due to this chaotic situation, and despite the fact that the literature concerning disaster response articulates the proliferation problem as one of the difficulties in disaster situation, solutions addressing this problem are seldom provided. To that end considering that dealing with the proliferation problem in the response phase is a decision-making problem under uncertainty, several concerns come to mind. What are the existing practices to reduce the partner proliferation if any? Where do the gaps lie in the existing decision-making frameworks that can be used to tackle the proliferation problem and what suitable tools can be borrowed from existing studies? Considering the lack of data in the response phase, what other sources are available for use in the decision framework aiming at reducing the partner proliferation? Answering these questions would conceptualise the primary research question: *How to reduce the proliferation of partners in a disaster response? (More explicitly, how to configure response networks quickly in the early hours after the disaster strike in order to avoid the rush of inexperienced and unsuitable partners* *into the area).*

The author argues that in order to answer the above question, the research needs to develop a decision-making model, which is missing from the literature. In the well-developed field of decision making, the topic of partner selection in a disaster response has been a source of limited discussion (Smirnov et al., 2007; Rolland et al., 2010; Javaid et al., 2013). The subject of partner selection in a disaster response has been treated with hesitation because of the unpredictability of the circumstances and the lack of data. To that end, few scholars have tried to generate data and frameworks to address this paucity. However, for a number of reasons the existing literature appears to be insufficient: First, although a number of studies try to generate data by predicting the human and material loss of the disaster, they lack generalisability because they are limited to a certain region or disaster. Second, the existing literature is sometimes contradictory, whilst some scholars predict the number of fatalities based on the damage to the buildings (Aleskerov et al., 2005; Chan et al., 2003), others found no correlation between the two (Peek-Asa et al. Cited by Alexander, 2000). Therefore, these findings need to be revisited and re-justified to obtain a mutual agreement between the various scholars. Third, the complex and technical papers in this field are impossible to use in practice by an average user due to the volume of variables, wealth of technical data and complicated computer simulations. The fourth reason is that the majority of the above criteria are drawn from data related to one or few events in specific countries and their extrapolation and generalisation is unreliable.

To that end, a model that has the capability to employ simply available data within an easy to use framework for non-expert practitioners, and is generalisable to different geographical areas and disaster is missing. The creation of a model with above capabilities can produce reliable data, which can further be used for partner selection in disaster response networks; hence reducing the partner proliferation problem. This can address the question "How to reduce the proliferation of partners in disaster response?" because it provides a step-by-step framework to quickly configure a response network in the early hours after the disaster strike in order to avoid this rush of inexperienced and unsuitable partners into the area.

In order to create a decision framework for partner configuration (tackling the proliferation problem) for the disaster response we need the following essential information about the affected area. What is needed? How much is needed? In addition, who can provide these needs.

By answering these questions, it is possible to connect the needs to the partners who can provide them and limit the number of partners who enter the affected area to the ones who have the capability to satisfy the needs for that particular disaster. The above arguments lead to formulating three propositions:

First proposition-What is needed? This question can be further explained as *"Based on the previous experiences in similar disasters what type of aid has been used for the typical affected population?"* To answer this question we need to identify what constitutes the "Similar disasters". To find out what constitutes similar disasters, statistical and mathematical tools are used to classify the disasters. This classification technique is called Disaster Severity Assessment (DSA) technique and is primarily introduced by Hasani et al. (2014). DSA technique categorises disasters based on the impact they create in the disaster area, and is expressed in the number of people affected through fatalities, injuries, and homelessness. This is called the "PREDICTION" phase in the PREDIS framework. The research continues based on the hypothesis that there is a relationship between the human impact of the disaster and the needs of the affected population. To investigate this hypothesis further the existing evidence and literature are reviewed to find out in the similar level of DSA, what sort of aid was required. For example, the investigation shows that shelter is more necessary at the time of tsunami whilst food is more essential when faced with an earthquake. It also provides a rule of thumb for addressing each need to identify how many units of food, water, and medical assistance etcetera is required for that particular level of DSA. This table is called standard minimum requirements and is obtained through a combination of data from various humanitarian resources.

The second sub question is- how much is needed? This question can be rephrased as *"Based on the previous experiences in similar disasters how many units of aid are required for this level of DSA?"* The answer to this question can be provided by combining the DSA framework with the minimum standard requirements of the disaster, which provides an estimation of the needs for that particular disaster. This phase is called "ESTIMATION" in the PREDIS framework.

The third proposition is- Who can provide these needs? This question can also be rephrased as *"Which partners out of the proliferated partners are capable of providing these specific types and amount of needs?"* The answer to this proposition is the essence of the OPTIMSATION" phase of the PREDIS model. At this point, the answers to the three questions of "What is needed? How much is needed? And who can provide the needs?" are connected to each other to finally select the most suitable partners based on the resources they have available at the time of the disaster. To answer this proposition the study combines the existing decision techniques and determinants, which have been identified as suitable for the characteristics of the disaster response. This process is explained in detail in the research design and methodology.

The combination of the answers to the above three sub questions is a decision framework called PREDIS, which has the capability of optimising the selection of partners at the disaster response phase using the data available at the time of the disaster with the minimum input and technical knowledge from the decision maker/user.This provides an answer to the primary question of “How to reduce the proliferation of partners in a disaster response?”

To evaluate the PREDIS model further a simulation game is conducted to incorporate the opinion of the potential users in evaluating this framework. To that end, the fourth proposition is put forward as “How effective is the decision support tool developed in the PREDIS model during the response phase”. To answer this question a simulation game has been designed to further evaluate and compare the result of the PREDIS model through the eyes of two different users: Expert and Non-Expert decision makers. The answer to the fourth proposition identifies the strengths and the areas of improvement in the PREDIS model.

1.5 AIMS AND OBJECTIVES OF THE STUDY

The purpose of this study is to carry out an examination of the partner proliferation problem in the response phase of disaster management decision-making. A thorough review of the literature, as well as analyses of similar conceptual frameworks in different contexts, helps in developing an adequate framework (PREDIS) and subsequently deriving hypotheses. It should also help to reveal, through testing, what is the relationship between the human impact of the disaster and required aid in the response phase. Furthermore, it also identifies the decision techniques that are exercised by various decision makers and their suitability for the disaster phase. The main objective of the present work, therefore, is to apply a theoretical set of augments related to the questions and propositions into an context in order to examine and contrast these arguments' predictive ability and limitations. The study aims to contribute to connecting various theories (Decision theory, Utility theory, Resource-based theory, and Resource dependency theory) in order to explore the suitable structures for disaster response operations further. It uses the decision-making process further to choose the actual partners in a disaster situation, as well as the determinants that influence the disaster's effects and required aid. The contribution of this study is based on the development of a comprehensive theoretical framework and a practical decision-making tool. To the best knowledge of the researcher, this is the first time such a theoretical framework has been tested and theoretically in the context of disaster response decision-making. To explore this claim, the contributions of the research are further explored as follows.

1.6 CONTRIBUTION

This research builds upon and therefore contributes to the interdisciplinary fields of the literature in this field. It builds upon the decision sciences where it coincides with the field of Virtual Organisation in conjunction with humanitarian operations.

The theoretical contribution is that this research provides a unique insight into the growing body of research that examines the proliferation problem in a disaster response network. It can be categorised as a part of decision-making under uncertainty where it tries to reduce the uncertainty by gaining accumulated access to other firms' resources based on the principles of Resource dependency theory and through collaboration. The significance of the model is in its ability to use the pre-existing data in order to predict the impact of the data before the release of the first official data within the first 72 hours. As mentioned previously to the best knowledge of the author, this research is the first work to investigate the partner proliferation problem in detail within the concept of a disaster response network. Moreover, it is the first framework, which predicts the impact of disaster without limiting it to one disaster, one geographical area, or one year unlike the similar predictive frameworks. The research also is one of the pioneers in using simulation game design for incorporating the human agents' opinions into the model. In that aspect, it integrates the hard and soft decision techniques within the concept of Systems thinking theory. Its methodological contribution is to combine the decision criteria and decision techniques from a variety of heuristic and mathematical decision techniques into the concept of decision-making in disaster management. It also uses a multi-layer approach to choosing the appropriate predictive techniques for the first phase of the study. It embarks with regression analysis and continues with MA rule in order to isolate the most appropriate method. It then compares the NRMSE of the predicted result of each method to choose the best prediction method. The practical contribution of the research fills the gap in the fledgling field of disaster management, especially by enriching the predictive power of the operations. Consequently, this may hugely improve the performance of the humanitarian operation, by empowering the elements of project management in short and long-term networks. In addition, this is the first time a holistic framework has been conducted with two practical significances. First, it relies on the available data at the time of the disaster, which are freely available to the public. This would hugely reduce the cost of the data gathering and would reduce the time required for collecting and analysing this data. Consequently, it speeds up the response of the operation to the disaster by almost 72 hours, which is vital at the time of the disaster. In addition, it is the only existing framework not limited to a certain type of disaster (although it just considers the five type of disasters) or geographical or chronological order. These unique characteristics make it possible for decision makers to compare the effects of the different types of the disasters in different areas happening at different times. Another contribution is that the model has the capability of accommodating the socio-economic characteristics of the affected population, which hugely influences the required aid in humanitarian response practices. The PREDIS model also has the capability of facilitating the predictions of damages as required by insurance industry. Another practical contribution is that by providing a range of predictions (minimum, maximum and best case scenario, worst-case scenario) it enables the decision maker to decide based on their budget limitations and personal preferences.

1.7 OUTLINE OF THE RESEARCH

The aim of this chapter is to provide a technique for partner configuration in disaster response networks based on a series of studies (including Disaster Severity Assessment, PREDICTION, ESTIMATION and OPTIMISATION) leading to the development of the PREDIS model. The first study as was mentioned before is the process leading to the development of DSA framework. This framework is built upon a set of 11,000 records of previous disasters since 1980 and it categorises the disasters based on their severity. The goal is to find a pattern between the impact of the disaster and the severity. The result can be further used to diagnose the severity of the disaster by comparing it to similar disasters in the past and predict the range of possible damage within minutes after the disaster strikes. This leads to another phase where a series of mathematical and statistical techniques including regression analysis and comparison of averages are used to find a pattern for predicting the number of fatalities, injured and homeless people in the affected area. This phase is called PREDICTION and results in two predicted scenarios for ranging from best to worst-case scenarios of a disaster's impact. The second study is the ESTIMATION where the evidence and documents in the existing humanitarian organisations are used to set a standard for the minimum requirements of the disaster response (based on the type of the disaster and the nature of the damage). This in combination with PREDICTION leads to the estimation of the needs for each disaster scenario. The third study is the OPTIMISATION of a set of hypothetical partners' resources to satisfy the needs for each disaster scenario. These three studies are the basis for the PREDIS model, which is then further tested and evaluated by two groups of expert and non-expert decision makers in the fourth empirical study called EVALUATION. The relationship of this chapter to the whole research is depicted in Figure **1-2**.

Figure 1-2 Research structure

CHAPTER 1
INTRODUCTION

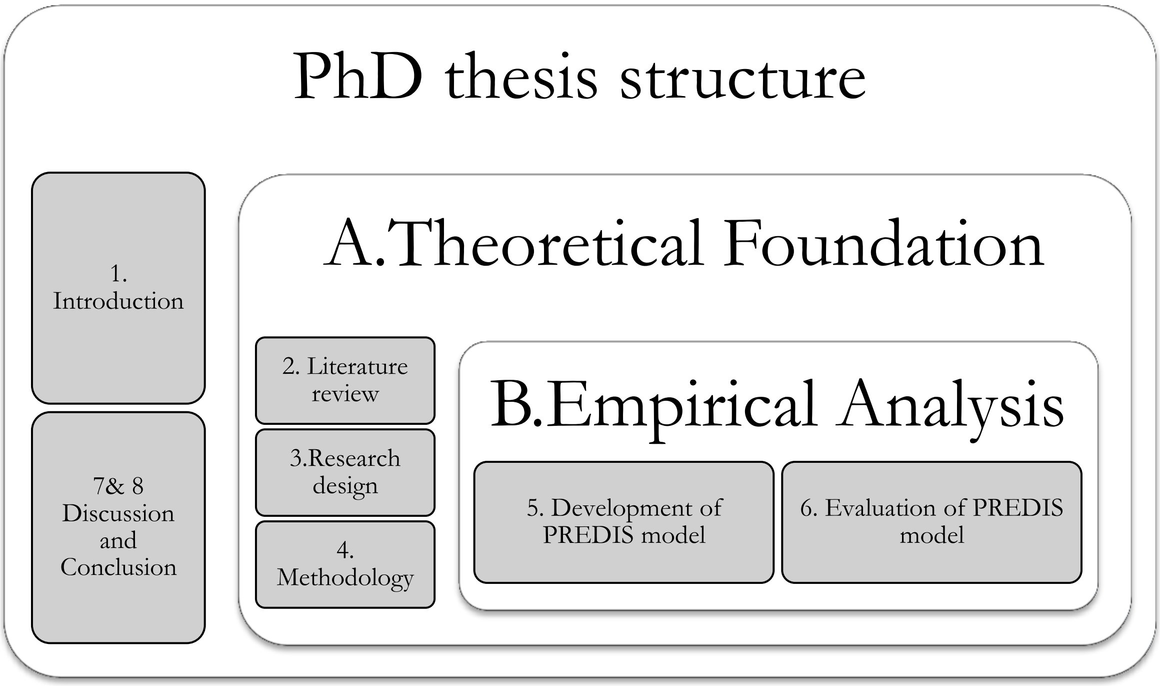


Figure **1-2** shows that the research comprises of a theoretical foundation and analysis in addition to the introduction, discussion, and conclusion chapters. The theoretical foundation consists of the process of setting the theoretical basis before starting the analysis. Therefore, the theoretical foundation embarks with an extensive literature review, then outlines the research design before discussing the methodology used in the analysis. The analysis consists of two main analyses. The first analysis, which leads to development of PREDIS model, comprises of three studies including PREDICTION (including the development of DSA), ESTIMATION, and OPTIMISATION. The second analysis is an attempt to evaluate the PREDIS model with a simulation game design. The outline of the chapters is further elaborated as follows.

Chapter 1-INTRODUCTION provides the background of disasters and their negative effects. The problems associated to the disaster situation are then outlined, and one of the most reoccurring problems is defined as the partner proliferation problem. This is set as the main research problem, which informs the motivation of the research as the paucity of a solution to this problem has been pointed out by various researchers in addition to the ethical conundrum of proliferated heterogeneous partners that faces the humanitarian community. The research questions are then articulated followed by the main aims and objectives of the research. The summary of the individual research chapters is then put forward.

Chapter 2- PROBLEM DEFINITION AND LITERATURE REVIEW is allocated to the problem definition in detail and a literature review on outlining the gaps in the existing research. The chapter starts by defining the types of disasters and in particular the sudden-onset disasters in the previous decades. Then the challenges facing the resolution of the partner proliferation problem in disasters is outlined giving two main reasons including the uncertainty inherent in the disaster situation which renders the long-term outlook impossible in addition to the lack of financial-aspects in the disaster response network which makes the existing financial measures obsolete. A review of the literature concerning the partner proliferation problems identifies the direction of recent experts' interest towards re-structuring the disaster response networks. However a decision-making model which clearly provides a guideline for this process is missing. To that end a further litearture review looks into the studies focusing on the network configuration and the decision criteria. The suitability of this criteria for the special case of disaster response is critically evaluated. This chapter is concluded by a summary.

Chapter 3 – THEORETICAL FRAMEWORK sets out the design of the researh by looking at the suitability of the collaborative structure for disaster response networks, which leads to the proposal of solutions for dealing with the partner proliferation problem. These solutions include the restructuring of the disaster response network within a conceptual structure of short-term VO organisation. To further facilitate the development of this structure suitable decision criteria are evaluated. Then the suitable theoretical basis are explored with an emphasis on the Resource- based theory and Decision theory before the outline of the design related to each research question.

Chapter 4 (METHODOLOGY) discusses the methodology by outlining the questions through the systemic lenses before describing the layers of research, which shows an induction in the predictive process of the research. Then the process of furthering the studies is outlined. For the purpose of the first study (PREDICTION), it emphasises the necessity of developing a predictive framework before identifying the assessment criteria for predicting the disaster impact. Then the existing criteria for prediction in the scholarly articles are articulated before defining the candidate criteria that might be useful for the purpose of this research. For the purpose of the second study again the suitable criteria for ESTIMATION is put forward. For the purpose of the third study (OPTIMISATION), the principles of hypothetical modelling are outlined before identifying the decision techniques for this optimisation. This chapter is finalised by a summary of the discussed material.

Chapter 5 (PREDICTION, ESTIMATION, OPTIMISATION) basically describes the details of the development process of the PREDIS model. This chapter embarks upon the first study (PREDICTION) by evaluating the assessment criteria, describing the data collection process, and statistical analysis of the collected data. It further desribes the process of developing the Disaster Severity Assessment (DSA) technique before appliying it in a predictive process. DSA then is used in three different methods for predicting the disaster impact in terms of the number of fatalities. The results of these three methods are compared and the most accurate prediction of fatalities is then used to further predict the injured and homeless population. The first study is the concluded with a summary. The second study (ESTIMATION) embarks upon the description of the process for data collection which leads to a framework for the pre-estimation of the minimum level of the needs based on the evidence of previous experience in this field. It also combines the data accumulated from various humanitarian sources with the effects of the disaster type, and the socio-economic characteristics of the disaster affected area. This study is finalised by a summary. The results of the first two studies gives rise to a hypothetical modelling in the third study (OPTIMISATION). It explains how to rank the potential partners in a Virtual Breeding Environment (VBE), before estimating the required needs in an example case based on the findings in the first two studies (PREDICTION, ESTIMATION). It then builds an AHP model based on the preferences of a hypothetical decisin maker by calculating and ranking the MAUT (Multi Attribute Utility Theory) for each partner. An optimisation process is used for selecting the partners based on the principles of Utility theory. This chapter is finalised by the summary of the process leading to the development of the PREDIS model.

Chapter 6 (ASSESSMENT AND EVALUATION) is allocated to the assessment of the PREDIS model developed in the fifth chapter. It introduces the validation and decision-making models and describes the quasi-experiment design in this research which is used for validation of PREDIS model. It describes the simulation game which is used as the treatment phase in the above quasi-experiment, as a validation tool considering the existing experiences in the field. However, it also mentions the limitations and opportunities inherent in this method. Furthermore, it evaluates the techniques developed in chapter 5. It includes the simulation of the hypothetical scenarios providing a quasi-experiment design where a simulation game evaluates the model from the expert and non-expert decision makers' point of view. It attempts to investigate if the PREDIS model can be used by non-experts in order to obtain the same result as experts. Then the framework for the simulation game is outlined before the design of the simulation game for the purpose of this research is revealed. The protocol for running the simulation game is put forward and the two questionnaires and their results are articulated. The chapter finalises with a summary of the process leading to the validation of the PREDIS model using the simulation game.

Chapter 7 (DISCUSSION) discusses how chapter 5 and 6 are linked and how they have answered the research question and the propositions. It starts by reviewing how the questions and hypotheses were outlined and therefore how the model was designed over two different phases. It reminds the reader that the logic behind this process was that if a predictive technique could be developed to approximately estimate the human impact and the needs of the affected population quickly after the disaster strike, it is possible to combine the decision makers' expertise and experiences with the data about the available resources to decide which partner should provide which requirements. To that end, it gives a quick review of the first phase which led to the development of the PREDIS model as a decision model for reducing the partner proliferation problem in a disaster response, which has been extensively discussed in chapter 5. It also evaluates how the prediction was conducted and how accurate the results were. Then it reviews the second phase leading to the evaluation of the PREDIS model in chapter 6. It also outlines the responses to three hypotheses considered for this phase.

The last chapter is dedicated to the CONCLUSION of the research. It embarks upon characteristics of the PREDIS model as a response to the main research problem. It then outlines the contributions of the research in terms of models and techniques as the tangible products of the process including PREDICTION, ESTIMATION, and EVALUATION frameworks. Then it further describes the contributions of the research to theoretical, methodological, and practical fields. Finally, it articulates the limitations of the research, before providing some suggestions for the direction of future research.

2 LITERATURE REVIEW

The second chapter describes in detail the issues and literature related to the proliferation problem in disaster response networks to which the research is referring. It puts forward a critical review of the existing literature in order to identify the gap in the research and provide the direction of this research. It also positions the focus of this research within the body of literature related to decision-making under uncertainty with the focus on partner selection and restructuring the disaster response network. In other words, this research is an attempt to provide a decision-making platform, which addresses the partner proliferation problem within a disaster response network. FIGURE **2-1** outlines the components of chapter 2.

FIGURE 2-1 THE OUTLINE OF CHAPTER

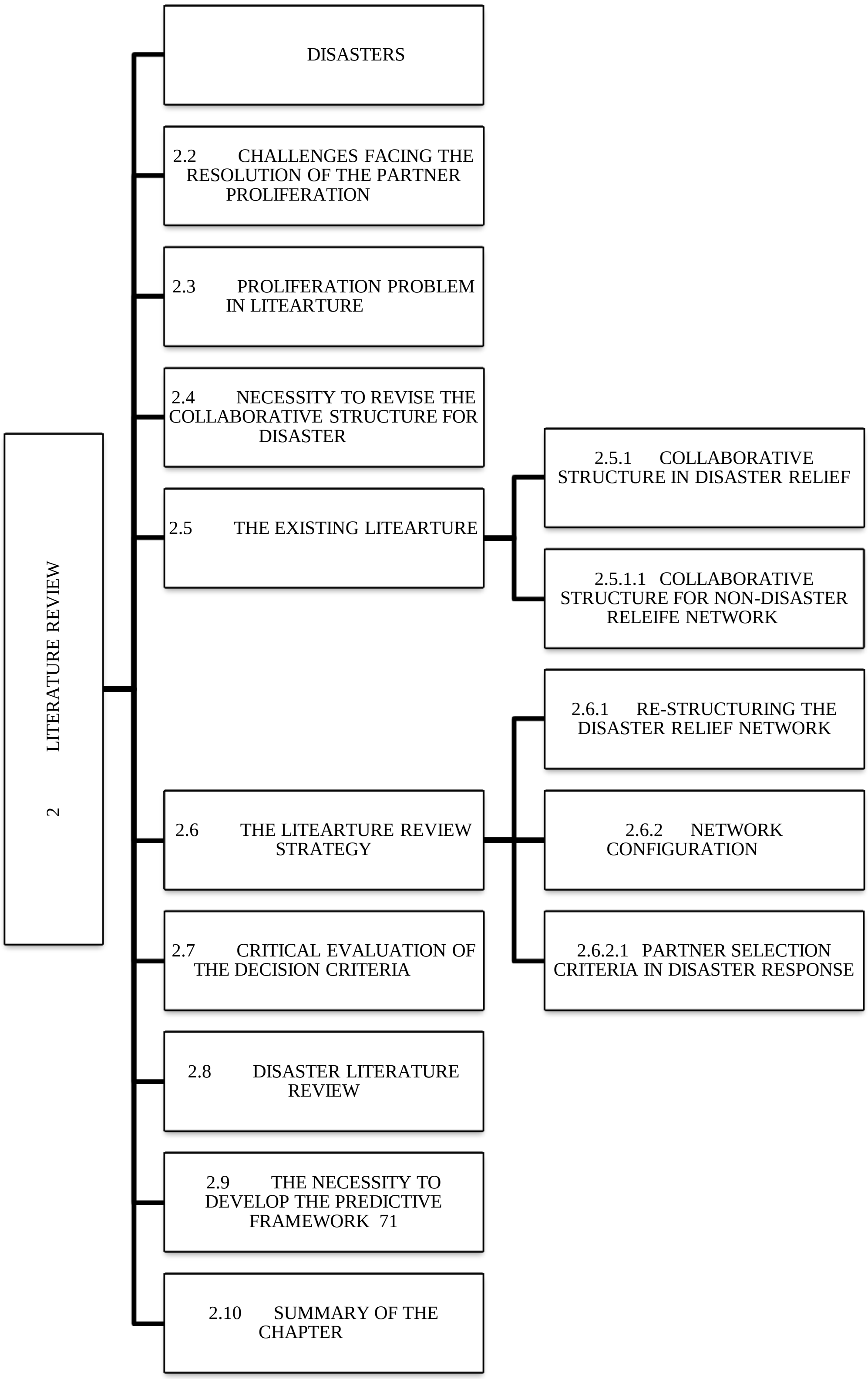


FIGURE **2-1** shows that the study defines natural onset disasters as being the most reoccurring disasters of the previous decades. It focuses on one of the most neglected problems in the disaster response phase - the proliferation of partners. It further investigates the existing approaches put forward in the existing literature in order to reduce or eliminate this problem. What is interesting in these suggestions is that they can be differentiated in their duration terms into long-term and short-term structures of collaborative networks. The first body of literature reviewed looks into the long-term and short-term collaborations to isolate the significance of each structure. The results of this section of the literature review produces recommendations for dealing with the proliferation problem by re-structuring the disaster relief network. This proposal will be discussed in the research design.

An existing approach to the proliferation problem in the literature suggests the use of decision-making methods to select suitable partners in order to reduce the number of beneficiaries. To investigate this suggestion the second literature review is conducted to identify and classify the decision-making methods and criteria available in the literature for partner selection in short-term collaborations. The result of this literature review leads to proposals for dealing with the proliferation problem by providing a decision-making method for partner configuration in disaster response networks. This suggestion is discussed in the research design.

As indicated in the introduction, this study focuses on the problem of partner proliferation in the disaster response phase and therefore defines disasters with a special emphasis on the natural onset disasters and the reason for this emphasis.

2.1 DISASTERS

Disasters are defined as intense forms of collective stress caused by a disaster agent (Britton, 1986) and resulting in *'a disruption that physically affects a system as a whole and threatens its priorities and goals'* (Wassenhove, 2005, p.476). The intense negative impacts of a disaster on people, goods, services, and the environment make the community incapable of coping (Kovacs and Spens, 2009), and in need of assistance from government and international agencies.

Disasters can be categorised based on their causes into man-made/natural and based on their progression speed into slow/sudden. If the disaster occurs naturally, for example as a result of climate change or earth movement, it is a natural disaster. It also may occur due to human activities of an environmental nature (e.g. chemical leaks) or induced by political conflict (e.g. refugee crisis). In this situation, it is called man-made. Apart from their causes, disasters can "*occur with little or no warning and often cause excessive injuries far surpassing the national response capacities*" (World Health Organisation, 2013, p.10) such as earthquakes. These types of disasters are called sudden onset. This is comparable to the slow onset disasters, which "*emerge gradually over time, often based on a confluence of different events*" (OCHA, 2011, p.3) such as famine. FIGURE **2-1** elaborates the different types of disasters from Wassenhove (2005) classification.

TABLE 2-1 CATEGORIES OF DISASTERS

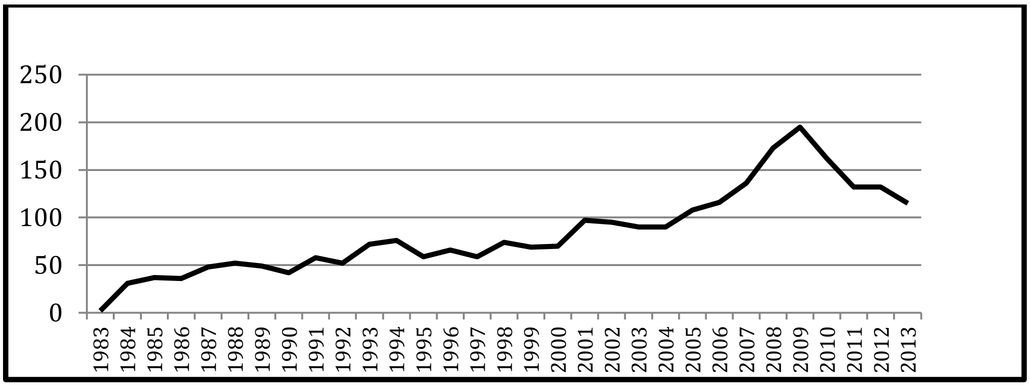
	Natural	Man-made
Sudden-onset	E.g. Earthquake	E.g. Chemical leak
Slow-onset	E.g. Famine	E.g. Refugee crisis

Adapted from Wassenhove (2005)

The focus of this study are the natural 'sudden onset disasters' because they have rapidly increased in frequency and severity during the past decade. For example, 1,449 natural sudden onset disasters were registered at the United Nations Office for the Coordination of Humanitarian Affairs or OCHA (reliefweb.int, 2013a) between 2003 and

2013. This is more than double in number compared to the number registered between 1993 and 2003 (FIGURE **2-2**).

FIGURE 2-2 THE GROWTH OF NATURAL ONSET DISASTERS



Source: Compiled from the data in relief web by the author

FIGURE **2-2** illustrates the growth in the number of natural sudden-onset disasters since 1983. The data are gathered from Relief Web and include cyclones, tsunamis, flash floods, earthquakes, and eruptions.

Despite the increase in frequency and severity of the disasters during the past decade the literature seldom addresses the existing experiences of failure in the aftermath of the Haiti Earthquake in 2010, and the Indian Ocean Tsunami in 2004, which signal the challenges facing the humanitarian network which have not been addressed. The proliferation of actors as was explained in the previous chapter is an understudied challenge facing humanitarian organisations, which this research aims to provide a solution for reducing it in disaster response networks. To that end, the next section studies the challenges facing the resolution of this problem in the existing literature.

2.2 CHALLENGES FACING THE RESOLUTION OF THE PARTNER PROLIFERATION

Various scholars have proposed methods to reduce the proliferation of partners. The majority of these works have emphasised on re-structuring the disaster response network either by adopting a collaborative structure (Telford et al., 2006; Balcik et al., 2010) or by shortlisting and selecting fewer beneficiaries (Telford et al., 2006; World Bank, 2005), such as selecting specific organisations (Moore et al., 2003), and determining organizations which can effectively collaborate (Kovacs and Spencer, 2009). However, further instructions for the methods of selection, re-structuring and configuration of effective partners are yet to be developed (Kovacs and Spens, 2009; Moore et al., 2003). The points above highlight the incompatibility of existing disaster relief network structures with the requirements of disaster relief operations. The next section outlines the reasoning behind this incompatibility and the necessity to develop a special framework for addressing the disaster response network.

2.3 PROLIFERATION PROBLEM IN LITEARTURE

A preliminary search in the science direct data-base , using the key word of “partner proliferation” in the fields of business, economics and decision sceiences, retrives no result. The same keyword in the scopus data-base retrives 39 articles, 5 book chapters and 4 conference papers related to the field of business, economics or decision sciences. Combining the keywords proliferation and disaster in the scopus, retrives 11 results. This further confirms the works of Telford and Cosgrave (2006) and Balcik et al (2010) who emphasized on the lack of literature focusing on this problem. Amongst the few existing studies, some suggest adopting collaborative structures (Telford and Cosgrave, 2006; Balcik et al., 2010) to overcome the proliferation problem however they do not provide a framework for an effective collavoration. Overall an optimal network structure to assist in the resolution of disasters is yet to be developed (Altay and Green, 2006). Other studies suggest determining which organisations can effectively collaborate (Kovacs and Spens, 2009) and choosing fewer beneficiaries (Telford and Cosgrave, 2006; World Bank, 2005) or certain organisations to work together in disaster response networks (Moore et al., 2003). However, there is a lack of research when it comes to the methods by which these certain organisations and partners need to be selected (Kovacs and Spens, 2009; Moore et al., 2003). There are also political considertaions when it comes to tackling the partner proliferation problem which might be partly responsible for the lack of research in the area. For example after Hurricane Katrina, the Red Cross and Salvation Army were restricted from entering the disaster zone to avoid reassuring and encouraging people who were refusing to evacuate the city (Benjamin et al., 2011). Similarly, in the Indian Ocean Tsunami (2004) political and cultural tensions between NGOs/military/government resulted in the military's suspicion that NGOs were spies and NGOs accusing the military of intervening in different religions in the area (Telford et al., 2006). To that end, the response collaboration needs to be restructured to accommodate the special characteristics of a disaster situation when addressing the partner proliferation problem. Addressing this challenge is however out of scope of this research.

In the light of the lack of research regarding the proliferation problem in the literature, and emphasie on the collaboration and selecting fewer beneficieries instead, the present research investigates the existing collaborative structures used for disaster response. The logic behind this is to look into the existing methods for network configuration or selecting fewer beneficiaries in the disaster relief networks which inspires a method for tackling partner proliferation in disaster response network. These however will further give rise to the identification of the experts' areas of interest and highlighting the unexplored areas, which will signal the required research design.

2.4 NECESSITY TO REVISE THE COLLABORATIVE STRUCTURE FOR DISASTER RESPONSE NETWORK

In order to highlight the suitable structure for disaster response which also addresses the partner proliferation problem, it is required to review the existing structure and stablish the necessity to revise the existing collaborative structures based on the characteristics of disaster response network. The problem arsises when the traditional network structures such as the supply chains are used for disaster response. A number of challenges are associates to the use of traditional network structures in the disaster situation.

First, these structures are designed for a more certain environment (Pettit and Beresford, 2009), where the efficiency of the collaboration is based on the information. The certain information is about where, when, and how much of the goods and services should be delivered. These data are generally unknown in disaster situations due to the unstable nature of the disaster relief network (Wassenhove, 2005). In other workds the lack of data in addition to the turbulence and unpredictability of the disaster situation (Pettit and Beresford, 2009) renders the long-term outlook adopted in existing collaborative structures unsuitable for the disaster response. The long-term outlook is also weakened due to the unequal and fluctuation of demand, and ineffective distribution of supply (Comfort et al., 2004; Tierney and Trainor, 2004), which influence the reliability of the data on them. These challenges together make the planning and long-term outlook quite challenging. To that end the suggestion is put forward that the disaster relief network needs to be restructured with an outlook that suits the characteristics of the disaster situation. To that end the literature regarding restructuring the network in disaster releief network and non-disaster releif networks are reviewed. Second, due to the lack of data in disaster situation a framework is required to work with minimum data available. A variety of literature have tried to generate the non-existent data either by classifying the potential impacts (Lemon, 1957; Friedman, 1975; Rutherford and De Boer, 1982; Ferro, 2005, Gad-El-Hak, 2007; Munich RE, 2007; CRED, 2009; Below et al., 2009; Ruwanpura, 2009; Wickramaratne et al., 2012) or by predicting the impact (Waarts, 1992; Vrouwenvelder, 1997; HKV, 2000; Jonkman et al., 2001, 2002; Spence et al., 2005; Wallingford et al., 2006; Jonkman, 2007; Klijn et al., 2007; Deltares.nl, 2014). This is an attempt to gather more data from a situation where data is less available.

2.5 THE EXISTING LITEARTURE

These literature are being reviewed in two parts. The first part focuses on the literature regarding the existing collaborative structure in order to find a suitable structure which has the capability to accommodate the characteristics of the disaster response network. The second part of the literature review focuses on the literature regarding the existing framework for disaster impact estimation frameworks. This is an attempt to find the most suitable framework for providing information about the disaster impact which then can be used to inform the response network and reduce the uncertainty in addition to partner proliferation problem.

2.5.1 COLLABORATIVE STRUCTURE IN DISASTER RELIEF

Various scholars suggest the use of collaborative networks such as supply chains (Maon et al., 2009), High Reliability Virtual Organisations (Grabowski et al., 2011) and public projects (Moe and Pathranakul, 2006) as suitable structures for disaster response networks. For example, the long-term structures such as supply chains (Maon et al., 2009;

Ebig and Tandler, 2009, Tatham and Spens, 2011) have been adopted by the main humanitarian organisations such as the International Federation of Red Cross, Red Crescent Societies, and World Food Program (Wassenhove et al., 2005) as the disaster relief network structures. However, the failure in disaster operations in the aftermath of large-scale disasters (Kovacs and Spens, 2009; Benjamin et al., 2011) identifies the need to re-structure the disaster relief network. With this in mind, scholars have recently started to employ temporary organisational structures (Simpson and Hancock, 2009) such as project-based networks (Moe and Pathranakul, 2006), ad hoc collaboration networks (Camarinha-Matos and Afsarmanesh, 2008a, 2008b; Nolte and Boegnick, 2012), horizontal cooperation (Schulz and Blecken, 2010) or the inter-organisational networks (Stephensen, 2005, Moore et al., 2003) to address the proliferation of heterogeneous partners (Jiang et al., 2012). The use of both structures (long-term and short-term collaboration) in the literature is further investigated as follows.

The subject of supply chain has attracted the most attention from the scholars focusing on partner selection in disaster relief management. The variety of approaches is presented in the literature reviews (Weber et al., 1991; Holt, 1998; Degraeve et al., 2000; De Boer et al., 2001; Wu and Barnes, 2011). Although in the underdeveloped field of disaster management the supply chain structure is introduced as an optimal network structure (Maon et al., 2009), there are various arguments against the suitability of these structures for disaster situations. For example, the supply chain structure has been suggested based on the assumption that 80% of disaster operations (activities that are performed before, during, and after a disaster with the goal of preventing loss of human life, reducing its impact on the economy, and returning to a state of normalcy, Altay and Green, 2006) is involved with logistics (Wassenhove, 2006). Therefore, a supply chain structure is suitable for managing the disaster (Balcik et al, 2010). However due to the lack of control and information in disaster situations, these approaches might fall short in practice. The reason is that these approaches require a certain amount of knowledge about 'when, where, what, how much, where from and how many times' which is generally unknown in a disaster situation due to the unstable nature of this entity (Wassenhove, 2005). For example, a huge amount of the disaster financial resources depends upon fund-raising (Oloruntoba and Gray, 2006) from occasional donors and a steady flow of funding cannot be guaranteed. In addition, demand, and supply are rarely equal or distributed effectively (Comfort, 2004; Tierney and Trainer, 2004) let alone their dramatic fluctuation during the course of disaster management operations (Wassenhove, 2005). In addition, long-term approaches are profit based whilst in a disaster situation the non-financial factors such as time values of commodities are much greater than the costs (Oloruntoba and Gray, 2006; Pettit and Beresford, 2009) which makes the conventional profit based values less accurate. The arguments above raise the suspicion that long-term collaboration might not be the optimal structure for disaster relief networks in all cases. To that end, an alternative option (short-term structure) is investigated as follows.

The use of short-term structures such as a project management structure (Moe and Pathranakul, 2006) and Virtual organisations (Grabowski and Roberts, 2011) for disaster response network due to its temporary nature. The VO-like organisations first appeared in an article by Drucker (1988), who described the emergence of a new generation of organisations. However, the expression 'Virtual Corporation' (Davidow, 1992; Byrne, 1993) was coined later in the literature. One of the early studies focusing on the 'successful partnership determinant' was conducted by Kantar (1994) who explained the phenomenon based on the 'Collaborative advantage' as a well-developed ability to create and sustain fruitful collaborations. In practice, working across organisations has been long recognised as the necessity in public management (Friend et al., 1974). However, in recent years, more companies in response to the volatile and competitive business environment (Camarinha-

Matos and Afsarmanesh, 2008a) have adapted collaboration to increase their chance of survival and gain a competitive edge (Romero et al., 2009). An extreme case of collaboration network is the Virtual Organisations (VO) as temporary alliances of independent enterprises (Afsarmanesh and Camarinha-Matos, 2005). This entity is composed in response to a single market opportunity (Martinez et al., 2001), which dissolves when the market declines (Brown and Zhang, 1999). In fact, the VO structure is a method used by the traditional companies to access the resources out of the boundaries of their own company (Jaegers et al., 1998) and a niche market (Brown and Zhang, 1999) by collaborating together. Jagers et al. (1998) believe that the idea of Virtual organisations/enterprise has developed out of the lean and agile manufacturing industry with the shift of focus on inter-organisations relationships.

The use of VOs in disaster relief related literature however is limited to a few studies. For example, Javaid et al. (2013) developed a reputation-based method for generating a disaster response network within the structure of a VO. There are other suggestions for the emergence of temporary forms of alliances (Jones and Bowie, 1998) from independent and heterogeneous enterprises (Camarinha-Matos and Afsarmanesh, 2006, Romero, 2009) such as humanitarian aid networks (Javaid et al., 2013; Garbowski and Roberts, 1999, 2011; Paszkiewicza, and Picard, 2011; Ermilova and Afsarmanesh, 2007).

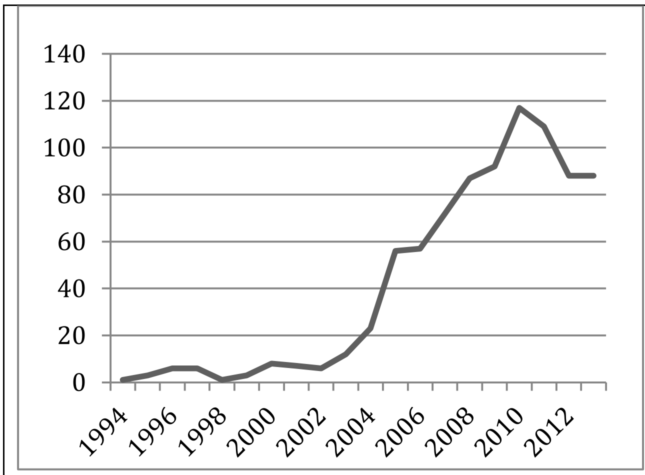
Due to the insufficiency of the available literature regarding short-term and long-term structures in disaster relief networks, the author looks into the literature, which utilises the short-term and long-term collaborative structures in the non-disaster relief situations. The following literature review is the product of this effort, which investigates the suitability of these structures for implementation in disaster relief networks.

2.5.1.1 COLLABORATIVE STRUCTURE FOR NON-DISASTER RELEIFE NETWORK

As was mentioned before, due to low volume of the literature regarding collaborative structures in disaster relief networks, the literature regarding the collaborative structures in the non-disaster relief situations is conducted.

To investigate the suitability of these structures, an extensive literature review has been conducted using different search engines in the area of business, management, and decision-making. The SCOPUS collection retrieved 842 results from 1994 to the end of December 2013 focusing on collaborative networks (FIGURE **2-3**). The search was limited to English sources published, including articles, articles in press, book, book chapters, and conference papers (FIGURE **2-3**). The keywords contained "Collaborative network (s), supply chain (s) (management), project management, virtual organisation (corporation) (enterprise), virtual breeding environment". The search was also limited to business and management studies (583 articles) and decision sciences (449 articles).

FIGURE 2-3 THE GROWTH OF LITERATURE FOCUSING ON COLLABORATIVE NETWORKS



Year	Article
1994	1
1995	3
1996	6
1997	6
1998	1
1999	3
2000	8
2001	7
2002	6
2003	57
2004	12
2005	23
2006	56
2007	57
2008	72
2009	87
2010	117
2011	109
2012	88
2013	88

Source: Compiled from SCOPUS

FIGURE **2-3** depicts the growth in the amount of literature focusing on collaborative networks .The first traces of the collaboration organisations are found in Kanter (1994) who was first to articulate the collaborative advantage as the road to success in collaboration. Ever since the literature focusing on the subject has increased. The growth of this literature signals the increasing interests of the scholars to the collaborative networks.

2.6 LITEARTURE REVIEW STRATEGY

In order to review this wide range of literature, a system approach to literature review introduced by Levy and Ellis (2006) is used. In this method a data-base search is put forward considering the keyword/backward/forward searching technique using the specific keywords. The end of the search is indicated when new articles only introduce familiar arguments, methodologies, and findings (Leedy and Ormrod ,2005) in other words no new citations are discovered (Webster and Watson,2002). The keyword search includes 'Collaborative networks', 'Collaborative performance', 'Collaborative network performance', 'Alliances performance', 'partnerships performance', 'Supply chain collaborative performance', 'Extended Enterprise collaborative performance', 'Virtual Organisations Collaborative performance', 'Public collaborative performance', Inter-organisational performance" amongst others. The various results were drawn from different databases, for example the keyword 'Collaborative networks performance' produces 2,841 results in Scopus, 38,043 articles in Science Direct and 19541 results in the university summon engine. However the majority of the results are overlapping because different search engines represent the same journals.

The results of the keyword search then were searched backwards (Levy and Ellis, 2006) by reviewing the bibliography of the most relevant articles, followed by forward searches (Levy and Ellis, 2006) of the most influential authors and the articles referring to them. For example, in the current study the publications by Abreu et al (2009), Afsarmanesh and

Camarinha-Matos (2003,2005), Azevedo and Almeida (2011) , Bititci et al (2005,2008,2012) , Camarinha-Matos, Alfaro-Saiz et al (2007) and Seifert (2004,2005,2007) were the initial sources of backward and forward searches. Although the literature review is an on-going process throughout the whole research, a sufficient amount of material for the literature review analysis was obtained when the familiar and repetitive citations and concepts were found to re-appear (Webster and Watson, 2002; Leedy and Ormond, 2005; Levy and Ellis, 2006). The distributions of the available resources are exhibited in FIGURE **2-4**.

FIGURE 2-4-THE COMPOSITION OF LITERATURE

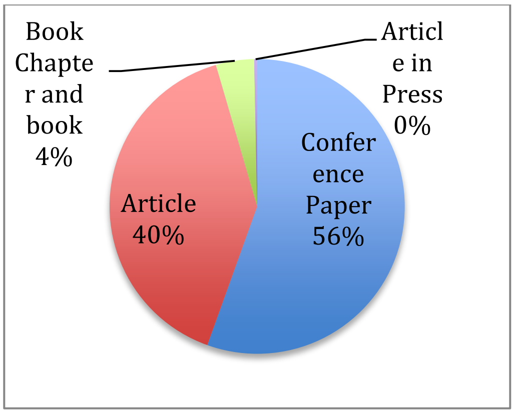


FIGURE **2-4** shows that the percentage of conference papers (56%) exceeds articles (40%) followed by other sources (4%). The validity of the data (Levy and Ellis, 2006) was primarily verified by obtaining them from high quality sources such as Scopus, Science Direct, JSTOR, Elsevier and the Summon search engine. They were required to meet a minimum standard such as being published in peer-reviewed journals with sufficient theoretical background (Levy and Ellis, 2006). The papers were also required to be published in a medium, good, high, or excellent grade journals as is shown in Table 2.2. This means that the articles used in the current literature review are at least published in a grade 1 journal or higher according to ABS ranking (Harvey et al., 2010) and Q4 journal or higher according to SJR ranking (2007). An example of the report on the quality of the reviewed publications is illustrated in detail in TABLE **2-2**.

TABLE 2-2 AN EXAMPLE OF THE QUALITY AND QUANTITY OF THE REVIEWED PUBLICATIONS

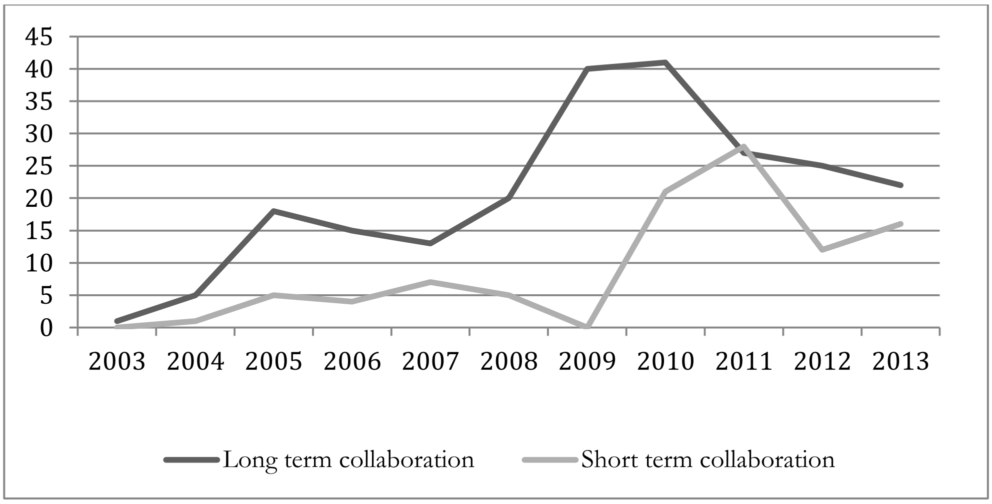
Journal Name	Paper Quantity	Journal Name	Paper Quantity	Journal Name	Paper Quantity	Journal Name	Paper Quantity	Journal Name	Paper Quantity	Accrediting body
ACM transactions on computer-human interaction	1	Knowledge-Based Systems	1	Building research and information	1	Computers in Industry	7	Knowledge and Information Systems	1	JSR
Computers in Human Behaviour	1	Non-profit and Voluntary Sector Quarterly	2	British Journal of Management	1	ACM transactions on computer-human interaction	1	Robotics and Computer-Integrated Manufacturing	1	JSR
Global Health Promotion	1	Research Policy	1	Computers in Human Behaviour	1	Strategic HR Review	1	Journal of Modelling in Management	1	JSR
Journal of Operations Management	3	The Milbank quarterly	1							ABS
Journal of Intelligent Manufacturing	5	Environmental Science & Policy	1	Journal of Intelligent Manufacturing	5	Chaos, Solitcons and Fractals	1	Assembly automation	1	JSR
Expert Systems with Applications	3	Omega: The International Journal of Management Science	1	European Journal of Operational Research	3					ABS
Information Sciences	1	Information Sciences	1	Telecommunication Systems	1	Journal of Manufacturing Systems	1	Journal of Manufacturing Systems	1	JSR
Ai and Society	1	Ai and Society	1							JSR
International Journal of Productivity and Performance Management	4	International Journal of Agile Management Systems	1	Business process management journal	2	Marketing Intelligence & Planning	1	Management Decision	1	ABS
Information	1	Benchmarking	1	Industrial	3					ABS

Resources Management Journal		an international journal		Management & Data Systems						

Guide to the chart colours
Excellent: The 'grade four' publication in ABS ranking or Q1 in SJR ranking or published book
High: The 'grade three' publication in ABS ranking or Q2 in SJR ranking
Good: The 'grade two' publication in ABS ranking or Q3 in SJR ranking
Medium: The 'grade 1' publication in ABS ranking or Q4 in SJR ranking

TABLE **2-2** shows that the current paper is built upon a set of quality sources of data. These articles were then filtered according to their focus on the collaboration duration (short/long-term) into 309 articles (FIGURE **2-5**). Virtual organisations, inter-organisational projects, product development projects, outsourcing projects, and temporary alliances are considered as short-term and supply chain, joint ventures, strategic alliance, and franchises are considered as long-term.

FIGURE 2-5 THE GROWTH OF STUDIES FOCUS ON SHORT/LONG COLLABORATION



Source: Author

FIGURE **2-5** shows that although both branches of literature have grown during the past years, long-term collaboration has attracted more interest with 212 articles in the past years recently compared to short-term collaboration with 95 articles. Long-term collaboration has especially been the subject of extensive research (Wu and Barnes, 2011; Aissaoui et al., 2007; De Boer et al., 2001) because more traditional collaboration networks follow a long-term outlook (Gallear et al., 2012) whilst a holistic literature review on short-term collaboration is missing. The majority of the articles focussing on long-term collaborations, focus on how to manage an "already formed" collaboration successfully. On the other hand the expert interest in short-term collaboration is directed towards the partner selection decision support or how to successfully choose the partners "before" starting the collaboration. To understand this segregation better, it is essential to describe the structure of a collaborative network as follows.

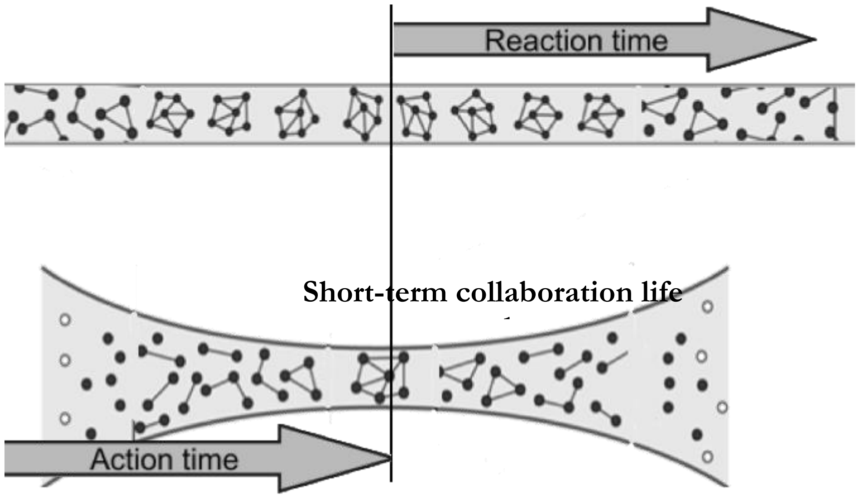
The analysis of the above literature highlights the direction of the expert interest towards long-term collaboration and negligence towards the short-term collaboration. The preliminary review shows that the existing studies extend from a wide range of collaboration forms such as supply chains, joint venture, alliances, projects, and Virtual Organisations, among others. However, the literature is more focusing on long term collaborative strcuctures such as supply chains and strategic alliance and are less concerned with short-term collaborations such as VO, project and joint ventures. Amongst 144 articles focusing on the short term collaborations those only 72 articles focus on short-term collaboration including 65 articles on VO, 7 articles on inter-organisational collaborative projects, and 13 articles on other collaborative forms including, new product development projects, and temporary alliances. Although the act of collaboration is associated with a higher competitive position (Romero et al., 2009; Camarinha-Matos and Afsarmanesh, 2008), the significant risk of failure is expected due to the selection of weak or unreliable partners (Wegehaupt, 2004 cited by Hans, 2008). The preliminary literature review also reveals a difference in one important aspect. The literature on long-term collaboration focuses more on the operation phase because there is time for continuous performance improvement whilst the literature on short-term collaboration is more focused on the initiation phase. The author believes that the shorter life cycle in short-term collaborations in comparison to long-term collaborations is the basis for the differences in the literature. Traditionally a prominent method to guarantee the success of an organisation is assessing/improving its performance (Neely et al., 2005) in order to gain insight into the future, and guarantee the long-term profitability (Lehtinen and Ahola, 2010).

However with the emergence of short-term collaborative networks (Cao and Zhang, 2010), such as joint ventures, alliances, and supply chains, the applicability of the traditional frameworks are being questioned by various scholars (Evans et al., 2004; Walters, 2005; Camarinha-Matos and Afsarmanesh, 2007; Folan and Browne, 2005; Bititci et al., 2005; Alfaro Saiz et al., 2007; Lehtinen and Ahola, 2010). In short-term collaboration the scarcity of time, renders it incapable of continuous improvement in the operation phase.

The alternative option to guarantee the success of the short-term collaboration is to choose the most suitable partners and therefore assure the quality of the created collaborations. The three phases of life cycle are present in both structures, the length of the operation phase in long-term collaborations significantly differs from the length of the operations phase in short-term collaborations. This characteristic is the main source of differences on which most of the other differences lie.

FIGURE 2-6 LIFE CYCLES OF COLLABORATIVE STRUCTURES

Long-term collaboration life cycle



Adapted from Seifert (2007)

FIGURE **2-6** shows that the long-term collaboration has time after and during its operation to react to poor performance, whilst the short-term collaboration needs to act in the early stages of its formation and finish its performance improvement before the collaboration dissolves, otherwise there will be no time to correct the performance failure. Because it is useless to assess where a temporary organisation failed when there is no chance to go back in time and correct the mistake. Therefore, failure in the operation of short-term or temporary collaboration means the failure of the whole organisation at once. To that end, researchers try to predict the future success of a short-term collaboration by evaluating the potential participants before the formation of the short-term collaboration (Seifert and Eschenbaecher, 2004; Parung and Bittitci, 2006, 2008; Camarinha-Matos and Abreu, 2007; Abreu et al., 2009; Romero, 2009, Rosas et al., 2011). These approaches face a main challenge. They fail to introduce a framework, which guides the researchers and practitioners to select and configure the suitable partners. Therefore, this section is dedicated to reviewing the literature concerning the re-structuring and partner selection in collaborative networks including disaster response networks, short-term and long-term collaborations and evaluating if the determinants and methods utilised for this task are suitable for disaster response networks.

2.6.1 RE-STRUCTURING THE DISASTER RELIEF NETWORK

The literature on this area is wide ranging; 16,591 publications in the source mentioned in the previous section have addressed the phrase 'Virtual organisation performance'. Although the richness of the literature in the field of collaboration performance focusing on the Virtual organisations indicates the attraction of the subject in theory, the collaboration act in practice is no guarantee for the success of a collaborative network (Bamford et al. 2004; Bullinger et al. 2003; Dürmüller 2002 cited by Westphal et al., 2008). In fact the failures among collaborative companies are more common than successes (Lewis, 1990; Elmuti and Kathawala, 2001; Zineldin and Bredenlow, 2003 cited by Bititci et al., 2008). The reason being the success of VO is influenced by interaction of contributors, however their individual contribution to the overall performance is difficult to assess (Westphal et al., 2010). Also the collaboration act creates a *Virtual* network of interactions which is independent from participative companies (Bititci et al., 2012) and the overall performance of the VO is not necessarily equal to the integrated performance of all participants. To that end the efficient operation of the VO needs to be supported with a suitable collection of partners who work together efficiently to achieve a shared goal and guarantee the success of the VO.

2.6.2 NETWORK CONFIGURATION

Another focus of literature as discussed above was the selection of fewer partners. In other words choosing certain organisations, which are suitable and able to provide for the disaster response. The reason is that the success of collaborations is determined by the quality of the created collaboration from the right partners. Therefore, the organisations should identify partners who are compatible with goals, similar objectives and the required skills based on an evaluation matrix of criteria. The main challenge to dealing with the proliferation of actors is limiting the number of partners entering the disaster scene according to certain criteria. This solution would reduce the decision-making dimension, and probably would improve the disaster operation by shortlisting the most qualified partners in a timely manner. To that end, the decision regarding how to select these partners is a decision-making problem in its own right. The literature concerning the partner selection in disaster relief network is limited to a few studies. A number of scholars have specifically provided tools to save time and efforts in the selection procedure (Baldo et al., 2009). These studies are either utilising the information system (Javaid et al., 2013), task allocation (Smirnov et al., 2007) and scheduling techniques (Rolland et al, 2010) or highlighting the necessity to develop the decision support in disaster situation (Rolland et al., 2010, Simpson and Hancock, 2009). Javaid et al. (2013) developed a reputation-based method for disaster team selection utilising existing ICT systems. Employing a simple accumulation method, they aggregate the weights for each task and calculate the reputation for each partner. Other related researches are limited to the attempts to adapt existing decision support methods from logistics or production management areas to the disaster decision such as Smirnov et al. (2007) who have tried to customise an existing task allocation technique to the disaster decision. However, their research is limited to information management techniques, and partner selection is just mentioned as a part of the resource allocation process. The other research belongs to Rolland et al. (2010) who attempted to address the existing scheduling decision-making to a disaster situation. The partner selection in this model is part of assigning personnel and setting up the response teams. Other attempts are only remotely related to the subject for example Hu and Li (2011) provide a method to reduce the partner selection criteria based on information entropy in mobilisation alliances. This shows that the decision-making in a disaster response network, and specifically methods to choose the disaster relief partners is yet to be developed. This also signals another opportunity for setting the direction of the present research.

The selection criteria have been set in the literature in various ways, for example according to the partners' attributes (Sarkis et al., 2007; Yu e al., 2010; Zhang and Geng, 2010; Yang and Lin, 2008; Li et al., 2000) or according to the partners' goal achievement probabilities (Rocha and Oliveira, 1999; Mun et al., 2011). Others suggest selection criteria based on performance indicators (Baldo et al., 2009), virtual score cards (Grudzewski et al., 2005) or the SCOR model (Bittencourt and Rabelo 2005), which are originally designed for a supply chain. Finally, Seifert and Eschenbacher (2005) suggest a planning tool for virtual organisations to anticipate the performance of a planned virtual team. To evaluate which criteria and method is suitable for partner selection in disaster response the second literature review focuses on two major issues: identification of suitable criteria for partner selection and the decision-making methods.

2.6.2.1 PARTNER SELECTION CRITERIA IN DISASTER RESPONSE

The evaluation indexes for partner selection in short-term collaborations can be numerical as well as heuristic. In the literature focusing on partner selection in short-term collaboration, 21 articles use the traditional numerical criteria for partner selection whilst 51 articles use the heuristic criteria.

However, the numerical criteria are not originally designed for short-term collaboration but they are borrowed from the literature on long-term collaboration, and are employed for partner selection (Baldo et al., 2009; Sarkis et al., 2007; Hans et al., 2008; Chen and Wang, 2009) as financial or quality based performance indicators. To that end, the author argues that they are difficult to obtain in the short-term or sometimes irrelevant to the disaster situation.

The reason is that they are not designed to address the characteristics of DRN. The numerical approaches which use certain data for partner selection such as price (Bittencourt and Rabelo, 2005; Mikhailov, 2002), time (Sarkis et al., 2007; Huang and Fan, 2007; Xiang and Qian, 2012; Mohamed and Abdelsalam, 2012), due date (Zeng et al., 2005; Zhan, 2008, 2009; Xiao et al., 2011), and budget (Fulga, 2007) are based on a fully informed decision environment and are time consuming to calculate. This author argues that these criteria are unsuitable for a disaster response due to the scarcity of data and also time pressure associated with the disaster situation. However the heuristic based approach such as selection based on trust (Msanjila and Afasarmanesh, 2008), readiness to collaborate (Romero et al., 2009), reputation (Solesik and Encheva, 2010) and so forth are probable candidates for disaster response. This is because they are based on the assumption that uncertainty of information is present in the disaster response. To that end, this research further explores the literature suitable for the disaster situation where the uncertainty and constant pressure for time is inherited.

The success of collaborations is determined by the quality of the created collaborations, which depends on the right partners. Therefore, the organisations should identify partners who are compatible with similar objectives and required skills, level of trust, operation, size resources, and so forth. With the emergence of short-term collaborative networks (Cao and Zhang, 2010) the applicability of the traditional frameworks, which tend to guarantee the success of an organisation by assessing/improving its performance (Neely et al., 2005) in order to gain insight to the future, and guarantee the long-term profitability (Lehtinen and Ahola, 2010) are no longer required. Because due to the rising competition in the markets companies are obliged to quickly adapt and share their resources in order to satisfy the single market opportunities which arise only one time, or in some geographical area. Such as the need created in a disaster area for food in a short period of time, which will not be repeated or the demand for building one shopping mall in a town, which will be satisfied and finished, by building one mall. This issue gives rise to the emergence of temporary forms of strategic alliances (Jones and Bowie, 1998) called VO (Virtual organisations). These entities comprise from independent, and heterogeneous enterprises (Camarinha-Matos and Afsarmanesh, 2006; Romero, 2009) and have developed from agile supply chains where the intra-organisation focus shifts to inter-organisation focus (Corvello and Migliarese, 2007). Examples of such entities are humanitarian aid networks (Javaid et al., 2013; Garbowski and Roberts, 2011, 1999; Paszkiewicza and Picard, 2013; Ermilova and Afsarmanesh, 2007), construction sector projects (Paszkiewicza and Picard, 2013), health care services (Ermilova and Afsarmanesh, 2007; Paszkiewicza and Picard 2013) or film production (Beckett, 2003). Although these manifestations of collaboration are associated with higher competitive position (Romero et al., 2009; Camarinha-Matos and Afsarmanesh, 2008), the significant risk of failure is expected due to the selection of weak or unreliable partners (Wegehaupt, 2004 cited by Hans, 2008). Therefore, in order to guarantee the success of a collaborative network such as a disaster response network, the partner configuration process is very important. A substantial number of studies focus on the partner selection in collaborative networks. Although the studies focusing on long-term collaboration are well established, the partner selection in short-term collaborations has yet to be unified and consolidated. In general, collaboration partner selection (for long-term and short-term) in the literature is addressed by traditional evaluation indexes. These criteria are defined in TABLE **2-3**.

TABLE 2-3 SUMMARY OF THE TRADITIONAL EVALUATION MEASURE

Scholar	Evaluation measure
Abreu and Camarinha-Matos (2009)	Alignment (fit) in interest, value, aim
Baldo et al. (2009)	Performance indicators (quality, accuracy)
Blanc et al. (2007)	Interoperability
Brookes and Altinay (2011)	Past association, resources, facilities, partner size, status, nature of business, motivation
Camarinha-Matos and Abreu (2007)	Survival capacity, Performance capacity
Cummings and Holmberg (2012, 2009)	Critical Success factor (related to task, learning, partner, risk)
Ding and Huang (2010)	Firm’s contribution

Duffy and Fearne (2004)	Level of performance (as a dependent to trust, efficiency, conflict resolution, commitment, communication, etc.)
Ferreira et al. (2011)	Key Success Factor (for each stakeholder, for example price for customer, reputation for partner and responsiveness for broker)
Francisco et al. (2012)	Alignment of internal fit with strategic goal
Fulga (2007)	Cost, Time, Budget constraint
Gradl et al. (2010)	Capital, Capabilities, Linkages
Grudsewski et al. (2005)	Competency
Hitt et al. (2000)	Market control (size, experience, resources), Partner (Capability, asset, cost of alternatives,)
Hsieh and Lin (2012)	Cost efficiency
Ip et al. (2003)	Failure probability
Jayaram and Pathak (2013)	Capability
Lasker et al. (2001)	Partner's contribution to the network
Lau and Wong (2001)	Information infrastructure
Liou and Chen (2011)	Internal Drivers (Risk sharing, Economies of scale) and External Drivers (Information revolution, Global competition)
Matopoulos et al. (2007)	Risk Sharing

TABLE **2-3** articulates the traditional evaluation measures. Utilising the accumulated measures from different angles is a common practice. For example, Hitt et al. (2000) built a measure based on the status of the firm in the market such as size, experience, and the characteristics of the partner itself such as assets, capability, etc. Cummings and Holmberg (2009, 2012) built a measure from four perspectives, task-related, risk-related, partner-related, and learning-related. Ferreira et al. (2011) built their measures from the stakeholder's perspective such as price for customer, reputation for partner, and responsiveness for broker. Some scholars use single measures suitable for the situation when uncertainty is low (Bierly and Gallagher, 2007). For example, Romero (2009) provides a framework to measure the readiness of the company for collaboration. They take a multilevel analysis and assess the strategic fit, organisational agility, and past performance. This measure therefore, requires a great deal of data about past records, and current situation of the partners, which may not be available or feasible to analyse during the disaster response. The same reasoning is applicable to the measures of achievability of the goals (Tiacci and Cardoni, 2012; Mun et al., 2009), and task performance (Yongli, 2008), which is calculated, based on the previous records of the partners. In fact some of the partners in a disaster situation are created ad-hoc (such as volunteers), and it is impossible to assess their non-existent previous records. However, they might provide the resources required for response, and it is not wise to ignore them because of the lack of measures just mentioned. Another measure is alignment where Francisco et al. (2012) used Control theory to measure if the partners' internal fit is aligned with strategic goals of the collaboration. Similarly, Jayaram and Pathak's study (2013) compared the design capability of the firm with the supply chain to identify if the company is aligned enough to be chosen for the collaboration. In another research study, Matopoulos et al. (2007) argue that the sharing of risk could influence the trust and therefore, the partner selection based on the distribution of the power. In the disaster response, the power asymmetry between different partners is inevitable and due to political reasons, it is impossible to avoid selecting a response partner on the basis of their power.

Another interesting approach is where the heuristic nature of criteria is recognised and calculating the exact number is avoided. For example, Duffy and Fearne (2004) state that it is enough to predict each partner's heuristic level of performance according to certain measures (trust and commitment, relational norms, involvement in decision and planning, and conflict resolution). In addition, Rosas et al. (2011) use competency to suggest partner selection by perceiving whether partners are likely to perform above, or below, the expected competency levels. The significance of their work is to recognise the differences between the hard/soft competencies. The soft competencies can be assessed by the perception of organisations' traits (diplomacy and honesty), recommendations, past behaviour, and expected performance. On the other hand, the hard competencies (Technical) can be accessed via 'capability', 'capacity', 'cost' and 'conspicuity'. Others introduce the probability of various measures as criteria such as failure probability (Ip et al., 2003), 'achievability probability' (Mun et al., 2009) which is basically an equation made of 'previous failure record'. For example, they record each time a partner fails to meet certain targets for quantity, cost, etcetera, and this contributes to their evaluation score. There are even attempts to estimate the success of a potential group of members before the actual formation with a forward control dynamic estimation (Azevedo and Almeida, 2011). This group of criteria is presented in TABLE **2-4**.

TABLE 2-4 SUMMARY OF THE HEURISTIC EVALUATION MEASURES

Scholar	Evaluation measures
Msanjila and Afsarmanesh (2008)	Trust
Mun et al. (2009)	Trust (goal achievement probability)
Naesens et al. (2009)	Strategic fit
Parung and Bittitci (2006, 2008)	The partners' contribution (input), involvement (health), and outcome
Pidduk (2006)	Requirements or skills or constraints, availability, social network; reputation; ambiguity
Romero et al. (2009)	Readiness to collaborate
Romero (2010)	Value: tangible (economic benefits, productivity related), and intangible (strategic, social, etc.)
Rosas et al. (2011)	Competencies such as diplomacy and honesty, recommendation, past behaviour, 'capability', 'capacity', 'cost' and 'conspicuity'
Roy (2012)	Trustworthiness
Solesvik and Encheva (2010)	Reputation, competence in software, product development, knowledge of partner's internal standards. Complementarity of partner's resource contribution, trust , experience , etc.
Tiacci and Cardoni (2012)	Achievability
Williams and Lilley (1993)	Strategic compatibility, skills, resources, size and financial capability, trust, operation compatibility, mutual dependency
Yongli (2008)	Task performance (quality, cost, cooperative satisfaction of the partners)
Yun (2011)	Knowledge disparity, organisation disparity, trust level, and organisational supply ability considered

The significance of the heuristic approach rendering them probable candidates for disaster partner selection is that they it is based on the assumption of uncertainty of information, which is inherited in the disaster situation as well as some market situations. However, the majority of the heuristic values require a long-term collaboration to establish their measurement frameworks. For example trust, reputation, the achievability probability, task performance etc., require previous engagement of the partners. This group of criteria is suitable for the situation when there is no time constraint such as in less competitive industries or the low-tech industries in which the technology does not change quickly (Bierly and Gallagher, 2007).

2.7 CRITICAL EVALUATION OF THE DECISION CRITERIA

The criteria, which are originally developed for short-term collaborations have the potential to be considered for a disaster situation, however the suitability of these approaches for the disaster situation should be examined.

First, the time pressure during the disaster renders data collection impossible or unreliable. Second, the historic data are non-existent or difficult to obtain unless they are obtainable in a real-time basis. For example, the criteria with time-consuming calculation processes such as cultural value or balance of power, sustainability are unsuitable for disaster response networks. Third, the criteria, which are purely financial, are unsuitable for the disaster situation, because human lives carry more weight in a disaster situation than financial efficiency.

Heuristic criteria could either use uncertain mathematical values such as risks and probabilities, or use the non-mathematical data such as quantified qualitative values such as trust and reputation. The uncertain mathematical values may include risk failure probability (Ip et al., 2003), success probability based on past collaborative performance (Yao et al., 2006; Jarimo and Salo, 2009; Kumar and Harding, 2011), ‘achievability probability’ (Mun et al., 2009) based on ‘previous failure record’, or other uncertain data and risk (Li et al., 2008; Ye and Li, 2009; Ye, 2010; Huang et al., 2010), project risk of failure (Fuqing et al., 2005), various risk values (Li et al., 2008,2009; Ye and Li, 2009; Ye , 2010), and capacity risk (Jarimo and Salo, 2009), defined as the expected shortfall from a target value, as the basis for their partner selection. These approaches are mainly based on previous records of performance/success/failure in the partner organisation, and are suitable for situations where the historic data are available. However, this is not the case in a disaster situation. Therefore, this category of criteria seems unsuitable for a disaster situation.

The risk-based approaches including the self-declared success probability (Ip et al., 2003; Fuqing et al., 2006; Yao et al., 2006) and internal/external risk model (Li et al., 2008) are unobtainable for disaster situations due to the time consuming process, and unreliability of the data gathering under pressure with damaged infrastructure.

A heuristic approach could also use the non-mathematical values such as competency. Competency is the result of integration, and interfaces between the capabilities/capacity of the company in exploiting the resources (Ermilova and Afsarmanesh, 2007; Romero, 2009). Some scholars suggest using the capacity (Tao et al., 2012; Paszkiewicz and Picard, 2011), competency (Yao et al., 2009, Rosas et al., 2011; Ermilova and Afsarmanesh, 2008; Grudsewski et al., 2005, Stoica and Guilic Micu, 2011; Zhong et al., 2009; Paszkiewicz and Picard, 2011) and capabilities (Chen and Li, 2007) to select partners. However, competency based approaches generally avoid calculating the exact number, instead they predict the linguistic/fuzzy level of expected performance by profiling competence (Ermilova and Afsarmanesh, 2008) or by perceiving whether partners are likely to perform above, or below, the expected levels (Rosas et al., 2011). This approach is suitable for disaster response network partners wherever it is possible to evaluate the competency or capability of the partners based on their previous record or the resources they may acquire during the response phase. These approaches are appropriate for the situation when there are no time constraints or uncertainty for achieving all relevant information (Bierly and Gallagher, 2007). In a sudden onset disaster, that is not the case, and time pressure is extreme. Therefore, this category of criteria also seems to be unsuitable.

A more practical approach to competency-based criteria is to use the actual resources as the criteria for partner selection. The resources according to Javidan (1998) may be physical resources (e.g. equipment, location, and assets), human resources (e.g. manpower, management team, training and experience), and organisational resources (e.g. culture and reputation). Some scholars use the less quantifiable organisational resources such as trust (Crispim and de Sousa, 2009; Lavrac et al., 2007; Msanjila and Afsarmanesh, 2008; Mun et al. 2009; Niu et al., 2012; Schmidt, 2007; Yun, 2011; Ryu et al., 2009; Sodhi and Son, 2009; Childe, 1998 cited by Lehtinen and Ahola, 2010) or reputation (Schmidt, 2007; Niu, 2012) heuristically calculated from people's opinions. The significance of these heuristic approaches is that they are based on the assumption of information uncertainty, which is inherent in the disaster situation. However, the paucity of a unified definition for these criteria makes it difficult to come up with a framework for partner selection using the dispersed body of definition. For example some scholars define trust simply as trust between partners (Ryu et al., 2009; Sodhi and Son, 2009). Some other scholars define trust as the belief held by the partners that one particular partner is committed, competent, and void of opportunistic behaviour (Childe, 1998 cited by Lehtinen and Ahola, 2010).

To summarise the majority of heuristic values require a long-term collaboration to establish their measurement frameworks. For example trust, reputation, the achievability probability, task performance require previous engagement of the partners. This group of criteria is suitable for the situation when there is no time constraint (Bierly and Gallagher, 2007). Therefore, although the cultural resources such as trust can be invaluable for partner selection, due to the lack of a unified framework in this research only physical and human resources are considered for partner selection. For example, the capacity of the partner to provide physical or human resources as the criteria for partner selection (Avila et al., 2010; Wu and Su, 2005). For example, matching a set of partners' capability to the requirements of a task by employing an industry wide search (Chen et al., 2007; Romero et al., 2009), and even taking into account the precedence of the tasks where the suitability of candidate A for task B qualifies candidate C for task D (Wu and Su, 2005; Yao et al., 2006; Huang et al., 2011). The set of partners may also be selected based on their capability to fulfil the particular objective or task (Tiacci and Cardoni, 2012; Crispim de Sousa, 2009; Talluri and Baker, 1996; Wu and Su, 2005; Chen et al., 2007; Mun et al., 2011; Tao et al., 2012) or to optimise the total result of the sub-projects allocated to various partners (Niu et al., 2012). Another criteria can be the alignment of the organisational resources such as strategy (Emden et al., 2006; Francisco and Almeida, 2012; Naesens et al., 2009; Tiacci and Cardoni, 2012; Bierley and Galaegher, 2007) tangible values (economic benefits, productivity related), and intangible values such as strategic, social etc. (Abreu, 2009; Romero, 2010), and technologies (Emden et al., 2006). Both these groups of criteria are subject to their own criticism, as mentioned above. These evaluation measures therefore are not suitable for the disaster situation where the uncertainty and constant pressure for time is present. To that end, the present research further explores the existing solutions introduced for the partner selection in short-term collaborations with time constraints, and examines if they are suitable for use in a disaster situation. This will be discussed later in the theoretical framework-Chapter 3.

2.8 DISASTER LITERATURE REVIEW

A preliminary search in th Scopus data-based with the keyword “Natural Onset disasters” in the field of business , decision sciences and economics, leads to 10 articles. The same keyword in Science Direct leads to 488 articles. However the research was intended to look into the frameworks for classification and prediction of the disasters impact so the review started from the encyclopedia of disasters (Gunn, 2007) who introduces various frameworks from a variety of scholars including Fujita, Saffir-Simpson, Richter and Mercalli.

The prominent research in the area were then identified (Rodriguez,2011; Mishra,2012; Jonkman, 2001,2002,2007; Doocey, 2007,2013; Gad-el-Hak, 2007). A number of organizational sources (Munich RE, 2007; CRED, 2009;Deltares.nl,2014) also were added to the initial literature review containing vital lead to the prominent frameworks. The result were analysed through the thematic analysis method (Levy and Ellis, 2006) as described earlier in two directions of backward and forward search until new titles no- longer appreard. The result were then consolidated to outline the necessity to develop a predictive framework by highlighting the categories of existing practice in disaster frameworks as follows.

2.9 THE NECESSITY TO DEVELOP THE PREDICTIVE FRAMEWORK

Due to the variety of disaster types and impacts, the impact of natural onset disasters appear to be incomparable. Attempts to provide the magnitude scales for various disasters (Gunn, 2007), such as Fujita scale for Tornados, Saffir-Simpson scale for Hurricanes, Richter and Mercalli scales for earthquakes, and Volcanic Exclusivity Index (VEI) make the comparison among similar types of disasters possible. For example, knowing that an earthquake with an 8 Richter magnitude makes it possible to say it is potentially more hazardous than an earthquake with 5 Richter magnitude. However, a method to compare different types of disasters -for example an earthquake magnitude measuring 8 Richter with a hurricane magnitude of 4 on the Saffir-Simpson scale has yet to be developed. In order to find a reference point to which all disasters are assessed, some scholars have adopted different approaches. The thematic analysis of the literature associated with these approaches reveals that these categories, based on their estimation/prediction and the use of conceptual/numerical measures can be categorised into four main approaches (FIGURE **2-7**).

FIGURE 2-7 APPROACHES TO DISASTER IMPACT COMPARISON

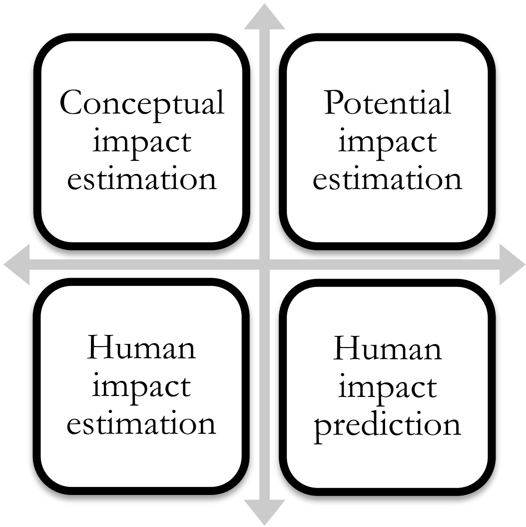


FIGURE **2-7** shows that one group of approaches is concerned with the estimation of the impact conceptually; this means they do not provide any numbers for the impact, but merely say that for example the earthquake has social impacts. The second group of approaches tries to estimate the potential impact for disasters by providing numbers but they do not provide predictions. The third approach focuses on the human loss estimation based on other criteria (e.g. damage to the building). The last group specifically provides predictions of the human loss. It is noteworthy to emphasise the difference between estimation and prediction. An estimation is inferred for a population based on the assumption that the sample data is a representative of the population and therefore "estimates" an unknown part of the dataset. However, a prediction is inferred for a random variable (which is not part of the dataset) based on a sample data or the whole population. In other words, the estimation is a calibration of the population based on a dataset, whilst the prediction calculates a value out of the dataset.

The first group tries to standardise the impact of disasters based on the social and cultural factors (Carr, 1932; Barton, 1969; Clement, 1989; Britton, 1986). However, these studies merely lead to conceptual frameworks. A more scalable approach is put forward to estimate the extent of potential destruction based on the type of the disaster (Lemon, 1957; Below, 2009), human, material, temporal, and areal factor (Lemon, 1957; Rutherford and De Boer, 1982; Ferro, 2005, Gad-El-Hak, 2007; Munich RE, 2007; CRED, 2009; Below et al., 2009; Ruwanpura, 2009; Wickramaratne et al., 2012), magnitude (Ruwanpura, 2009), and the coping capabilities of the affected population such as vulnerability and exposure (Friedman, 1975; Peduzzi et al., 2009), proneness and resourcefulness (Mishra, 2012), in addition to damage to infrastructure (Rodriguez,2011), and humanitarian aid supplying power (Ebig and Tandler, 2009). This group of research basically estimates the potential impact that a disaster may cause by taking into account the physical and socio-economic factors of the affected area.

The third group are more specific in terms of assessing the human loss in disasters as a result of various factors such as damage to the buildings (Aleskerov et al., 2005; Chan et al., 2003; Liao et al., 2005; Pai et al., 2007; Glass et al., 1977; Osaki and Minowa. 2001), the health and socio-economic status of the victims including wealth, age and gender (Chou, 2004; Kelman, 2004; Jonkman and Kelman, 2005; Doocey et al., 2007a), the location of individuals at the time of the disaster including outdoors, poorly constructed buildings, mobile homes, vehicles (Takahashi and Kubota, 2003; Daley, 2005; Doocy et al., 2013), the number of displaced population (Doocey et al., 2007b), vulnerability of the inhabitants/area (Brown and Graham, 1988; Wallingford et al., 2006; Deltares.nl,2014), the population density and the expected number of people remaining during the flooding (Klijn et al., 2007), dam failure (Hartford, 1997), time available for evacuation or rescue (Brown and Graham,1988; Ferro, 2005) in addition to warning efficiency, and the effect of rescue actions (Reiter, 2001), the possibilities for warning, evacuation and shelter, and the loss of shelter due to the collapse of buildings (Jonkman, 2007).

Probably due to the wealth of research on the third group, the fourth group of researchers went further and actually predicted the material (Friedman, 1974; Petak and Atkinson, 1985), and human loss of the disasters. Their predictions are based on expected geographical characteristics of the affected area such as water depth and flow velocity, rise rate (Waarts, 1992; Jonkman, 2007; Deltares.nl, 2014), potential dyke area for flooding, the size of the flooded area, the distance to safe areas (Klijn et al., 2007), hazard rating (Wallingford et al., 2006), drowning patterns (Vrouwenvelder, 1997; HKV, 2000; Jonkman et al., 2001, 2002) or physical vulnerabilities of the land (Spence et al., 2005; Jonkman, 2007). FIGURE **2-8** provides further examples for each category of the literature assessing the disaster impact.

FIGURE 2-8 THE PERSPECTIVES TO THE DISASTER IMPACT ASSESSMENT MODELS

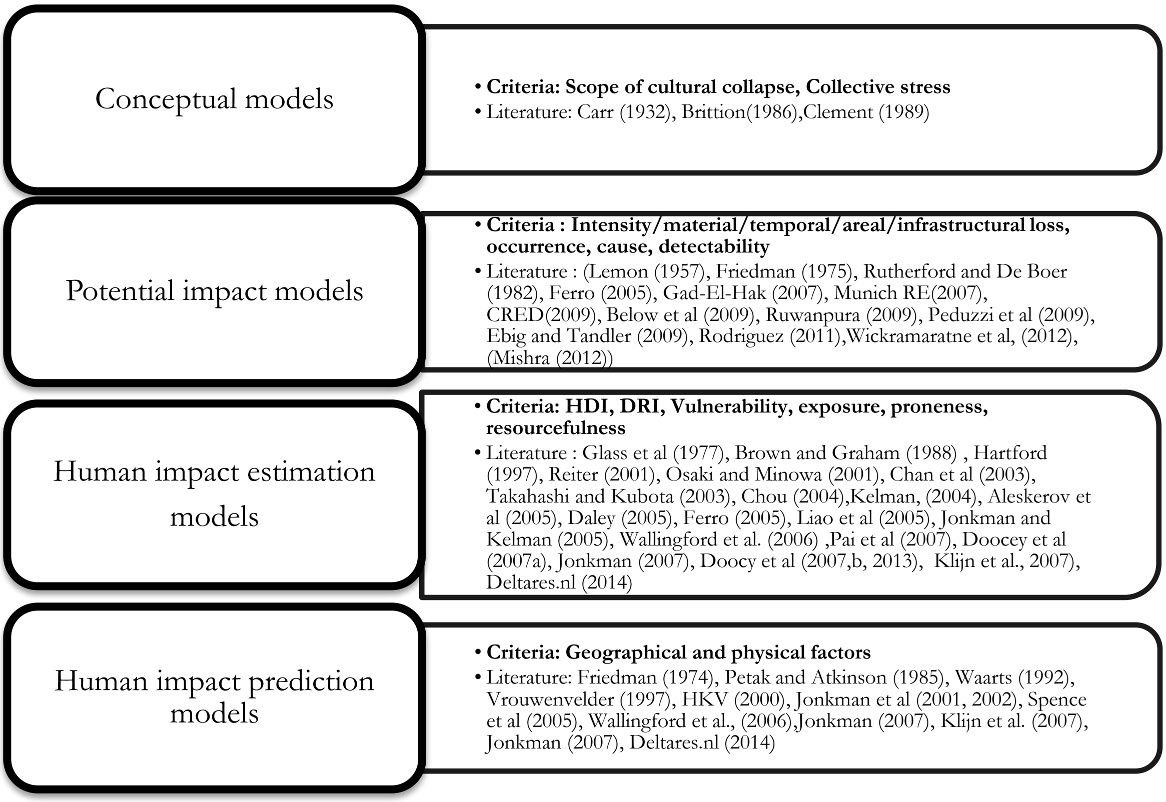


FIGURE **2-8** depicts that the conceptual approach to the impact of the disaster, are limited to the cultural and social distress resulting from a disaster, without quantitatively measuring them. Whilst a scalable approach has been adopted taking into account the quantifiable factors such as Intensity/material/temporal/areal/infrastructural losses, occurrence, causes, detectability of the disaster in quantitative units. However, the scholars fail to take into account the qualitative factors of the affected area such as their capabilities and risk factors. This issue is addressed in the third group of literature where they quantify the qualitative factors such as the affected countries' human development index, the disaster risk index, exposure and proneness to disasters and the resourcefulness of the affected population. Finally, the predictive approaches are mainly focusing on the physical characteristics of the disaster and the affected geographical area, without taking into account the coping capabilities of the affected countries. To that end a predictive framework, which employs both qualitative and quantitative factors in disaster, is missing. In addition, a predictive framework, which is based on the post-disaster data, fails to help in planning the response.

There is a need to develop a framework, which can predict the disaster human impact based on the simple data, which are available at early hours of the disaster strike. A group of complicated models have been designed to combine some elements of the above studies to suggest a model with 100 variables (McClelland and Bowles, 1999,2002) or to provide a compare based module (High-water Information System – Damage and Casualties Module) to calculate the expected damage and number of casualties due to the flooding. This utilises the geographical orientated data concerning e.g. economy, traffic, buildings and population (Deltares.nl, 2014). However, in the early hours after the disaster strike it is difficult or impossible to obtain the data about health or location of the people at the time of the disaster strike. In addition, the technical data about water depth and flow velocity are not available in all regions.

The present research argues that despite the existing research on the groups of literature above, a framework for predicting the human impact has yet to be developed. A number of reasons are associated with this claim. First, the most of the existing literature focuses on a single type of disaster such as flood, earthquake, eruption, etc. Therefore, a holistic framework to accommodate all types of disasters is missing. Second, the existing literature sometimes contradicts each other, for example many research studies predict the fatalities based on the damage to the buildings (Aleskerov et al., 2005; Chan et al., 2003; Liao et al., 2005; Pai et al., 2007; Glass et al., 1977; Osaki, and Minowa. 2001) whereas some researchers have not found an easy correlation between the pattern of building damage and the fatalities (e.g. Peek-Asa et al. cited by Alexander, 2000). The third reason for developing a new model is that although a rich body of complex and technical papers has been put forward as mentioned above, most of the findings are yet to be customised for practical use in real situations. For example, conceptual frameworks are impossible to use in practice. The framework with 100 variables is difficult and time consuming to use for an average decision maker and the extremely technical frameworks, which require a wealth of technical data and complicated computer simulation support might fall short in the disaster situation in many countries.The fourth reason is that the majority of the above criteria are drawn from data related to one or few events in specific countries and their extrapolation and generalisation is unreliable. The literature review contributes to the necessity of developing a model which employs the data universally available at the time of the disaster.

2.10 SUMMARY OF THE CHAPTER

The literature review chapter was put forward to pursue the following purposes:

The first purpose was to draw a picture of the proliferation problem in disaster response networks. This purpose was achieved by reviewing the limited literature, which pointed out this problem amongst others.

The second purpose was to investigate the existing attempts in the literature for addressing this problem. These attempts are twofold, firstly, to re-structure the disaster relief network in a short or long-term collaboration. The literature review on this area showed that the long-term collaboration has attracted more interest from researchers. Therefore, one of the gaps is to look into the short-term collaborative structures for disaster relief networks.

The second approach proposed by other scholars was to select fewer partners. This is a decision-making problem, and to that end, the literature regarding partner selection criteria and techniques were reviewed. The results showed that there are a number of criteria associated with partner selection in collaborative networks in general. The time horizon effects which criteria is used for partner selection. In addition, two streams of decision-making techniques are used in the literature including heuristic and mathematics. An investigation of the suitability of the criteria discussed, and techniques for partner selection in disaster relief network is missing from the literature.

The third purpose of this chapter was to identify the gap in the research, and provide the direction of this research. As was mentioned previously as a result of these two literature reviews, two gaps were identified. First, the suitability of the short-term and long-term collaborations for the disaster relief network needs to be investigated as well as the suitability of decision criteria, and techniques for the partner selection.

To position the focus of this research within the stream of literature as the last goal, the initiation phase of the short-term collaboration, which is associated with the decision-making process for partner configuration will be the subject of further studies.

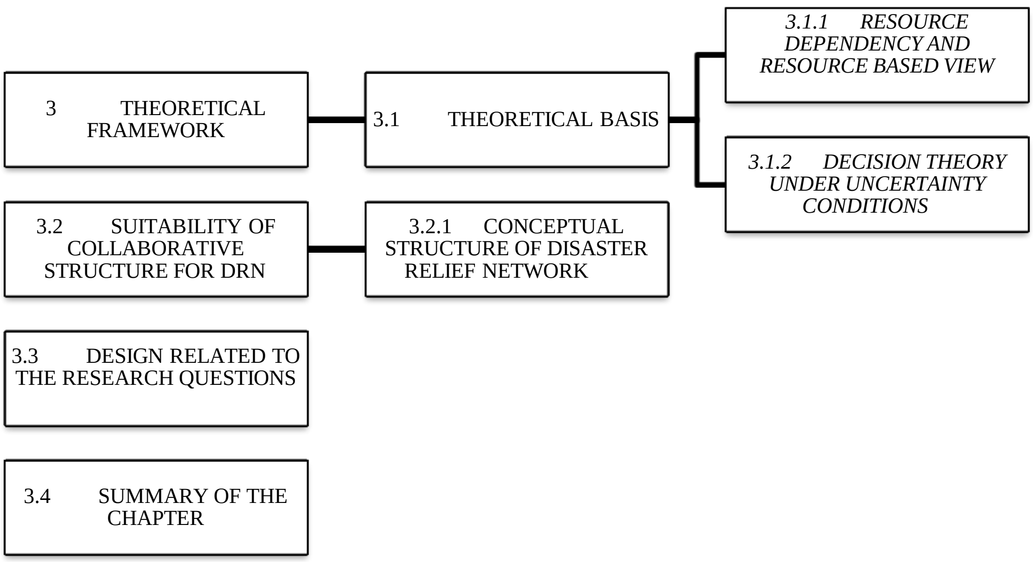
In addition to the original purposes of the chapter, which provides the research direction of the next chapters, the literature review provides further contributions, which could be the subject of further studies as follows. The literature review identified that despite the development of a substantial amount of literature addressing the decision support techniques for partner configuration, there is no consistency and uniformity between the employed frameworks. Even though some of the criteria have the same name (For example trust), their definition varies from one scholar to another. For example, “trust” is used in different concepts for partner selection. For some scholars it means collaboration without exploiting each other financially (Sodhi and Son, 2009) whilst for others it means being a member of another collaboration (Jarvenpaa and Leidner, 1999) or the general reputation of the enterprise (Rasmussen and Wangel, 2006). The severity of the problem would be clearer when it is compared to the long-term criteria with clear definitions. For example, the criteria designed for supply chain such as reliability, and flexibility has a unified definition agreed on and used by the scholars provided in Supply-Chain Operation Reference Model Version 7.0 (SCOR). This reference model published and constantly revised by the Supply Chain Council (2005) provides definitions of all criteria and sub-criteria for performance measurement, and instructions for obtaining the required data. Stewart (1997) noted there it is the product of 12 months of cooperation between 70 manufacturers from a diverse range of industries. This model is capable of assisting the manufacturers around the world to configure their internal and external supply chain according to SCOR criteria. The clarity and the vast acceptance of this reference model have pushed scholars on short-term s to adapt these criteria even though they are not designed for short-term collaborations and their usefulness as a short-term concept is yet to be justified. Therefore, it can be argued that due to the growth of the short-term collaboration in the literature, a huge disparity exists amongst the scholars working on short-term collaboration partner configuration. To summarise they use different criteria (mathematical, heuristic). Furthermore, they use old criteria developed for other collaborations such as supply chain (SCOR's model amongst others), and even when they use the same criteria (e.g. trust), they refer to various definitions of the same term. This disparity exhibits the necessity to develop a compatible reference model, which has the capability to assist practitioners and scholars to configure the short-term collaboration partnership. Further investigation needs to evaluate the dispersed criteria suggested by various scholars, and to integrate them into a holistic framework or reference model that is generally accepted by the community of scholars. The goal is to acquire the same level of universality that already exists in traditional and long-term collaboration reference models, in order to assist practitioners and scholars to configure short-term collaborations quickly with a more probable successful result. However, this process is out with the scope of this research, because it requires the cooperation of a wide range of participants to develop a similar process that Stewart (1997) described for the development of SCOR model for supply chains.

To that end, the focus of this thesis is just on the partner selection problem in disaster response networks. It is an attempt to provide a framework, which has the capability to assist in selecting partners within the first 72 hours after a disaster strikes. In this process, the research also investigates the collaborative structure, criteria, and techniques for partner selection in disaster response networks as well as developing a decision-making technique.

3 THEORETICAL FRAMEWORK

The theoretical framework illustrates the process of the research in order to evaluate the solutions to the research problem, in terms of its suitability for this specific research. The result singles out the potential methods to tackle the research problem. Furthermore, the chapter investigates the theoretical aspects of the research and their relationship with the research problem and the proposed solutions. The result sets out the outline of the research design and the general steps required to answer the main research problem, and the other propositions. FIGURE **3-1** outlines the structure of the chapter as follows.

FIGURE 3-1 OUTLINE OF THE CHAPTER



In the light of the gaps identified in the previous chapter, this chapter argues that the short- term and long-term structures should be adapted in combination to accommodate the various phases of the disaster life cycle. The reasons underlying this conclusion, is further explored in the chapter. It also critically evaluates the decision criteria and techniques for partner selection in a disaster relief network and provides suitable criteria and techniques for this research. This chapter also puts forward the research strategy and the theories that the research builds upon. The result of this chapter informs the methodology in the next chapter by setting out a theoretical framework upon which the methodology, the process and therefore the result of the research are built. In fact the result of the research can be explained in relation to the theories outlined here.

3.1 THEORETICAL BASIS

There are many candidates for underlying theories in both areas of decision sciences under uncertainty and collaborative networks. Although all of the following theories are capable of partly explaining the collaborative partner selection, the author argues that under the special characteristics of the disaster response, only a few theories can underlie the present research.

Researchers focusing on VO have emphasised various theories including resource dependency, transaction costs, game theory, contingency and complexity theory (Camarinha Matos and Abreu, 2007). The researchers focusing on longer term collaborations such as supply chain utilise similar theories such as transaction cost economics (Nyaga et al., 2010; Cao et al., 2011), Exchange theory (Skelcher and Sullivan, 2008; Nyaga et al., 2010), and Resource based view (Cao et al., 2011). Kleijnen and Smits (2003) also suggest the use of Economic theory to squeeze the multiple performance measures of a supply chain into the single measure of utility. Moreover, traces of Systems thinking theories can be found in the work of Folan and Browne (2005), and who suggest the use of Holmberg’s (2000) Systems thinking based framework for supply chain performance as Sitek (2010) states, in virtual organisations the individual contributions are not equal to the joint output. These theories are articulated in TABLE **3-1**.

TABLE 3-1 THEORIES UNDERLYING THE DOMAINS OF THIS RESEARCH

Theory	Scholar
Exchange theory	Levin and White (1962); Skelcher and Sullivan (2008)
Game theory	Camarinha-Matos and Abreu (2007); Thoben and Jagdev (2001) Saxton (1997)
Contingency	Camarinha-Matos and Abreu (2007)
Systems thinking, Complexity and Chaos theory	Folan and Browne (2005); Sitek (2010)Camarinha-Matos and Abreu (2007)
Resource based view	Cao et al. (2011); Jap, Barringer, and Harrison (2000); Saxton (1997)
Resource dependency	Camarinha-Matos and Abreu, (2007); Gazeley (2010); Barringer and Harrison (2000); Saxton (1997)
Decision theory	Neasens et al. (2009)

TABLE **3-1** articulates various theories, which have been used by other scholars to explain decision-making under uncertainty or decision-making in collaboration.

Exchange theory- this theory explains that when the partners share the same goals, they are internally motivated to interact with each other to access other partners' resources (Levin and White, 1962; Skelcher and Sullivan, 2008). Though this is a totally valid theory for the purpose of this research it does not go into further details about what happens if the resources are not equally distributed between partners. In the disaster situation, the decision makers do not necessarily constitute all of the partners, also the time pressure and the need to mobilise all the resources practically renders the notion of "equal partners" obsolete. This is because the resources need to be obtained from any possible source and decision makers cannot afford to exclude the more powerful partners, which understandably are capable of providing more resources. Due to this ever-present asymmetry Exchange theory is used in the research only as a principle within Resource dependency theory.

Game theory- this theory is used in the concept of VO (Camarinha Matos and Abreu, 2007; Thoben and Jagdev, 2001), and strategic alliances (Saxton, 1997) can explain why the partners enter and exit a collaboration (Dekkers, 2012) based on their anticipated gains and the perceived actions of other partners. To that extent, decision collaboration can be justified when its utility is higher than the sum of utilities for individual partners (Myerson 1997; Axelrod and Hamilton 1981; Camarinha Matos and Abreu). For the purpose of this research, however the author argues that although Game theory is rooted in the principles of decision-making under uncertainty, it is out of the scope of this research. The reason is that the focus in this research is not on how the partners decide on entering/existing the disaster response network. Rather it focuses on how the disaster response network should ultimately decide if the partners should enter the collaboration. In other words, in this research the assumption is that the partners have already decided about entering the disaster response network by rushing into the affected area, and creating the proliferation problem. Therefore, instead of defining Game theory under the principles of Utility theory, this research uses the Utility theory on its own merit (in combination with three other theories as is described in the next section) to inform the unilateral decision from the point of view of decision makers at the time of the disaster. Utility theory is also explained in detail in the next section.

Contingency theory- this theory is very helpful in describing the necessity to form collaborations. Granwoski and Roberts (1999) argue that collaboration takes place in order to follow the Contingency theory approaches to organisational structures in in order to maximise its ability to decrease uncertainty in its turbulent environment. They claim that these structures may provide significant advantages to VOs in their flexibility, which is needed to handle the high information requirements of the VO's diverse activities that seek to mitigate risk. Although the contingency principles underlying the collaboration act under uncertainty in this research, it is not discussed further because the necessity of collaboration in the disaster response is not under research. The author assumes that the fact that the proliferation of partners happens during the disaster response means that all the parties agree upon the necessity of collaboration in a disaster response, and therefore further justification is not pursued.

System theory, Complexity and Chaos- Even though System theory has been discussed in the concept of collaboration (Folan and Brown, 2005; Sitek, 2010) its use in the disaster response seems inappropriate. The reason is that based on the principles of System theory the notion that the system will return to a state of equilibrium after the changes (Durkheim, 1966; Parsons, 1951) is far from the reality. In fact the principle of Complexity theory challenges this notion by arguing that the system (in this case, the proliferate response network of partners with chaotic patterns of entrance to the disaster affected area) might not return to the equilibrium at all. Instead, these changes may deviate the system, due to a butterfly effect, on to completely different paths of development (Kaufman, 1993, Walby, 2007). However, there are two schools of Complexity (Medd, 2001; Harvey, 2001; Walby, 2007), which interpret the complexity and chaos differently. Although some scholars (Abbot, 2001) believe that the changes in the system are disproportional and therefore unpredictable (in mathematical terms, the relationship between cause and effect is non-linear), this research is based on the SantaFe school of thought, which believes that the chaos can be mathematically harnessed into complicated but predictable patterns of cause and effect (Waldrop, 1992). This school is the basis for the notion of prediction in this research. It is noteworthy to remember that Complexity and Chaos are not a unified body of theory, rather they are a set of theoretical and conceptual tools ranging from ecology to mathematics (Thrift 1999; Walby, 2007).

Resource dependency theory- This theory in general is concerned with reducing uncertainty by collaborating with others and has been used in the concept of VO (Camarinha

Matos and Abreu, 2007) or other forms of collaborations (Saxton, 1997; Barringer and Harrison, 2000; Gazeley, 2010). This theory is one of the underlying theories in this research and will be explained in detail in the next section.

Decision theory- This theory assist the agents to select decision criteria, evaluate, and compare the options and act upon them. It was pioneered by Neumann-Morgenstern (1944) and was further extended by Tversky and Kahneman (1981,1992). In general this describes that when a rational decision maker is faced with choices, s/he will prefer the prospect that offers the choice with higher desirability. This theory is explored further in the chapter.

3.1.1 RESOURCE DEPENDENCY AND RESOURCE BASED VIEW

Hillman et al. (2009) further explain that the resource dependency theory is a primary theoretical perspective to understand the inter-organisational relationships, and explore how their formation helps an organization acquire resources to reduce uncertainty and interdependence. The virtual organisation formation within the highly uncertain disaster environment, which is the subject of the present study, follows the same principals. VO is formed to assist the companies in collaborating with each other in order to align their actions, achieve a higher level of performance in a shorter period of time (Francisco et al., 2012), and react to the uncertain environmental factors. This phenomena can be explained through the Resource dependency theory where the external resource scarcity (Barringer and Harrison, 2000), forces companies to form inter-organizational networks (Skelcher and Sullivan, 2008) in order to acquire critical resources and reduce uncertainty (Barringer and Harrison, 2000).

Resource dependency theory (Pfeffer and Salancik, 1978) explains that the firms engage in collaboration to reduce the uncertainty driven by the logic of strategic resource needs and social resource opportunities (Eisenhardt and Schoonhoven, 1996). It is noteworthy to mention that Transaction cost theory (Williamson, 1975) is also capable of explaining this phenomena, but is not used in this research because it fails to assign a significant role to the partner's resources (Das and Teng, 2000), which is the focus of present research. In fact, the Transaction cost theory explains how to minimise the sum of production and transaction costs, whilst the Resource dependency theory explains how to maximise the firm value by gaining access to other firms' resources. Another reason for choosing Resource dependency theory over the Transaction cost theory is that the former emphasises that the industry, in which partners originate from, influences the decisions about collaboration. However, in the disaster situation the decision makers cannot concern themselves with this limitation and have to choose between all available partners no matter their industry, this is the principal in the Resource dependency theory (Das and Teng, 2000).

The resource-based view is used in addition to the resource dependency in order to strengthen the reliance of this research on the partners' resources in comparison to other decision criteria for partner selection. The Resource based view basically explains that the resources available in the organisation dwarf the competitive advantages within the environment (Das and Teng, 2000). In other words if companies would like to be successful (perform better), they need to focus on their resources rather than trying to raise other environmental competence. This is in addition to the fact that in the disaster situation, the data about resources held by the partners are more quickly available than the other decision-making criteria such as trust, strategic fit, task performance, and so forth (TABLE **2-4**).

These principles help to explain why other decision criteria that have been used for partner selection are not used in this research for selecting humanitarian partners (Chapter 2). Of course this reason is in addition to the fact that the financial and profit based approaches, which can be used in partner selection for commercial collaborative networks, defeat the purpose of the disaster response or require a great deal of time to be calculated and therefore are unobtainable in a disaster situation.

3.1.2 DECISION THEORY UNDER UNCERTAINTY CONDITIONS

Decision theory pioneered by Neumann-Morgenstern (1944) allows agents to select decision criteria, evaluate, and compare the options and act upon them. Some scholars define Decision theory as a combination of Utility theory and Probability theory (Russell and Norvig, 1995). Decision-making in a disaster situation, which is the subject of this research, is a decision scenario under uncertainty. It is noteworthy to remember a distinction between risk and uncertainty. In the literature, Knight's (1921) definition is prominent, where he differentiates between a set of scenarios involving the selection of mutually exclusive outcomes with a known probability (risk) and unknown probabilities (uncertainty). It is essential to remember the latter is the subject of this research due to the extreme situation of a disaster's uncertainty. The literature regarding decision-making under uncertainty is mainly divided in two branches; Rational choice and Expected utility (EU) and Behavioural and Prospect theory (Tversky and Kahneman, 1992). The former has arisen from mathematical literature, and provides clear formulations, whereas the latter is more practice-based and tries to show the controversies in the Expected utility theory (Keykhah, 2000). This research is not an attempt to focus on the challenges facing Utility theory or study how and why decision makers decide the way, they do. To that end, the research has just focused on Utility theory, in order to maximise the preferences of the decision makers who decide based on the reasons out of scope of this research. In fact, the investigation into the reasoning behind their preferences can be the subject of further studies on Prospect theory by other scholars.

Utility theory provides a formal and complete framework to determine the preferences of a human agent (Russell and Norvig, 1995). The utility function then maps the agent's preference regarding a possible action by $\mathbf{U_i} = \mathbf{U}(\mathbf{A_i} \,|\mathbf{A_g}, \mathbf{Env}) = \mathbf{f}\ (\mathbf{V_i}, \boldsymbol{\varepsilon}_\mathbf{i})$ where $\mathbf{U_i}$ is the utility function of the option $\mathbf{A_i}$, anticipated by agent $\mathbf{A_g}$ in the environment state of Env. The deterministic function of $\mathbf{V_i}$ shows the known value and $\boldsymbol{\varepsilon}_\mathbf{i}$ is the uncertain value of the perceived state.

The Expected utility model is a theory of decision-making under risk introduced by Tversky and Kahneman (1981). This model is based on a set of axioms providing the criteria for the rationality of choices. The choices of an individual who conforms to the axioms can be described in terms of the utilities of various outcomes for that individual. The utility of a risky prospect is equal to the expected utility of its outcomes, obtained by weighting the utility of each possible outcome by its probability. When faced with a choice, a rational decision maker will prefer the prospect that offers the highest expected utility. It can be defined by the formula $\boldsymbol{Expected\ Utility} = \sum_{\boldsymbol{i=1}}^{\boldsymbol{N}} \boldsymbol{u}\ (\boldsymbol{i}) * \boldsymbol{p}\ (\boldsymbol{i})$. Where $\boldsymbol{u}\ (\boldsymbol{i})$ connotes the utility of outcome $(\boldsymbol{i})$ and $\boldsymbol{p}\ (\boldsymbol{i})$ connotes the probability that $(\boldsymbol{i})$ will occur. In the present research, this theory is used for partner selection from the perspective of the decision maker. To use MEU (maximum expected utility) the numeric utility function that quantifies how desirable a particular state of the world is from the viewpoint of the decision maker who holds the preferences. The MEU principle advocates that selecting the partner leads to the greater utility for decision makers. The process of using these principles is discussed in detail in the fifth chapter.

3.2 SUITABILITY OF COLLABORATIVE STRUCTURE FOR DRN

This perspective is supported by Noran (2011) who suggests a short-term structure for managing the phases of short-term collaboration such as preparation, response and recovery and also long-term structure to manage mitigation and preparation. Although this suggestion for using VO as the short-term structure for disaster response phase is adapted by others (Grabowski and Roberts, 2011,Javaid et al, 2013), the reasoning behind this choice is yet to be justified.

Comparison between the characteristics of VOs and disaster response networks show that they are both temporary alliances of independent organisations which share resources and information to collectively access the market /damaged regions and provide for a one-time-created demand/request for help. Using networks as their structure they could decentralise and cover various sub-tasks according to their heterogeneous nature, while dynamically adapt to the turbulent situation and when the demand declines due to the disaster relief /market situation, they would dissolve and become independent entities again. These common characteristics are highlighted in TABLE **3-3** in order to provide sufficient evidence that the Virtual Organisation is a suitable structure for the Disaster Relief Network (DRN).

TABLE 3-2 OVERLAPS BETWEEN CHARACTERISTICS OF VO AND DRN

Characteristics	Virtual organisation	Disaster Response Networks
Heterogeneity	Tan et al, 2008, Brown and Zhang1999	Notle and Boenigk, 2012,Comfort (2007), Tierney and Trainor (2004)
Cost/Time Effectiveness	Tan et al, 2008)	Notle and Boenigk, 2012).
Collective access to resources/donation	Tan et al, 2008, Jaeger et al, 1998, Brown and Zhang1999	Comfort, 2004,Nolte and Boenigk, 2012
Temporariness	Tan et al, 2008,Brown and Zhang1999, Jaeger et al, 1998, Martinez et al, 2001	Moe et al, 2007, Tierney and Trainor, 2004
Lack of hierarchy	Jaeger et al, 1998,Corvello and Migliarese, 2007	Notle and Boenigk, 2012, Tierney and Trainor, 2004
Network structure	Tan et al, 2008,Jaeger et al, 1998	Nolte, and Boenigk, S.2012, Tierney and Trainor, 2004
Independent participants	Jaeger et al, 1998, Brown and Zhang1999	Tierney and Trainor, 2004
Spontaneous	Jaeger et al, 1998	Nolte and Boenigk, 2012
Dynamic	Jaeger et al, 1998,Brown and Zhang1999)	Tierney and Trainor, 2004
Uncertainty	Jaeger et al, (1998)	Tierney and Trainor, 2004

Participants equality	Jaeger et al, 1998)	Notle and Boenigk, 2012
Boundary crossing	Jaeger et al, 1998, Brown and Zhang1999	Tierney and Trainor, 2004
Mutual dependency	Martinez et al, 2001	Notle and Boenigk, 2012
Geographical dispersion of actors	Jaeger et al, 1998,Brown and Zhang1999, Martinez et al, 2001	Tierney and Trainor, 2004
Niche market demand	(Brown and Zhang, 1999)	Tierney and Trainor, 2004
High partner turn over	Jaeger et al, 1998,Corvello, Migliarese, 2007)	Tierney and Trainor, 2004
Unpredictable changes	Brown and Zhang1999),	Notle and Boenigk (2012)
Flexible	Brown and Zhang1999)	Notle and Boenigk (2012)
Time Constraint	(Brown and Zhang1999)	(Notle and Boenigk (2012)
Complexity	(Corvello, Migliarese, 2007)	Notle and Boenigk (2012)
Decomposable tasks	(Martinez et al, 2001)	Tierney and Trainor, 2004

Source: Author

TABLE **3-2** OVERLAPS BETWEEN CHARACTERISTICS OF VO AND DRN denotes that in both structures, the effectiveness in time and cost is crucial; the temporary network is created to cross boundaries of individual organisations and allow the collective access to resources or donations. The network structure of independent yet mutually dependent and equally important partners emphasizes the lack of hierarchy. Instead the uncertainty and highly unpredictable changes in the environment is addressed by spontaneous, complex, dynamic and flexible actions. In both forms of organisations, the attempt is to respond to the niche market demand/disaster created demand, by allocating the decomposed tasks to geographically dispersed partners, under time constraints to allow the collective access to resources/donations.

3.2.1 CONCEPTUAL STRUCTURE OF DISASTER RELIEF NETWORK

Drabek (1986) for the first time analysed over 1,000 disasters, from which the four phases of preparedness (planning and warning), response (evacuation and emergency), recovery (restoration and reconstruction), and mitigation (perceptions and adjustment) are derived. A summary of the typical activities of disaster life cycle is presented TABLE **3-3**.

TABLE 3-3 TYPICAL ACTIVITIES OF DISASTER LIFE CYCLE

Mitigation	Response
Zoning and land use controls to prevent occupation of high hazard areas	Activating the emergency operation plan
Barrier construction to deflect disaster forces	Activating the emergency operation centre
Active preventive measures to control developing situations	Evacuation of the threatened population
Building codes to improve disaster resistance of structures	Opening of shelter and provision of mass care
Tax incentives or disincentives	Emergency rescue and medical care
Controls on rebuilding after events	Fire fighting
Risk analysis to measure the potential for extreme hazards	Urban search and rescue
Insurance to reduce the financial impact of disasters	Emergency infrastructure protection
	Fatality management

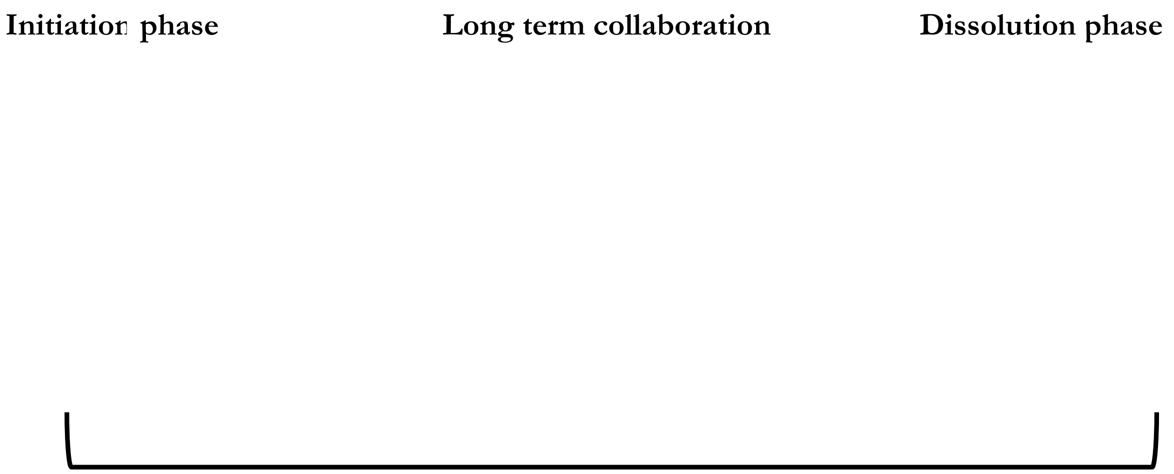
Preparedness	Recovery
Recruiting personnel for the emergency services and for community volunteer groups	Disaster debris clean up
Emergency planning	Financial assistance to individuals and governments
Development of mutual and agreements and memorandums of understanding	Rebuilding of roads and bridges and key facilities
Training for both response personnel and concerned citizens	Sustained mass care for displaced populations
Thread based public education	Reburial of displaced human remains
Budgeting for and acquiring vehicles and equipment	Full restoration of life line services
Maintaining emergency supplies	Mental health and pastoral care
Constructing and emergency operations centre	
Developing of communicating systems	
Conducting disaster exercise to test the capabilities and training	

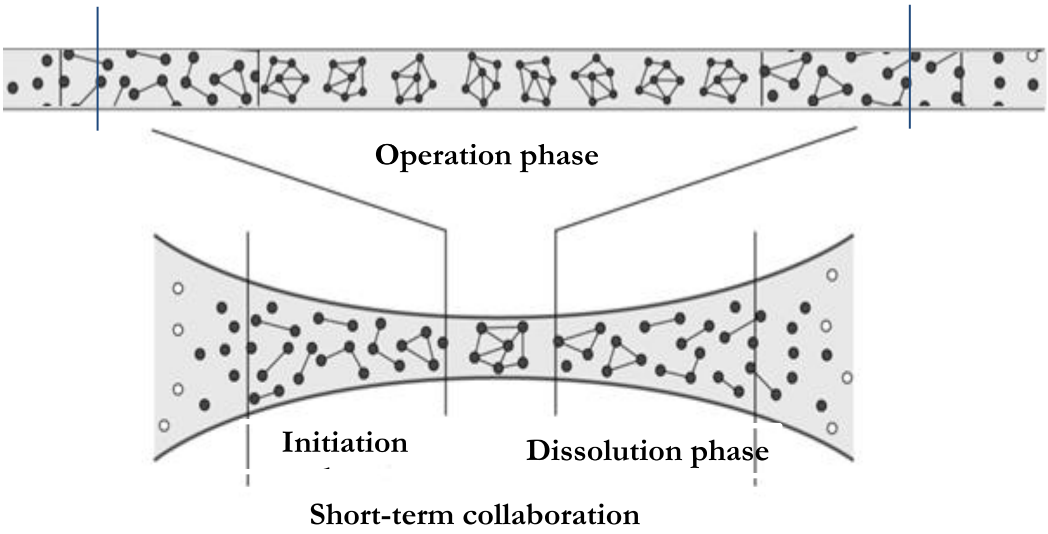
Source: Altay and Green 2006

Although the Drabek's cycle for disaster management operation is very popular, the scholars use the same for both long-term and short-term structures. However as it was explained in the previous chapter, the response phase is identified with its temporary nature, time pressure and therefore the lack of long-term outlook. Recently Noran (2011) tried to distinguish between the two by suggesting a combination in which the short-term preparation, response and recovery are to be structured as a VO with a short-term outlook and mitigation and long-term preparation to be managed as a long-term structure. To further investigate this claim the life cycle of both structures are being reviewed.

The life cycle of VO has been extensively modeled by various scholars (Jaegers, 1998, Thoben and Jagdev, 2001, Sitek, 2007,Sitek et al. 2010) where the VO life cycle is defined as the process of initiation phase including partner selection, operation phase where the day to day activities take place and dissolution phase is when the objectives of the collaboration are accomplished and the partnership dissolves (FIGURE **3-2**).

FIGURE 3-2 COMPARING SHORT / LONG-TERM COLLABORATION LIFE CYCLE



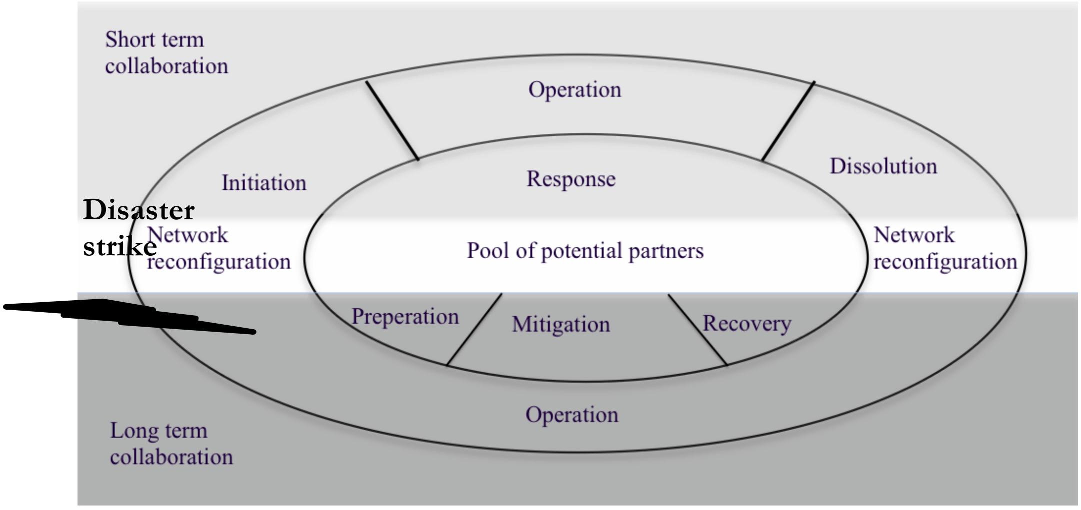


Adapted from (Sitek, 2010, Seifert, 2007, Thoben and Jagdev, 2001)

FIGURE **3-2** denotes that although the three phases are present in both structures, the length of the operation phase in long-term collaboration significantly differs with the length of operations phase in short-term collaboration. Operation phase in long-term collaboration starts when the initiation phase finishes, where the dispersed partners get together to form a collaborative network. In long-term the partners collaborate together without much change to the structure of the network and after a long time, the network may dissolve. However in short-term collaboration, the operation is a very short phase sandwiched immediately after initiation and right before dissolution. It just lasts for completing one project and as soon as the demand for that project is ceased, the collaboration is finished.

To that end in the specific case of disaster response networks, the author combined the Drabek's (1986) and Noran's (2011) structures for the disaster operation (Four phase model) with Thoben and Jagdev's (2001) and Sitek et al's (2010) structures for VO life cycle, to develop a conceptual model as illustrated in FIGURE **3-3**.

FIGURE 3-3 DISASTER/COLLABORATION LIFE CYCLE CONFORMITY MODEL



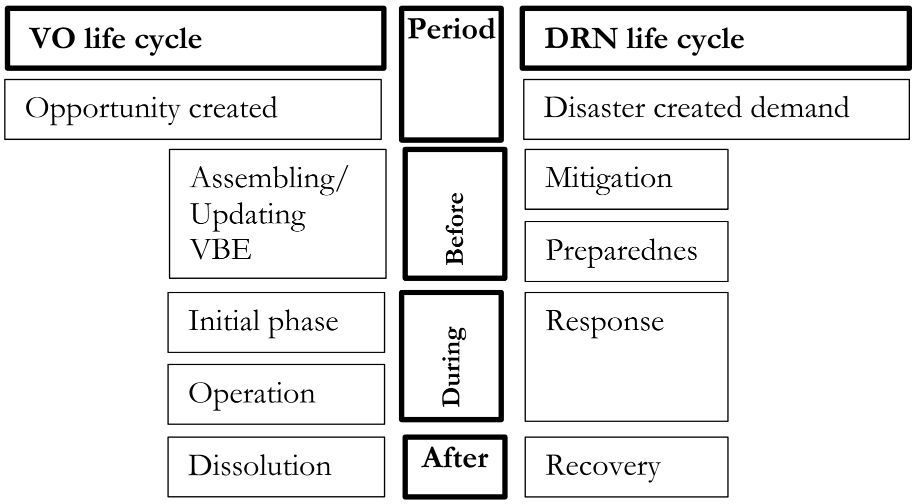
Source: Author

FIGURE **3-3** denotes that the demand creation (request for help in disaster situation or demand for a special product in the market) is followed by initial phase including preparation and configuration tasks (Sitek et al., 2010,Ermilova and Afsarmanesh, 2006, 2007) and selecting a subset of partners out of Virtual Breeding Environment (Camarinha-Matos and Afsarmanesh, 2003). *"A virtual breeding environment (VBE) is a long-term pool of potential partners, which provides the environment for the establishment of cooperation agreements, common infrastructures, common ontologies, and mutual trust, which are the facilitating elements when building a new virtual enterprise*" (Camarinha-Matos and Afsarmanesh, 2003, p.157).

The life cycle continues by the day-to-day operation (Sitek et al, 2010) and dissolves when the market declines. Combining the two life cycles the conceptual model of disaster operation structure illustrates that the both life cycles start with a sudden change in the environment such as a business opportunity (VO) or disaster strike (DRN) which creates demand for product/services. This incident requires the network re-configuration from a pool of potential partners (VBE). The result creates the response phase operated by a VO (short term collaboration) within the three-phase life cycle (initiation, operation and dissolution). After dissolution of VO due to the completion of the response phase, the network will be re-configured into the existing long-term collaboration structures such as supply chains, which already exist for long-term recovery, long-term mitigation and long-term preparation. To better visualize this imagine the Red Cross-and its long-term suppliers as the long-term structure by which the Red Cross manages its preparation and mitigation phase. When a disaster strikes in Sub-Saharan Africa it creates a certain demand for medical equipment and nutrition’s. For this particular response, Red Cross picks and choose just the partners who would provide the needs for specific disaster. When the response is over, the VO dissolves but the long-term partners are still there for the long-term recovery phase. This structure continues until another disaster strikes and leads to the temporary collaborations of partners in VO. The collaboration will assemble and update the pool of potential partners (VBE) to facilitate the partner selection in the next opportunity. To summarize, the present model, keeps the long-term structure for the majority of the disaster life cycle including recovery, mitigation and preparation. The remainder of the life cycle (response phase), which is associated with the immediate aftermath of the disaster -where the community is under shock and in need of urgent help- is modeled by short-term structures such as VO. The huge overlap between characteristics of VO and disaster management cycle exhibits the capability of VO structure in accommodating the response phase’s requirements.

Other than the overlap between the characteristics of VO and DRN, their life cycle stages are also overlapping which further signals their similarity. Disaster life cycle operation includes activities that are performed before, during, and after a disaster with the goal of reducing its impact and returning to a state of normalcy. FIGURE **3-4** depicts the overlaps in different phases of DRN and VO operation. In this model both life cycles start with a sudden change in environment such as a business opportunity (VO) or disaster strike (disaster management cycle) which creates demand for product/services.

FIGURE 3-4 OVERLAP BETWEEN VO AND DRN LIFE CYCLE PHASES



Source: Author

FIGURE **3-4** denotes that following the demand creation, the disaster 'response' phase is executed which starts with activating the operation plans. In VO life cycle the demand creation is followed by initial phase including preparation and configuration tasks (Sitek et al., 2007, 2010,Ermilova and Afsarmanesh, 2006, 2007) and selecting a subset of VBE (Camarinha-Matos and Afsarmanesh, 2003) and day-to-day operations (Sitek et al, 2010). The VO dissolves when the market declines whilst the disaster management cycle moves to recovery phase. The VO will assemble and update its breeding environment, which will facilitate the VO partner selection in the next opportunity. It is noteworthy to mention these phases are not mutually exclusive or independent; rather, overlap and interrelations enable them to operate concurrently (Shaluf, 2008, Maon et al, 2009); For example, mitigation and recovery are often simultaneous, similar to preparedness and response because the chain must be built quickly (Maon et al, 2009).

To summarise FIGURE **3-3** shows that the short-term collaborative structure is a suitable way to address the response phase, whilst the long-term collaboration is suitable for the other three phases of disaster life cycle. Also TABLE **3-2** exhibited that the structure of a VO overlaps in various characteristics with the characteristics of the DRN. To that end the VO seems like a suitable short-term structure to address the DRN. FIGURE **3-4** further elaborates how the different phases of a VO life cycle could conform to the different phases of a DRN life cycle. However how to pick the existing partners in a VBE for the purpose of a VO structure for disaster response is a decision-making problem. To solve this problem the criteria and methods for decision-making needs to be evaluated in order to select the suitable criteria and method for partner selection in disaster response.

3.3 DESIGN RELATED TO THE RESEARCH QUESTIONS

In general, the Multi-Cluster/Sector Initial Rapid Assessment (MIRA) report is released 72 hours to three weeks after a disaster strike, and contains valuable information about various impacts of the disaster. The Inter-Agency Standing Committee (IASC), which is a collaboration between UN based organisations, releases this report and main humanitarian bodies such as IFRC. The problem is that in early hours after a disaster strike this report has yet to be released whilst most of the decisions about partners and emergency aids need to be taken. The model presented in this research is an attempt to provide guidelines for this aftermath period of the disaster, where no official report exists. This research utilises a variety of techniques to investigate the possibility of developing a decision-making tool for partner selection in a disaster response network during the first 72 hours after the disaster strike. The problem is the lack of information immediately after the disaster strike. These data about the human impact and requirements are the basis for the disaster response decisions regarding allocation of resources, selecting the partners, etc. Most of the decisions need to be made before this time to prevent fatalities and the spread of disease, etc.

To that end, the author builds upon the principles of Resource dependency theory and Decision theory under uncertainty to develop a decision technique in the explained situation. The logic behind this attempt is that if a predictive technique could be developed to approximately estimate the human impact, and the needs of the affected population immediately after the disaster strike, it is possible to combine the decision makers' expertise and experiences with the data about the available resources to enable decisions about which partner should provide which requirements.

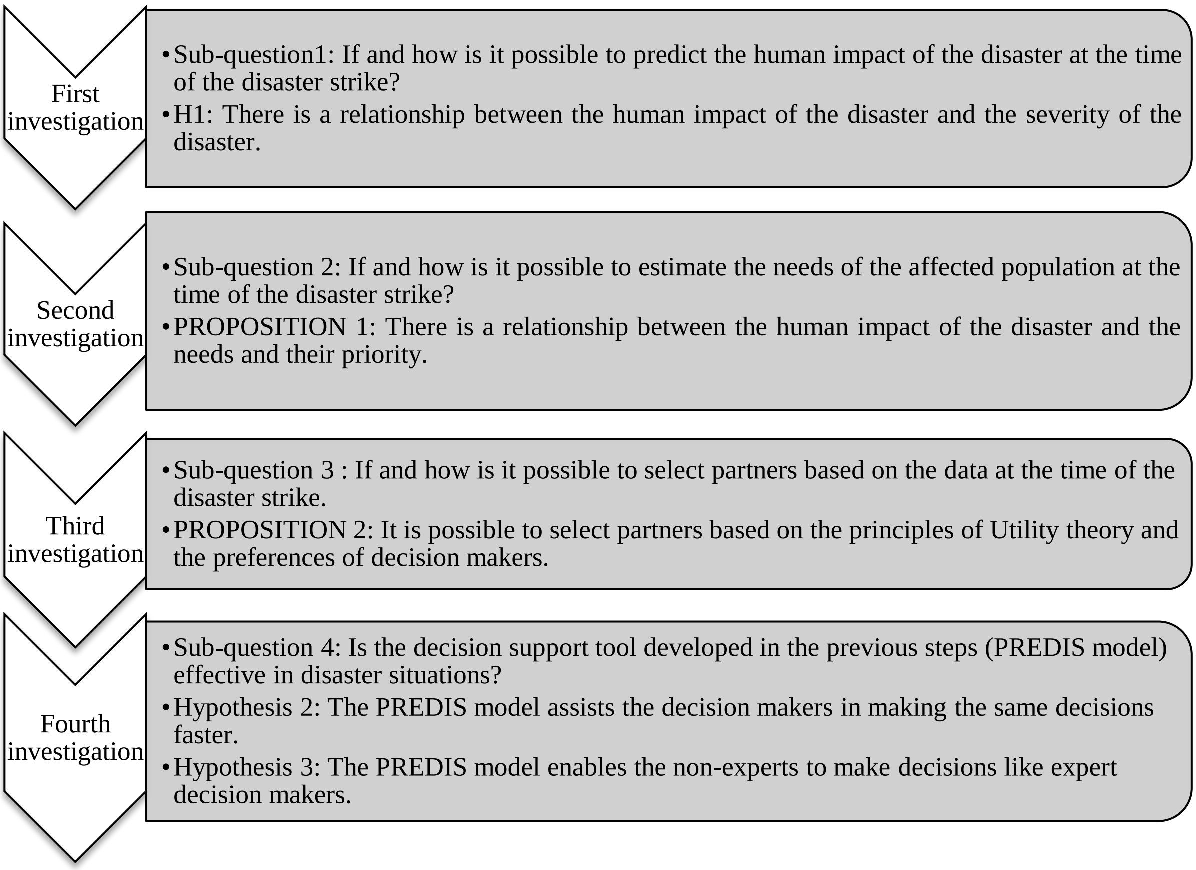
As mentioned earlier, the resource based decision criteria are the most suitable for this research. This in combination with the principles of Resource dependency theory, Resource based view and Utility theory outlines the design of this research. The principles of the Resource based view outlines that if the collaboration wants to be successful it needs to focus on the resources, also based on the principles of the Resource dependency theory the companies collaborate in order to acquire critical resources and reduce uncertainty (Barringer and Harrison, 2000), which is the case in the disaster situation. In order to select partners the research suggests using the resources based criteria including physical and human resources. The relevant data are available at the time of the disaster. It is possible to optimise the allocation of these resources to the needs arising out of the disaster if an accurate prediction of the requirements is available. The idea is to find a way to predict the human impact of the disaster (including the number of fatalities, homeless, and injured), and by using the historic data about how many units of resources are required in similar situations, estimate the approximate needs. The rest would be an optimisation problem using the mathematical programming based on the principles of the utility theory. This summary explains the essence of the PREDIS model developed in this research. To that end, three main studies are put forward to answer three propositions.

First proposition- If and how is it possible to predict the human impact of a disaster at the time of the disaster strike? The answer to this proposition is the essence of the first study (PREDICTION), which uses statistical and mathematical techniques with a soft system approach to provide a predictive model for the human impact of disasters. This is designed based on the hypothesis that there is a relationship between the human impact of the disaster and the severity of the disaster.

Second proposition- If and how is it possible to estimate the needs of the affected population at the time of the disaster strike? The answer to this proposition is the essence of the second study (Estimation), which uses archival data to provide evidence-based estimations for needs in each disaster situation. This is based on the hypothesis that there is a relationship between the human impact of the disaster and the needs of the affected population.

Third proposition- If and how is it possible to select partners based on the data at the time of the disaster strike? The answer to this proposition is the essence of the third study (optimisation), which uses an optimisation technique for selecting hypothetical partners. This process is depicted in FIGURE 3-5.

FIGURE 3-5 THE DESIGN OF THE RESEARCH (PROCESS AND QUESTION)



In order to investigate the above Propositions, three separate yet interrelated studies are planned in which the result of each study is fed into the fourth study and gives rise to the overall result of the research.

So as to investigate the suitability of PREDIS model further, the author comprehensively evaluates and assesses the model itself from the perspective of real decision makers. By designing a separate simulation game the author attempts to answer the following proposition:

Fourth proposition: Is the decision support tool developed in the previous steps (PREDIS model) effective in disaster situations? Two hypotheses are considered for answering this hypotheses in this research

Hb: The PREDIS model assists the decision makers in making the same decisions faster.

Hc: The PREDIS model enables the non-experts to make decisions like expert decision makers.

FIGURE 3-6 THE GENERIC FLOW OF THE RESEARCH DESIGN

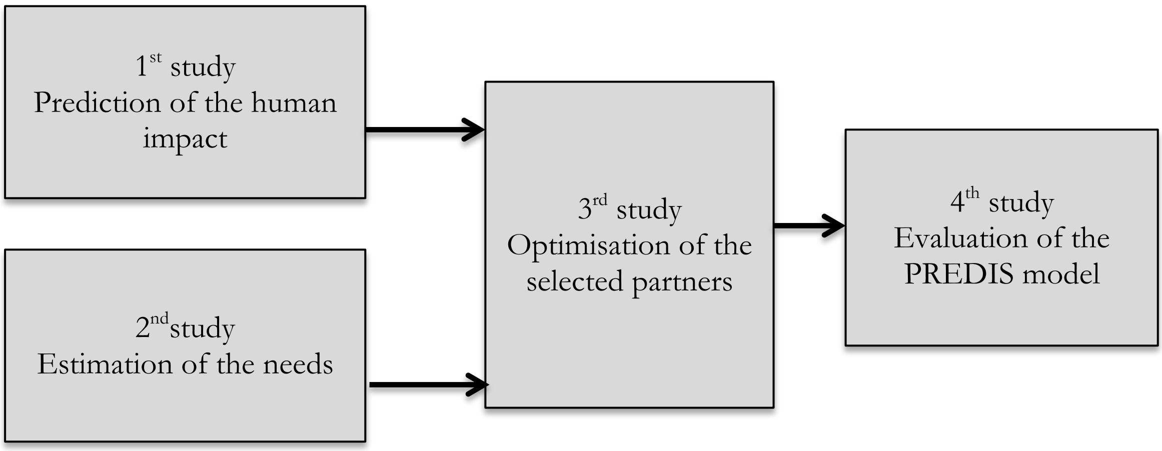


FIGURE 3-6 shows the generic flow of the design where the result of the predictions and estimations of the first and second study feeds into the third study to use the Expected utility theory and Resource dependency theory to develop a decision support tool to select the most suitable partners. Experts in the final study further evaluate the PREDIS model by participating in a simulation game.

3.4 SUMMARY OF THE CHAPTER

This chapter builds upon the literature review in the previous chapter. In the light of the problem defined in the literature review, and the solutions associated with that in the literature, the research design evaluates the possible directions of the research. The aims of the chapter included:

- To critically evaluate the solutions provided by other scholars on the research problem, as discussed in the literature in terms of its suitability for this specific research study. This was addressed by looking into two solutions discussed in the literature. First the re-structuring the DRN was investigated. The result was a conceptual framework, which suggested using a VO for the structure of a DRN. The second solution was partner configuration in DRN. This was addressed by looking into the decision-making criteria, and techniques reviewed in the previous chapter. Each category was evaluated in terms of its suitability for DRN.
- To single out the potential methods to tackle the research problem. The results of the previous step was used to single out physical and human capital/resources as the selection criteria, and AHP and mathematical programming as the potential candidates for partner selection in DRN.
- To investigate the theoretical aspects of the research and their relationship with the research problem and the proposed solutions. By investigating different theories, the design of the research was built upon Resource dependency theory, Resource based view and Utility theory.
- To develop the propositions of the research. In the pursuit of the research question, three propositions required answers. First, if and how is it possible to predict the human impact of the disaster at the time of the disaster strike? Second, if and how is it possible to estimate the needs of the affected population at the time of

the disaster strike? Third, if and how is it possible to select partners based on the data at the time of the disaster strike.

- To set out the outline of the research design and the general steps required to answer the main research problem and the other propositions. The generic flow of the design shows two separate processes. First, it comprises three studies including predictions, estimations, and optimisation, which form the body of the PREDIS model. The result was evaluated then using a separate simulation game design to assess the PREDIS mode.

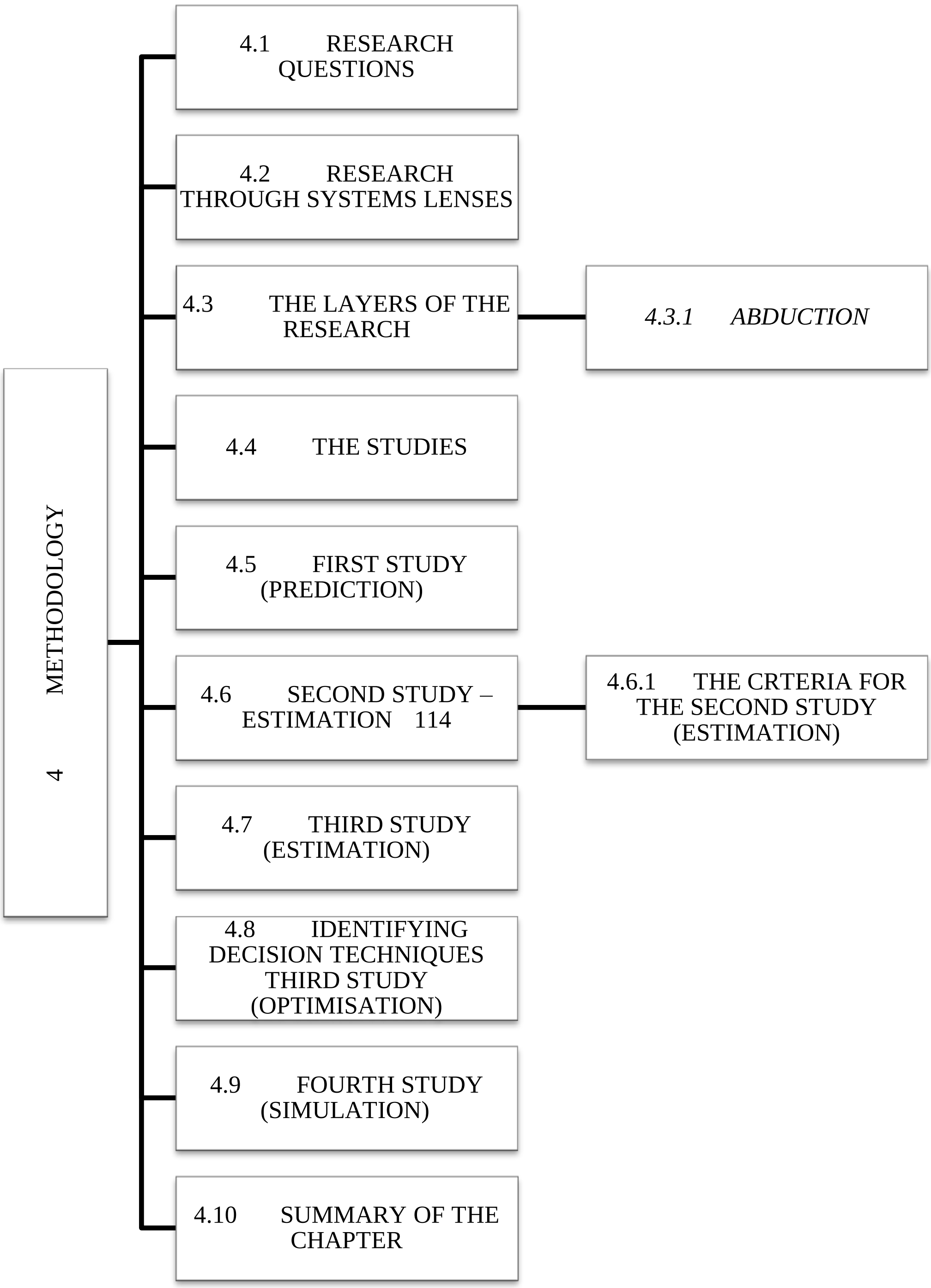
CHAPTER 4
METHODOLOGY

4 METHODOLOGY

This chapter outlines the enquiry paradigm of the research, which gives prominence to the research methodology, prior to outlining the research. It embarks upon outlining the research question, before explaining how the research will be approached through the soft system lenses. Then the layers of the research are outlined before articulating the elements of the studies including prediction, estimation, and optimisation of the predictive framework for partner selection in disaster response networks. It outlines the variables and sources of the data collection in addition to selecting the decision techniques required for developing the final decision-making model. FIGURE 4-1 outlines the contents of this chapter.

CHAPTER 4
METHODOLOGY

FIGURE 4-1 THE OUTLINE OF THE CHAPTER 4



CHAPTER 4
METHODOLOGY

4.1 RESEARCH QUESTIONS

The central question of a methodology is - "How can the knower find out about 'What can be known?' " (Lincoln and Guba, 1994). Followed by "How to discover whatever they believe can be known?" (Guba and Lincoln, 1998). Although no single methodology within the qualitative or quantitative research can serve as a panacea for all situations, each methodology should adapt many methods (Durant-Law, 2005). For example, differences in epistemological beliefs should not prevent a qualitative researcher from utilising data collection methods more typically associated with quantitative research, and vice versa (Johnston and Onwuegbuzie, 1973). To that end, the present research following this logic, adapts the mixed method research within the overall frame of three studies (prediction, estimation, and optimisation) in addition to another study used for validation of the model resulting from the first three studies. The present chapter is dedicated to explaining the design and techniques required to obtain data and analyse them in order to answer the primary research question and the subsequent questions associated with each study.

The primary research question is: How can the proliferation of partners in a disaster response be reduced within 72 hours after the disaster strike? (More explicitly, how can response networks be configured quickly in the early hours after the disaster strikes in order to avoid the rush of inexperienced, and unsuitable partners into the area).

The review of the literature in chapter 2 put forward two main solutions including restructuring and partner configuration to reduce the partner proliferation. In order to re-structure the network we require to know the answer to the following propositions:

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METHODOLOGY

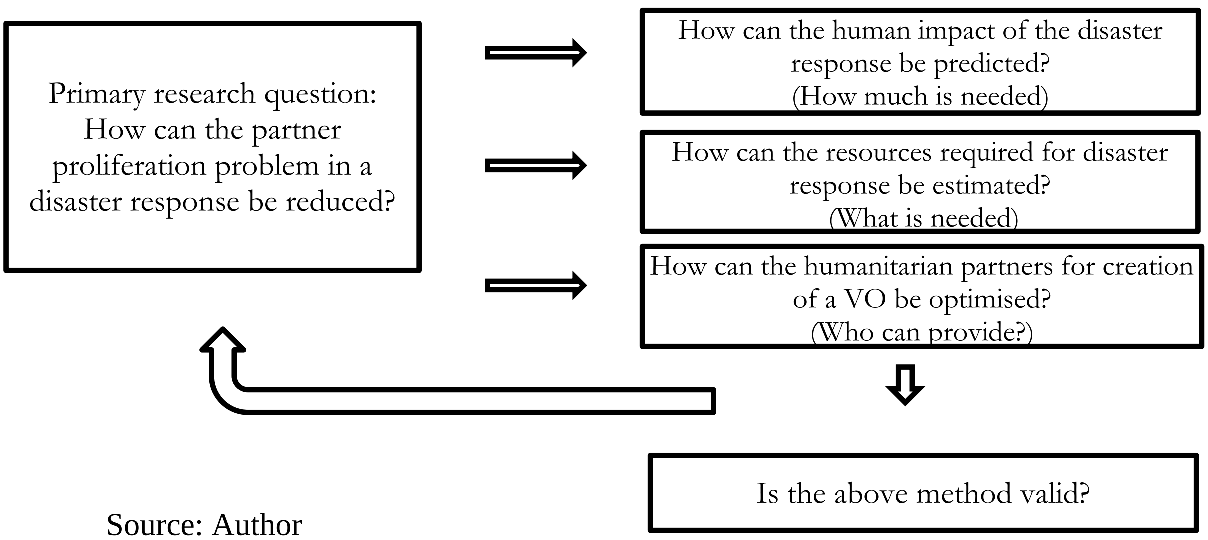
The proposition associated with the first study (PREDICTION) is how much aid is needed? In order to investigate this propostion, the first study is put forward.

The proposition associated to the second study (ESTIMATION) is: What type of aid is needed? In order to investigate this propostion, the second study is put forward.

The proposition associated to the third study (OPTIMISATION) is: Who can provide? In order to investigate this propostion, the third study is put forward.

The response to the above three propositions will provide an answer to the overall question: How can the proliferation of partners in a disaster response be reduced? FIGURE 4-2 is a schematic explanation of how to connect the pivotal research question to the propositions in each study.

FIGURE 4-2 QUESTIONS INVESTIGATED IN THE PRESENT RESEARCH



Source: Author

FIGURE 4-2 shows that the primary research question “How can the partner proliferation problem in a disaster response be reduced?” can be answered by restructuring the disaster response network into a VO. The process to address this investigation leads to a series of studies (PREDICTION, ESTIMATION, OPTIMISATION). The propositions associated with these studies are as follows:

To answer the question “How can the human impact of the disaster response be predicted?” The study (PREDICTION) has been designed.

To answer the question “How can the resources required for disaster response be estimated?” The second study (ESTIMATION) has been designed.

To answer the question “How can the humanitarian partners for creation of a VO be optimised?” The third study (OPTIMISATION) has been designed.

The result of this process has led to the development of a decision support model that needs to be validated. Therefore, the last study has been designed to confirm if the model is valid.

4.2 RESEARCH THROUGH SYSTEMS LENSES

In this research, the problem is the proliferation of the actors at the time of the disasters.The extra-ordinary situation of the disasters in addition to interaction of heterogenous partners under extreme uncertainty and lack of data, produce a complex system. This requires a systems approach as oppose to mechanical approach which reductionistically looks into the individual elements. General systems theory (Bertalanffy, 1969) claims that it is possible to find patterns and laws that can be applied to a system as a whole instead of its components. In fact the existence of laws of similar structure in different fields enables the use of systems which are simpler or better known as models for more complicated and less manageable ones (Bertalanffy, 1950).That is the essence of the research design in this research, where first the pattern of disaster impact is identified in different types of disaster. Then the whole model is simplified into a simulated model in order to compare the simulated world with the real world problem through the hypothetical scenarios with real decision makers. In this design the problem of the proliferation of actors in disaster response networks is outlined in chapter 1 and 2 where the problem and the related literature unfold. This leads to chapters 3 and 4 where the design of the research is put forward as well as the methodology which describes the approaches are taken to tackle the problem. The real world problem is finally described in chapter 5, where the records of actual disaster scenarios are outlined. Chapter 5 consists of a series of researches, which ultimately leads to the identification of a set of patterns by which the impact of the disaster and the needs are predicted. This leads to the introduction of the PREDIS model which is a simplified representation of the real word built based on the patterns discovered. Chapter 6 is an attempt to compare the simplified version of the real word with the real world situation. This is conducted by a simulation game where the scenarios are being verified using the real decision makers. Finally, chapters 7 and 8 outline the results and raise a series of proposals for further research, and actions to improve the real life situation. However, the actual actions for improvements to the proliferation problem should be practiced in the real world and fed into the PREDIS model if necessary to repeat the problem solving process in the future.

4.3 THE LAYERS OF THE RESEARCH

A paradigm is a world view underlying the theories and methodology of a particular scientific subject (Oxford dictionary,2014). Therefore, the inquiry paradigm sets the researcher’s perspectives towards the world, phenomena and reality. An inquiry paradigm is essential for answering the question or designing the research because it “defines for inquirers what it is they are about, and what falls within and outside the limits of the legitimate inquiry" (Lincoln and Guba, 1994, p.108). Consequently, the methodology chosen for each research depends on the epistemology of that research which itself depends on the ontology (Grix, 2002) defined within the framework of the inquiry paradigm. Therefore, in order to design the research methodology, the inquiry paradigm needs to be addressed in its entire three aspects - ontology, epistemology, and axiology. Ontology is the philosophical approach to the worldview about reality (Heron and Reason, 1997). The ontological question concerns "What is the form and nature of reality and what can be known about it?" (Lincoln and Guba, 1994). Mingers and Bocklesby (1997) distinguish three main paradigms, each of which has been referred to by a variety of names: empirical-analytic (positivist, objectivist, functionalist), interpretive (subjectivist, constructivist), and critical (critical systems, critical realism). In a series of arguments, Mingers (2011) explores the mutual contributions of systems thinking theory to the Critical realism approach. He discusses that the "emergence" as a property of a system is certainly a key feature of Bhaskar's critical realism. In fact the emergent properties of an entity are properties possessed only by the entity as a whole, not by any of its components. This is the essential concept of collaborative network structure suggested for disaster response network and therefor is the philosophical stand of this research. The critical realism epistemologically asserts that the world is socially constructed and therefore the interpretative element is present in this field (Sayer, 2000; Easton,2010). This is further confirmed by Mingers (2011) who states that although the experience of a system is internally constructed, it is moderated by interactions with the external world. However he further asserts that the complexity effects can be generated within the traditional systems thinking framework resulting from interactions between large numbers of relatively simple units.

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Epistemology according to Lincoln and Guba (1994) is concerned with finding out the relationship between ontology and the inquirer. In this research, as the reality is constructed within the relative mind of the human, the only way to unlock the reality is subject to the modeller/observer/analyst decision maker. Such a perspective is subjectively influenced by the skills, experience, and intuition of the analyst (Rose, 1997); or processes of decision-making and preference as the complexity itself are a subjective issue. To address this issue in the present research, the final partner configuration procedure employs the different decision makers' preferences for partner selection; in addition to holding simulation game sessions in order to validate the model. Therefore, the suggested combination of partners for a same disaster situation would be different for each decision maker based on their perceptions (Guba and Lincoln, 1994).

Ontology and epistemology deal with the truth, however axiology is about values and ethics (Mingers, 2003). Axiology is also called Value theory, and includes the disciplines of ethics, pragmatics, and aesthetics (Banathy and Jenlink, 2004). Values provide the standard for the evaluation of epistemological and ontological claims. Therefore, the crucial axiological question for a researcher is - 'What is the ultimate purpose of the inquiry?' (Durant-Law, 2005). The axiological concern of the humanitarian network is to ensure that the inquiry is moral and ethical. Such a human systems inquiry (Churchman, 1971, 1979, 1982) should be value oriented, and bounded to the social imperative, implying the primacy of human loss over the financial loss. Saunders et al. (2009) argue that researchers demonstrate axiological skills by being able to articulate their values as a basis for making judgments about what research they are conducting and how they go about doing it. Choosing the topic suggests what is more important to the researcher. The topic, directly related to the humanitarian problem of proliferation of actors within the broader field of operations research, represents the concerns of the author for the improvement of quality of humanitarian response. However, all the above steps need to be conducted in compliance with the special characteristics of a disaster. For example, the traditional performance measures can no longer measure the success of the humanitarian network (Simpson and Hancock, 2009; Oloruntoba and Gray, 2006; Pettit and Beresford, 2009) as non-financial factors such as human lives and the time values associated with rescue are unquantifiable in a disaster situation (Oloruntoba and Gray, 2006; Pettit and Beresford, 2009).

In addition, the choice of philosophical approach is a reflection of the author's values, as is the choice of data collection techniques. The suggestion for selecting partners based on the resources required to address the human impact of the disaster in this research, tends to accommodate this axiological consideration. This is based on the belief that the survivors of disasters have the right to continue to have their needs supplied above a minimum level of standard requirements. This is essential for them to continue their lives with dignity until the situation returns to normal. Therefore, the most important aspect to be considered for the selected network of partners is their collective ability to provide the minimum standard requirement for the affected population. In addition, the fact that the final decision-making is bound to the preferences of human decision makers embraces the moral/ethical dimension of the affected population's socio-economical preference as a crucial and defining characteristic of the inquiry process.

4.3.1 ABDUCTION

The choice about the research approach provides an insight towards the research design, including its data collection, analysis techniques, procedures, and how to interpret the evidence. In addition, the type of research question helps the evolution of the approach. The reason is that inductive research is required to examine why, and deduction is required to explore what questions. However some believe that the advances in science might not follow the pure inductive/deductive approach (Kirkeby, 1990; Taylor et al., 2002). Therefore the abduction is introduced (Pierce,1931). Abduction is defined as the systematised creativity to break the limitation of induction or deduction. Deduction derives logical conclusions from a theory and presents them in the form of hypotheses to test. Induction conversely observe the world to draw propositions and generalize them in theoretical frame. Abduction on the other hand neither drives theory from observation or use theory to drive hypothesis, instead it observes an existing phenomena and examine it from a new perspective (Kovac and Spense,2006). This creating knowledge by searching and matching theories from other fields to explain the existing phenomena is quite common in operations research and case study research (Dubois and Gadde,2002;Kovac and Spense, 2006). In the process of abduction data collection and theory building is conducted simultaneously and there is interactions between empirical research and theory. This is the process of the research in this thesis, where the disaster proliferation phenomena is being investigated by matching different theories, conducting trial and error attempts of predictions to see which tools is fit better within the collected data.

4.4 THE STUDIES

The prediction describes the activity in real setting and prescribes the specific action to achieve some specific end (Gonzales, 2009). To that end, the present design follows the normative path, which offers patterns to prescribe better choices of partners and desirable courses of action. This ultimately optimises or maximises the decision makers' preference in a disaster situation. Three sets of studies were conducted to provide the basis for the model of partner ranking/configuration.

The first study constitutes PREDICTION. The methodology followed in this study is a combination of predictive tools including statistical and mathematical tools combied with the analysis of the panel data obtained from 4252 records of previous disasters since 1980. First the criteria used for prediction in the disaster related literature, is performed. The significance of each criteria is investigated using regression analysis and the following criteria are shown to be significant : HDI, DRI, population, population density and disaster type. Although the regression analysis is further used to predict the impact using the significant criteria, the NRMSE showed that the predictions are far from the actual impact. This is achieved by comparing the result of the prediction with the actual impact of the disaster. Following this result a pattern recognition tool called MA rule is used to build a rule-based scenario analysis platform using the significant criteria. The result of the prediction using MA rule is found to be more accurate using NRMSE. The result answers the question how much aid is needed as it provides a range of possible impacts for injuries, fatalities and homeless.

The second study constitutes ESTIMATION. The methodology followed in this study is an archival analysis of various sources which explicitly are described in the chapter 5. The result provides a list of minimum standard requirements for each disaster type. This data answers the propostion what is needed? This result combied with the predictions in the first study could ESTIMATE the range of the required resources for each disaster scenario.

The third study constitute OPTIMISATION. The methodology followed in this study is to provide an optimization problem. In this study a disaster scenario is described and the required aid is calculated using the PREDICTION and ESTIMATION studies. The result is then matched with a number of partners and their capacities to provide the resources. The method to choose the partners is to maximize the ultility function built upon the preference of the decision makers. In this method each decision maker provide their preferences towards each type of partners. This becomes the basis to calculate the AHP weight for each partner's resources. The result then is put into an optimization process, with two constraints: the total resources obtained from all partners should not exceed the required resources and the total resources acquired from each partner should not exceed that partner's capacity. This model asnwers the third proposition "who can provide?".

The above three studies give rise to the development of PREDIS model. The next study is an empirical study called EVALUATION. This study is basically an attempt to identify the validity of the PREDIS model by putting forward a smiluation game. In this method the result of the theory building (PREDIS model) is fed into the actual decision-making process (simulation) to observe its effects and draw conclusions. In this method two sets of decision makers (experts and non-experts) are put through a quasi-experiment design. The pre-test phase is consist of a questionnaire about the way the decisison makers decide now when presented by a disaster scenario. Then they are exposed to the PREDIS model framework as treatment. Finally they are asked to decide about the disaster scenario using PREDIS model. The result of two phases then is compared to examin if " the decision makers decide quicker using PREDIS model" and if "the non-experts decide similar to experts using PREDIS model".

FIGURE 4-3 THE RESEARCH STRATEGIES IN THE SEQUENTIAL ANALYSIS

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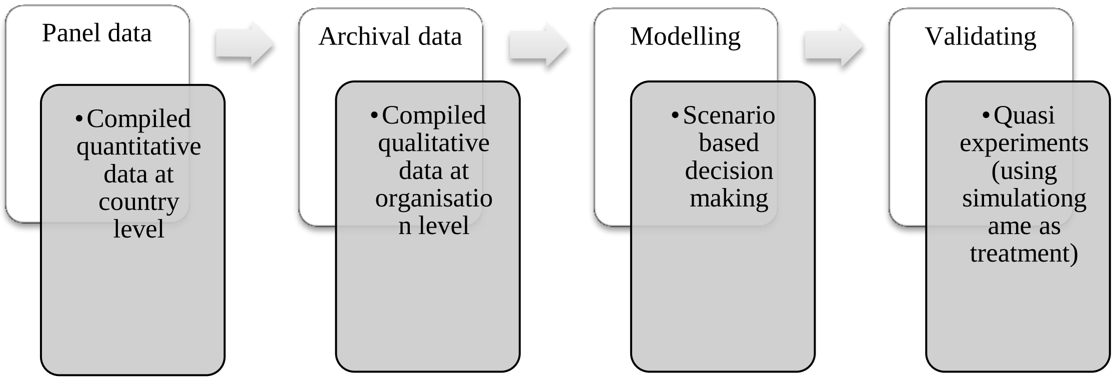


FIGURE **4-3** shows that the first study (PREDICTION) compiles the available quantitative data in a panel data analysis to find the pattern of the disaster impact. The second study (ESTIMATION) compiles the qualitative archival data to compose a table for minimum standard requirements. The data obtained in these two studies are used in the third study (OPTIMISATION) for modelling a scenario based decision-making and finally the model is validated in a quasi-experiment using the simulation game as the treatment within the last study (EVALUATION).

4.5 FIRST STUDY (PREDICTION)

The first research study has been conducted by building and analysing the panel data, compiled from various data sources at the country level including geographical, temporal, human, and economic information on disasters. The panel data is the collection of information about the same units repeated overtime and can it can use survey data, official statistics, etc. (Andreb et al., 2013). In the present research, the panel data was a combination of data from various documents obtained from UN agencies, non-governmental organizations, insurance companies, research institutes and press agencies (Emdat.be, 2014; Munichre.com, 2014; ReliefWeb, 2014; Gdacs.org, 2014).

Priority was given to data from UN agencies, governments and the International

Federation of Red Cross and Red Crescent Societies. For example if the report from UN had discrepancies with a report from a NGO, the UN report was considered for the purpose of this research. This prioritisation is not only a reflection of the quality or value of the data, it also reflects the fact that most reporting sources do not cover all disasters or have political limitations that could affect the figures. These sources are explained in detail in the data collection part. The inductive approach in the first research (PREDICTION) has been adapted in order to provide a partner configuration model, as the backbone of the research, which constitutes three complementary decision-making models that will give rise to the second and third study (ESTIMATION, OPTIMISATION) in the research. The assumption associated with this study is that 'There is a relationship between the human impact of the disaster and the severity of the disaster'. Therefore, the study is an attempt to find out if the severity of the disaster could totally or partially explain the human impacts of the disaster.

The design chosen for this part is panel data analysis. As the increasing number of panel studies in the recent years shows, the panel design has become increasingly attractive in social research. Panel design can answer more research questions in a much more convincing manner than other research designs and collect repeated measurements from the same people or subjects over time, reveal changes at the individual level and show different patterns from time series data (Andreb et al., 2013).

Panel data is widely used in econometrics, but the author believes that it is suitable for the present research because it provides such a rich environment for the development of estimation techniques and theoretical results. In particular, panel data improve opportunities to describe trajectories of growth and development over the life course and to study the patterns of causal relationships over longer time spans (Blossfeld, 2009), which is the case in the big data set associated with the disaster impacts in all countries from 1980 to 2013. The analysis of panel data allows the model builder to learn about processes while accounting for both heterogeneity across individuals, firms, countries, and so on and for dynamic effects that are not visible in cross sections (Greene, 2008). This characteristic also helps in this specific occasion where the author could immediately identify any special patterns in the data. Gradually, using the principal of soft systems methodology and the long process of trial and error combined with the result of the existing literature in the impact of disasters, the determinants and the causality links in addition to framework for prediction were generated. This process is explained in detail in the chapter 5. Because the product of the first study (PREDICTION) is a predictive framework it is important to reveal the necessity of developing this framework, whilst there is already some framework in place for disaster prediction. The following section outlines the reasoning behind developing a new predictive framework in this research.

4.6 SECOND STUDY – ESTIMATION

The second set of data is gathered by reviewing the archival data about the day-to day operation of humanitarian bodies in various disaster response projects. The details about the sources are explained in the chapter. The qualitative data obtained from this method have been used to develop a second framework for needs assessment in disaster response networks, in addition to a framework for prioritising needs in different geo-economical settings. These data for the present research are collected from a variety of Government archives including Census Bureau, Department of Labour, military, European Central Bank (ECB), Federal Emergency Management Agency (FEMA), private/public organisations including various bodies of UN (UNDRO, UNICEF, UNHCR), World Health Organisation

(WHO), Global Health Council (GHC), IFRC, Office for the Coordination of Humanitarian Affairs (OCHA), and various foundations and associations including OXFAM, The Association for Healthcare Resource & Materials Management (AHRMM), Sphere project, National Voluntary Organisations Active in Disaster (VOAD), Health Industry Group Purchasing Association (HIGPA) and Health Industry Distribution Association (HIDA). The full list of documents utilised for this study can be found in chapter 5.

4.6.1 THE CRTERIA FOR THE SECOND STUDY (ESTIMATION)

Various scholars and organisations have tried to categorise the requirements in the response operations. The preliminary review has identified myriads of requirements (Altay and Green, 2006; FEMA, 2007; UNDRO, 1992; Sphere project, 2011; IASC, 2011; IFRC, 2009). The list of these requirements is presented in FIGURE **4-4**.

FIGURE 4-4 THE REQUIREMENTS OF THE DISASTER AFFECTED AREAS

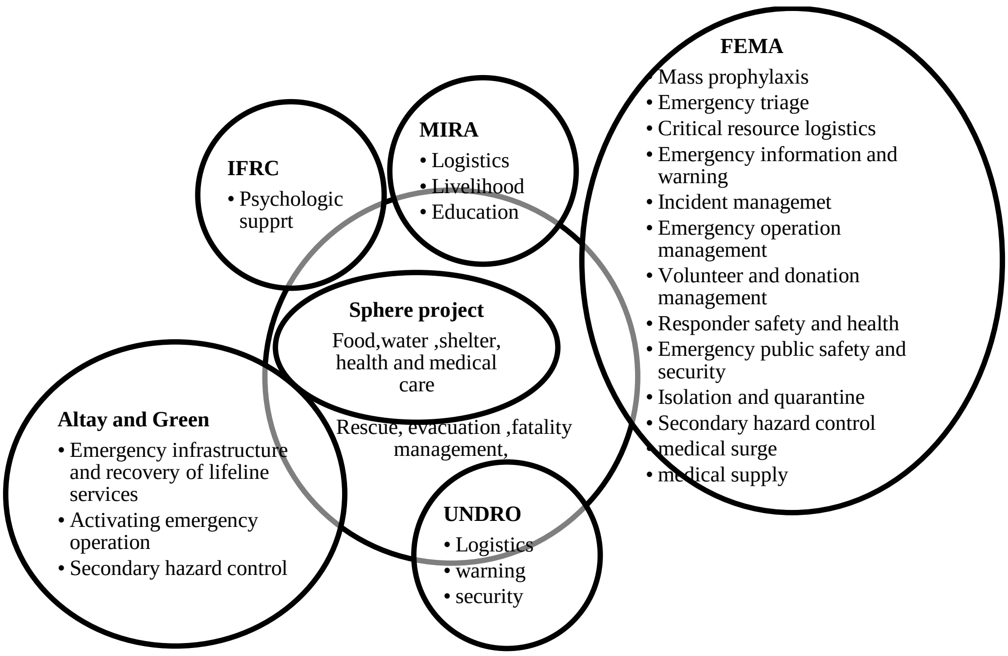


FIGURE **4-4** shows where the six sources (Sphere project, 2011; IASC, 2011; IFRC, 2009; UNDRO, 1992; FEMA, 2007; and Altay and Green, 2006) overlap. This is in other words, where different sources agree that the same criteria are required. This result can be summarised as follows:

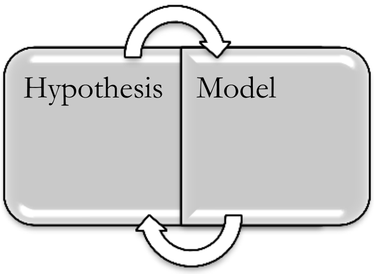
- Basically, all the sources emphasise the importance of the key life-saving activities including food security and nutrition, shelter and settlement (including non-food items), water and sanitation and health actions.
- Except for the Sphere project, which focuses solely on saving the lives of the survivors, the rest of the sources agree that rescue, evacuation and fatality management, education and logistics are also important.
- Some sources add a few activities, which are just emphasised by them like psychological support by IFRC, warning and security by UNDRO, livelihood by MIRA. Other than that, only Altay and Green add emergency infrastructure and recovery of lifeline services, activating emergency operation. In addition, only FEMA emphasises the importance of mass prophylaxis, emergency triage, critical resource logistics, emergency information and warning, incident management, emergency operation management, volunteer and donation management, responder safety and health, emergency public safety and security, isolation and quarantine, secondary hazard control, medical surge and medical supply. Both FEMA, and Altay and Green emphasise the importance of secondary hazard control.

To summarise the key life-saving activities or mass care activities are shared by all sources and therefore are the focus of this study. Due to the lack of secondary data regarding the specific requirements of non-key-life-saving activities, these have been excluded from the study. However, the author believes that the principles of this research can be extrapolated to the other activities. In the sense that the same process for analysing archival data can give rise to the identification of the standard minimum requirements for non-key life-saving activities and therefore combined with the results of the PREDICTION, partners can be selected based on their resources required for non-key-life-saving activities. However, data collection on this scale requires the cooperation of various humanitarian organisations including the UN, IFRC, and government related organisations, in addition to the private and public humanitarian organisations and charities (similar to the process in the sphere project) and is out with the scope of the current research.

4.7 THIRD STUDY (ESTIMATION)

The third sequence of the present research tests the results obtained from the first two studies by predicting the human impact and needs for a real disaster situation. Because hypothetical models are often used as the basis for decision-making, diagnosis, or prediction (Gladun, 1993), the present research uses a hypothetical modelling to provide a PREdictive model of DISaster response (PREDIS). In this stage the prediction of disaster impact and requirements, leads to the diagnosis of the severity of the disaster aftermath and employs the hypothetical decision makers' preferences to choose between hypothetical partners. The reason for using hypothetical modelling is that for the decision-making process to be run, we require specific data about the partners and decision makers' preferences. These data are unavailable and obtaining them could be the subject of multiple PhD research studies, funding, and the cooperation of various humanitarian bodies. To that end, at this stage, a hypothetical modelling is used to run the PREDIS model. In theory, the hypothetical model is constructed where the scarcity of reliable data about the essential characteristics renders the acquisition of such knowledge through direct observation difficult or impossible (Gladun, 1997).

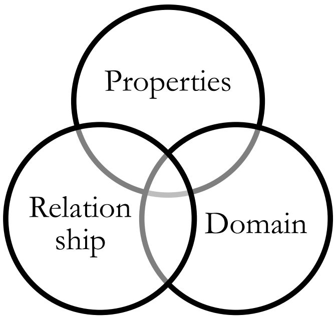
FIGURE 4-5 THE CYCLE OF THE HYPOTHETICAL MODELLING STUDY



Adapted from Gladun (1993,1997)

FIGURE **4-5** shows the process of a model-based study, which enriches the starting hypothesis or generates new hypotheses, which leads to further development of the model. When we reach the second study (ESTIMATION) it means that the first hypothesis in the first study or PREDICTION (Ha: there is a relationship between the human impact of the disaster and the severity of disaster) is already confirmed. This leads to the generation of two propostions in the second study or ESTIMATION (first propostion: there is a relationship between the disaster human impact and the needs and their priority). With the confirmation of these two hypotheses, in the second proposition in the third study (OPTIMISATION) is put forward (Second proposition : It is possible to select partners based on the principles of utility theory and preferences of decision maker). These hypothesis along with two propositions lead to the development of the hypothetical model in the third study as follows. Based on the constructive philosophical position of the present research, the author followed Von Frassen's definition of a model based on constructive empiricism. He states where the theory is a reality constructed by the inquirer and is believed to be true by the inquirers (Frassen, 1980), the model can be defined as a combination of three components. A domain of objects together with a description of the properties they can have and the relations they can bear to one another (Barret and Stanford, 2006).

FIGURE 4-6 CHARACTERISTICS OF A MODEL



Adapted from Barret and Stanford, 2006

FIGURE **4-6** shows that the hypothetical modelling is typically a man-machine procedure with two alternating actions. First, hypotheses concerning properties, domain, and relations of the modelled object are generated, second the selection, and specialisation of hypotheses. At the start of modelling, the expert enters into the system concepts and relationships that reflect his initial understanding of the object. This stage is addressed in the first two studies by finding relationships and patterns between the disaster impact, disaster severity, and needs. This connects three domains of disaster management in the first study (PREDICTION), Resource-based view in the second study (ESTIMATION) and decision-making in the third study (OPTIMISATION). As was mentioned before this model holds the properties related to PREDICTION, ESTIMATION, and OPTIMISATION.

This man-machine procedure substantially reduces the "intellectual intensity" and ensures exhaustive analysis during hypothetical modelling (Gladun, 1993). The result of the created PREDIS model is run in a hypothetical optimisation case where the hypothetical decision makers enter their preferences towards the hypothetical set of partners into the PREDIS model platform and the result is the optimisation of selected hypothetical partners based on the principals of decision theory (Specifically multi-attribute utility theory). The decision techniques suitable for this part of the research are further explored in the next section.

4.8 IDENTIFYING DECISION TECHNIQUES THIRD STUDY (OPTIMISATION)

For the optimisation of a partner selection for partner proliferation problem which is the subject of the third study (OPTIMISATION), a decision technique is required that needs to be selected from the above methods. The partner selection criteria in general should be embedded in the framework of the decision support tools for partner configuration. For the particular case of this research the decision methods used in literature were compared to identify the most suitable technique to be used in the research. A review shows a variety of hard methods (with quantitative and numerical values) and heuristic methods (with linguistic and quantitative values) in the decision-making field.

There is one specific group of hard or mathematical methods capable of accommodating numbers and crisp values (as oppose to fuzzy or qualitative values) such as goal programming and integer programming. For example, Talluri and Bake (1996) have used integer programing to select efficient partners out of a pool or partners, which have been previously shortlisted using DEA. However, for the purpose of this research they seem to be unsuitable because they formulate the problem in objective terms, and fail to accommodate subjective attributes. In this research, where the final decision about the partner selection needs to be based on the subjective preferences of decision makers, these methods fall short. In addition, due to the high load of computation, these methods are not suitable for this particular research, which utilises in this research a big dataset.

Another set of methods, that has been vastly used in this area are different evolutionary algorithms, such as TABU, GA, ACA and PSO. For example, Feng et al. (2000) used GA to optimise partner selection, whilst Qu and Sun (2005) developed a GA model for optimal resource configuration in order to select partners in a product chain. Zhong et al. (2009) also used a combination of two algorithms of GA and ACA for modelling the partner selection in VE. Recently improving the objective function for partner selection in optimisation has attracted the interest of the researchers in the field of virtual enterprises. For example, Kennedy and Eberhart (1997), Yin (2004), and Fang (2006) have used PSO algorithms in the objective function for partner selection, converging to optimal or local optimal. Ip et al. (2003) pointed out that dynamic alliances are essential components of global manufacturing. Based on the concept of the inefficient candidate, they built a risk-based partner selection model by using GA to minimise the risk in partner selection. However, they failed to consider both qualitative and quantitative evaluation attributes simultaneously. Sha and Che (2006) proposed an approach, which is based on the GA, AHP and the multi-attribute utility theory to satisfy simultaneously the preferences of the suppliers and the customers at each level in the network. This approach seems likely to outperform that of the single-phase GA in supplier selection. Liao and Rittscher (2007) constructed a multi-objective supplier selection model under stochastic demand conditions. They extended the measurement of supplier flexibility to consider demand quantity and timing uncertainties comprehensively. Moreover, they proposed a problem specific GA to handle the combinatorial optimisation problem. Their solution alternatives and objective trade-offs are valuable for the final supplier selection. Wang et al. (2009) emphasised that partner selection is a key step in organising a well-designed dynamic supply network. They carefully analysed various collaboration patterns between distributed partners with the corresponding evaluation criteria for collaboration time and cost, and then proposed a GA solution for collaboration cost optimisation-oriented partner selection. Yeh and Chuang (2011) also developed an optimum mathematical planning model for green partner selection by adopting two multi-objective GAs to find the set of optimal solutions. The Ant Colony algorithm just takes the single objective and is not suitable for multi-objective problems (Zhong, 2009), which is the case in disaster response. Crispim and De Sousa (2009) use a Tabu search metaheuristic in combination with a fuzzy TOPSIS algorithm to rank the alternative VE configurations. However, the main drawback of these methods is that they require a high level of specialised knowledge that is likely to be well beyond that possessed by disaster response decision makers. Another drawback is that they become very slow when the number of partners arises and therefore they might offer a local optimal solution instead. Therefore, in the disaster response situation where the number of partners is high, these methods cannot be used effectively.

Expert systems such as fuzzy logic use linguistically-expressed expert's experience for multi-criteria optimisation (GARDAŠEVIĆ-FILIPOVIĆ and ŠALETIĆ, 2010) or supplier selection in order allocation (Kannan et al., 2013) in addition to all the studies above where the fuzzy method has been used in combination with MADM. These methods are only as strong as their database, so in the absence of such a strong database the rule based system may fail (Hans, 2007). The same problem might occur with Neural Network as it needs a large dataset for training and without it the result might not be trustworthy or can fail to be generalisable. It is noteworthy to mention the difference between the large dataset used in the first study (PREDICTION) and the non-existent database in the third study (OPTIMISATON). OPTIMISATION is about the decision makers choosing the partners based on their preferences. However, there is no record of decision makers' choices of partners in the disaster response in the literature whilst there is a good record of disaster impacts in the literature. The same reason is applicable for not using the expert systems such as fuzzy set theory in the OPTIMISATION. Because this method is based on drawing fuzzy based rules out of the series of data, and in the absence of data, the rules cannot be drawn.

Another group of methods, which seem to be more suitable for this research are the methods, which have the capability of accommodating the non-crisp values, such as non-certain preferences of decision makers, which are required for partner selection. One of the good candidates for this is the multi-attributive decision-making (MADM) such as AHP and ANP or TOPSIS. A MADM is a branch in the decision-making for choosing between a finite numbers of alternatives. In the PREDIS model, we assume that the number of partners in disaster response is finite so it seems appropriate to use MADM. One of the weaknesses all MADM methods discussed face is the rank reversal problem, which means that result of the ranking (direction of maximising or minimising and the ranking method itself) differs with the quality of the information available and the set of criteria representing the reality. However, in the uncertain environment of the disaster response, the decision maker always has to settle for available or obtainable data. This is because of the time pressure and the destroyed infrastructure most of the times it is impossible to improve the quality of the data. Therefore, the low quality of the data is going to affect the result of their decision, no matter what decision-making method they choose. Thus, these methods still seem like good candidates. Within the above MADM methods (which are the most popular) ANP has been used by various scholars such as Chen et al. (2008) for selecting partners for strategic alliances and by Liou et al. (2011) in strategic alliances in the air industry and Ustun and Demirtas (2008) in supplier selection. However, this method is incapable of accommodating the subjective perspectives of decision makers, which is one of the elements of the optimisation model in PREDIS. Another option, Technique for Order Performance by Similarity to Ideal Solution (TOPSIS), has been used for group decision-making under uncertainty of information in order to select suitable partners (Ye, 2010) or for supplier selection in a supply chain (Liao and Kao, 2011). Erkayman et al. (2012) have used it for strategic alliance partner selection in third-party logistics. All three studies have combined TOPSIS with Fuzzy logic to accommodate the uncertain numbers. Wang and Liu (2007) have used TOPSIS in partner selection in logistics strategic alliance combined with AHP. This method can rank alternatives regarding defined criteria by minimising their distance from a positive ideal solution and maximising their distance from the negative ideal solution. This method also is based on objective values and therefore it ignores the subjective decision maker preference in our method. The most suitable option within MADM is AHP, which is used extensively in partner selection and special case of VO amongst the other networks. For example, Mikhailov (2002) and Yang (2002) have both used fuzzy AHP to select partners for a VO. Wang and Kao (2007) used Fuzzy MADM to select distribution centres, Zohghadri et al. (2011) used AHP for partner selection in product development projects, and Chu (2000) proposed employing the AHP method to select the partners from a pool of candidates. The AHP is a good method for our research because unlike the other MADM methods mentioned above, it accommodates the subjective values, including the decision maker’s preferences. **Error! Reference source not found.** articulates the weaknesses of the decision methods as described above.

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TABLE 4-1 THE CHALLENGES FACING THE USE OF DECISION METHODS

METHOD	WEAKNESS	SOURCE
AHP	Failure to accommodate quantitative data (Subjective preferences of decision makers)	Mikhailov (2002)
	Rank Reversal Problem - result of the ranking differs with the quality of the information available, set of criteria representing the reality, the direction of maximising or minimising and the ranking method itself	Crispim and De sousa (2009).
	Fails to consider the interactions among the various factors subjective experts' advice	
ANP	Considers the complex relationships between factors and clusters, but cannot solve the optimisation problem because it does not take numbers.	
	Rank reversal problem	
	Subjective experts' advice	
Heuristic algorithms (TABU, ACO, GA, PSP)	Become very slow when the number of partners arises and therefore they might offer a local optimal solution instead.	Jarimo et al. (2009)
	Cannot take multi-objective problems/ difficult to use for average user.	Zhong (2009)
Fuzzy logic Neural network	Are as strong as their data and in the absence of such data, may fail to provide a trustworthy view on the partner selection, difficult for average users to operate.	Hans (2008)
TOPSIS	Based on objective data therefore the subjective requirements could easily be neglected.	Wu and Barnes (2011)
	Rank reversal problem	Hodgett (2013)
Mathematical programming	Formulates the problem in objective terms and cannot accommodate subjective attributes.	Wu and Barnes (2011)
	Difficult to use in large-scale planning due to substantial load of computation.	

Source: Author

In order to evaluate which decision-making method is suitable for a disaster response network, the partner selection can be viewed as a multi-criteria decision-making problem (Crispim and de Sousa, 2010). The final goal of the partner selection process is to create a successful collaboration in accordance to the characteristics of DRN as a special case of VO. One of the most obvious characters of the disaster relief operation is the time pressure inherited in them. In a disaster situation, time is vital for most of the activities; an efficient partner selection and network formation needs to be done quickly. To that end, the decision-making methods with a high execution time such as evolutionary algorithms, which slows down towards the end need to be avoided. They also require a high degree of technical mathematic understanding, which the average decision maker in disaster response network might not have. Another characteristic of any decision-making method run by people is that their preferences may hugely influence the result. Thus, the methods in which the subjective preferences of decision maker preferences are not accommodated should be avoided such as ANP and TOPSIS. To that end, the AHP and fuzzy logic are perfect for accommodating the decision makers' preferences. However, fuzzy logic is difficult to comprehend by an average user and requires a large dataset to draw upon the fuzzy based rules. Many of decision makers in disaster situations are not mathematically trained in calculating complex heuristic values. In addition, mathematical programming could be used in the areas when we have exact numerical values. Consequently, the suitable candidate for optimisation is AHP to rank the utility of hypothetical partners based on the decision maker's preferences and to select the optimal partners. This selection is planned to be made based on the resources the hypothetical partners may have available in accordance to the estimated needs of predicted impact of disaster (calculated in the first and second study, PREDICTION and ESTIMATION). This process is explained in detail in chapter 5.

4.9 FOURTH STUDY (SIMULATION)

Simulation is defined as a representation of a real-world environment, system or process used for scientific purposes, when the real system may not be observed directly because of the inaccessibility, cost, danger (Barton, 1994). In other words, it is the imitation of the operation of a real-world process or system over time (Banks, 1998). Simulation approaches include system dynamics, discrete event modelling and agent based modelling. By taking the simulation off the computer screen and bringing it into the experiential world of the players (Colella, 2000), participatory simulation or simulation games are born. In this method, an environment is created where players take decisions based on underlying rules that are consistent with the real world and comprehensible (Anand et al., 2013). The reason is it supports the understanding of complex social phenomena by a generative approach, which involves reduction, performance, training, proof, and discovery in social science (Gentile et al., 2014). In this context, the main goal of the game is to simulate the actors' decision-making processes. This leads to the demonstration of the consequences within social systems where the users have to cope with difficulties arising from the complex nature of these systems (Westera, 2008). Some researchers believe that simulation games are the third research methodology in line with induction and deduction (Axelrod, 1997).

4.10 SUMMARY OF THE CHAPTER

The methodology chapter was put forward to outline a methodology for investigating the research questions. This process will be approached through soft system lenses, which is capable of addressing the complex and ill-defined problems. It also puts forward the principles of the research's inquiry paradigm. A necessity to develop the predictive framework was then argued by explaining that despite the existing research in the literature, a framework for predicting the human impact and estimating the needs at the time of the disaster has yet to be developed. This gave rise to the empirical part of the research. To that end, it proposed three studies to develop a decision-making model, followed by an experiment for verification of that model from the decision maker's view. The first study was put forward to PREDICT the disaster impact out of the database of previous disasters. To achieve this, the criteria for prediction and the sources for data collection were articulated. The second study aims to ESTIMATE the minimum standard requirement for disaster response. This identifies the sources required per person affected by disaster. Combining this estimated data with the predicted data in the first study provides a series of scenarios, which identify in each disaster (based on their type and severity) how many units of resources are required. The third study (OPTIMISATION) utilises the AHP in combination with the principles of utility theory to select the suitable partners. This process takes place in order to take into account the preferences of the decision makers in the process of partner-selection, which is an important factor in disaster situation. The details of this process are discussed further, in the next chapter.

5 PREDICTION, ESTIMATION & OPTIMISATION

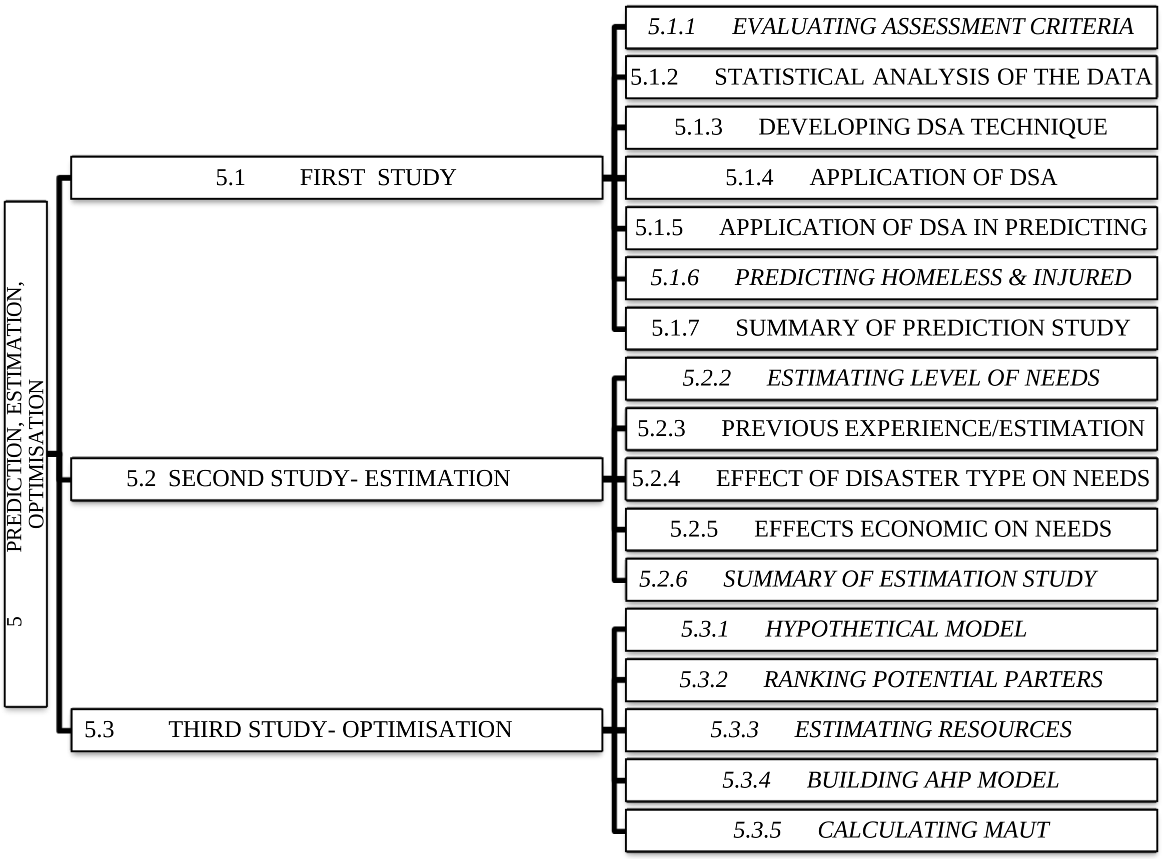
The aim of this chapter is to provide an outline for the part of the research comprising of three separate and yet interrelated studies. The results of these three studies will be the structure of PREDIS model.

The first study – (PREDICTION) provides a technique for predicting the human impact of the disaster including the fatalities, injured and homeless people. To that end, first the assessment criteria introduced in previous chapters are evaluated to establish which one is suitable for disaster impact prediction, before the data collection procedure is outlined. The collected data then is statistically evaluated to identify their predictive validity. The validated data then is used to develop the DSA technique, before describing the application of DSA in prediction. The process of prediction is further outlined using various methods including regression analysis and MA rule analysis. The result of prediction then is evaluated and the summary of the study is articulated.

The second study – (ESTIMATION) provides a technique for estimating the needs in disaster situation. First, the data collection procedure is outlined, before reviewing the previous experiences in need estimation. The minimum standard requirement for each disaster scenario is then outlined based on the accumulated data from archival humanitarian sources. The effects of two factors on the needs estimation, is investigated including the type of disaster and economic characteristics. The study is concluded with a summary.

The third study (OPTIMISATION) sets out the principals of the PREDIS decision platform in disaster scenarios where an optimisation technique is introduced for selecting the hypothetical partners. This study embarks by explaining the hypothetical model, and ranking the potential partners in a VBE. Then an exemplary case is outlined to estimate the required resources for this special case. After that, the AHP model for decision makers' preference is built and MAUT for each partner is calculated. Afterwards, the partners are ranked and selected based on a utility function. The result of the study then is summarised before providing a summary of the chapter. The components of this chapter are outlined in FIGURE **5-1**.

FIGURE 5-1 OUTLINE OF THE CHAPTER 5



To summarise, the first study (PREDICTION) provides a technique for assessing the human impact of the disaster including the fatalities, injured and homeless people. To develop this technique first the related literature was reviewed and the final method was built upon the existing literature in addition to the findings of the author. The results produce a scenario-based prediction of the human impact of the disaster. The second study (ESTIMATION) reviews the existing sources in humanitarian organisation to provide a basis for estimating the needs in disaster situation. The third study (OPTIMISATION) combines the results of the first two studies in order to simulate the partner selection procedure hypothetically and gives rise to a platform for PREDIS model. By knowing the required needs and resources, the hypothetical partners' capabilities and resources are being matched to them using the preferences of hypothetical decision makers built upon the principles of Resource- based theory and Utility theory. Although the first three studies (PREDICTION, ESTIMATION, OPRIMISATION) are based on the secondary data, the fourth empirical study (SIMULATION) uses a simulation game to collect primary data about reactions and opinions of the experts to validate the introduced model.

5.1 FIRST STUDY

The aim of the first study is to find a pattern in the disaster historic data that makes it possible to predict the human impact of the disaster. The author tried to use the data, which have been already available since 1980 and calculated for most of the countries represented in the UN. To that end, the existing criteria from the literature were considered and evaluated to come up with a set of criteria.

5.1.1 EVALUATING THE ASSESSMENT CRITERIA

Before evaluating the above criteria, it is noteworthy to lay down a few statistical assumptions due to the unique characteristics of the data set. The data set (Appendix **5**) was accumulated and combined from various sources (articulated in detail in Table **5-1**) to cover all the natural disasters of their kind since 1980 equal to 4252 events. These characteristics give rise to the following assumptions.

The first assumption is that the distribution of this data is assumed normal under the two theorems of Probability theory including the Law of large numbers and also Central limit theory. The Central limit theorem states that, the average of a sufficiently large number of independent random variables will be approximately normally distributed, regardless of the underlying distribution (Rice, 1995). To achieve this, the distributions of above data, which have been accumulated from 4, 252 records of previous disasters, are assumed to be normal.

The Law of large numbers dates back to Bernoulli and Poisson, whilst further contributions, were made by Chebyshev, Markov, Borel, Cantelli, and Kolmogorov (Kontorovich and Brockwell, 2014). These laws, which are applied to sequences of independent variables, explain that when the data accumulates, the averages will converge to the true expectations, and inferences will become increasingly more valid. One of the earliest accounts (Prince, 1895), states that after 1,000 independent trials, the variation between different groups (of randomly selected observations) falls to under 3 per cent. This basically means that the estimated error would be hugely reduced when the dataset is large.

The second assumption is that in this situation the test of significance is obsolete because the standard error does not exist (Morrison and Henkel, 1970). In addition, because the error does not exist the R-squared, which is calculated, based on error will not be meaningful. The author in this research agrees with their view. However, because most readers would like to see the Significance test, this is performed in the next section. Nevertheless, the author notes that the significance of the variables and also the explanatory power of R-SQUARE in these tests may not be relied upon depending on the reader's statistical grounds. Meaning if the reader agrees with Morrison and Henkel's (1970) opinion, they will not count R-SQUARE as a good explanatory factor and vice versa. Thus, the agreement of the scholars on this matter is highly subjective to their view. The author also believes that this disagreement between the views of the reader may not be a problem in pursuing the rest of the study because the actual predictions are not based on regression analysis but are based on the comparison of averages and therefore the explanatory power of R-SQUARE is not required. The details of the predictive procedure are explained later in the chapter.

5.1.1.1 DATA COLLECTION FOR THE FIRST STUDY

The first step is to analyse the data in order to recognise a pattern emerging from the datasets. At this stage the data from various sources were compiled together to provide a set of panel data at the country level. Extracting certain information from a number of raw data sets and combining them into a new data set built a working dataset. In the current study, four varied sources were considered. First, the prominent natural disasters occurring after 1980 mentioned in the Encyclopaedia of Disasters (Gunn, 2007) including 32 disasters were considered. The result was compared to the 10 costliest and 10 deadliest disasters in NatCatSERVICE (Munich RE, 2007) leading to a more complete list of disasters. The data were next compared to the EM-DAT and Munich RE, accumulating to 4252 disasters. This process required a definition of the target population, the time period under investigation and the variables of interest (Andreb et al., 2013). The target population in our case follows the EM_DAT definition, which includes the disasters that have affected more than 10 people, and were declared in need of international assistance. The time period is between 1980 and 2013.

Variables within the context of the research can be categorised into time-constant and time-varying variables. Context is defined as the environment in which a unit is observed. In this research, the context is the country. Time-varying variables X characterising the unit or the context: for example the population of the country changes along time, this also can be used as explanatory factors in different settings. For example, the higher the population of the country is, the greater the probability of fatalities because of disaster.

Time T: Some researchers consider time as an explanatory factor. However, in the present research time is an indicator of other characteristics that change over time such as population, and is not the causal factor on its own. The time varying variables are the date of the disaster, the type of disaster, the population and its density within the country, HDI of the country, DRI of the country, the human impact (killed, injured) and the magnitude of the disaster. These variables are articulated and defined in Table **5-1**.

Table 5-1 the time-varying variables

The variables	Source	Definition
End date	Gunn (2007), NatCatSERVICE (2007), CRED (2009) DesInvestar (2013), Gadacs (2014), reliefweb (2013a)	The date in which the disaster end
Type of disaster	Below (2009), (CRED, 2009)	Earthquake, cyclone, eruption, flood and storms
Population	World Bank (2013)	The population of the affected country at the time of the disaster
Population density	World Bank (2013)	Population density of the country at the time of the disaster
Country's HDI	HDR, UNDP (2013)	A combination of health, education

The variables	Source	Definition
		and living standards
Country's DRI	UNU (2012)	A combination of exposure, vulnerability and investment capacity
Number of killed	Gunn (2007), NatCatSERVICE (2007), CRED (2009) DesInvestar (2013), Gadacs (2014)	The number of people who died in the disaster
Number of injured	Gunn (2007), NatCatSERVICE (2007), CRED (2009) DesInvestar (2013), Gadacs (2014)	The number of people injured in the disaster
Magnitude	Gadacs (2014)	Magnitude of the disaster based on GDACS's alert level (red, orange, green)

In principle, panel data can be seen as a data cube with three dimensions:

Units *i =1, n*. In this research, there are six units of disaster (earthquakes, tsunamis, cyclones, eruptions, floods and storms)

Time points t = 1,T. In this research, there are 33 time points from 1980 to 2013.

Variables v =1,V. In this research, there are nine initial time-varying variables (Table **5-1**). However, a number of variables have been calculated from these variables, which will be discussed later.

The time-constant variables Z =the unit (disaster type) or the context (Country).

Typical time- constant variables in this research are the geographical location. It is possible to assume that these variables function as explanatory factors in social and political research. For instance, it is expected that the countries with disaster prone locations, are affected more frequently by disasters such as Bangladesh, USA, or Japan.

In the format adapted in the present research, each single measurement occupies one row, hence as the observation of the data implies not all types of disaster occur every year in each country. Furthermore, in some countries some types of disaster might occur more than once a year, also not all data about the disasters are available. Therefore, the number of rows/records available in this research is 4252. The number of columns equals the number of variables V (here is V equals nine). Therefore, the matrix of panel data is equal to 4252 x 9 = 38268.

Data population: The procedure resulted in the identification of more than 4252 disasters. However, as is seen in the table, not all the data are available for these disasters. An example of this sample population of records is presented in Table **5-2**.

Table 5-2 Disasters magnitude information from three sources

Year	Disaster type	Origin	Munich RE & Disasters Encyclopaedia		CRED		
			Overall Loss ($)	Fatalities	Fatalities	Affected people	Overall Loss (People)
1983	Earthqua	USA	Not specified	Not specified	1545	31	Not specified
1985	Earthqua	Mexico	Not specified	10,000.00	9500	2130204	4104
1988	Earthqua	Armenia	14,000.00	25,000.00	Non-existent in data base		
2010	Tsunami	Chile	30,000.00	520	562	2671556	30000
2011	Tsunami	Japan	210,000.00	15,840.00	19846	368820	210000
2004	Tsunami	Indonesia	4,451.60	286,000.00	165708	532898	4451.6
1991	Flood	China	13,600.00	2,628.00	1729	210232227	7500
1993	Flood	China	4252.00	3,300.00	1000		6061
1993	Flood	USA	21,000.00	48	48	31000	12000
2004	Cyclone	USA	18,000.00	36	10	30000	16000
1999	Cyclone	USA	Not specified	Not specified	70	3000010	7000
1985	Eruption	Colombia	1,000.00	21,800.00	21800	12700	1000
1991	Eruption	Philippines	Not specified	700	640	1036065	211
2002	Eruption	Congo	Not specified	250	Non-existent in the data base		

NatCatSERVICE provided by Munich RE (2007) considers 26,000 natural disasters after 1979, while the Centre for Research on the Epidemiology of Disasters (CRED, 2009) provides the EM-DAT based on 17,000 natural and technological disasters that have happened since the beginning of 20th century. Furthermore, DesInvestar provides data about affected population, roads, properties, but does not cover all the countries and lacks many disaster prone countries such as USA, Malaysia, China, Pakistan, etc. In addition, all the above sources contain a considerable amount of outliers and missing values. Although scholars have suggested alternatives for data amendments by estimating them according to expert opinion (Rodriguez et al., 2011), due to the limitations of the current research scope, the raw data obtained from the above sources were considered as they are. It is noteworthy to mention, because the CRED providing EM-DAT database has less missing values, this data has been considered as the basis for calculations. The reason is that it is impossible to match the same disaster in two sources, because they all provide different statistics for the same variable. This is probably due to their different approaches to data collection, and sources.

Another limitation is in some cases despite the importance of the disaster, due to the lack of data, the disaster could not be assessed. Therefore these disasters are indicated as NOT VALID and omitted from the analysis. For example, the Congo volcanic eruption (2002) which was the most destructive effusive eruption in modern history, or the Armenian earthquake (1988) with 25,000 fatalities could not be traced in EM-DAT (provided by CRED) or DesInvestar. Therefore, the lack of necessary data such as on affected people renders them impossible to be analysed based on the procedure of this research. Other exceptions are the disasters that happened in more than one country and the information has been mentioned separately in EM-DAT (provided by CRED). In these cases, the author accumulated the data, and the calculations are based on the accumulated amount such as Tropical Cyclone Frances (USA, 2004). In fact, most of the cyclones that have happened in the continent of the Americas, effect more than one country and follow the same rule. The used raw data set can be found in Appendix **5**.

5.1.2 STATISTICAL ANALYSIS OF THE DATA

CHAPTER 5 PREDICTION, ESTIMATION & OPTIMISATION

The dependent variables in this analysis are defined as: Fatalities (The number of people killed as a result of the disaster), Injured (The number of people injured as a result of the disaster) and Homeless (The number of homeless people as a result of the disaster). It is noteworthy to mention, that Homeless here is different from the displaced. The displaced population might have resources to flee the affected area and stay with relatives or in hotels, so they are not in immediate need of shelter and food. Therefore the word " homeless" has been chosen for people who have lost their homes, remain in the area, and are in immediate need of shelter and food. This number could be equal to or less than the displaced population.

The independent variables in this analysis are defined as: Human Development Index (HDI), Disaster Risk Index (DRI), Disaster type, Population, and Population density. Most of these variables were explained in detail in the previous section excluding the type of disaster, which could be man-made (technological) or natural. The physical manifestation of a natural disaster might originate from solid earth such as earthquakes or volcanos, or be caused by atmospheric processes such as storms and cyclones. It also could be caused by the deviations in the water cycles such as floods (Below, 2009). All of the above criteria except for the type of the disaster are numerical and comparable to each other. The human impact of the disaster may vary based on the type of the disaster. This was explored in the methodology chapter.

Another application of the fatality ratio could be to compare the severity of the two situations. For example, as a result of Venezuela's (1999) flash flood, 30,000 individuals died (emdat.be, 2014) whilst during and after the Haiti Earthquake 2010 out of a population of 9,896,400, the death toll reached 222,570. To be able to compare the severity of these two situations, the population and their density are considered (Table **5-3**). This comparison shows that the Haiti earthquake is much more severe than Venezuela's flash flood.

Table 5-3 the example of fatality ratio calculated for various disasters

Date	Country	Name	Population	Population density	Fatality	Fatality ratio
20/12/1999	Venezuela	Flash flood	23,945,002	27.15	30,000	0. 461
12/01/2010	Haiti	Earthquake	9,896,400	359.09	222,570	0. 626
26/12/2004	Sri Lanka	Tsunami	19,435,000	309.92	35,399	0. 058
26/12/2004	Indonesia	Tsunami	221,293,797	122.16	165,708	0. 061
26/12/2004	Thailand	Tsunami	65,087,400	127.40	8,345	0. 010

In addition, the comparison between the Indian Ocean tsunami (2004) in different countries shows that the fatality ratio in Indonesia ($\frac{165708}{221293797*122.16} * 1000000$) and Srilanka ($\frac{35399}{19435000*309.92} * 1000000$) was very close, and in Thailand ($\frac{8345}{65087400*127.40} * 1000000$) it was much less severe (respectively 0. 058, 0. 061, 0.010). Although these effects have numerous socio-economic and political reasons (which could be the subject of another study) the fatality ratio, which shows the proportion of lost and remaining population, could partially explain the severity of the human impact. To that end, present research suggests that the fatality ratio is a more accurate measure for comparing the severity of the human impact in various disasters than the simple fatality numbers. There were just 72 records where data were available for all eight criteria including Cause, Alert level, Magnitude, Affected population within 100km, Country's HDI, Country's DRI, Population, and Population density. The regression analysis of these data (Table **5-4**) shows that H0 for all variables except magnitude is rejected. H0 here investigates if the relationship between the above criteria and fatalities is accidental.

Table 5-4 Analysis of all the variables

Regression Statistics	
R	0.46671

R Square	0.21781				
Adjusted R Square	0.09975				
Standard Error	30,739.41655				
Total Number Of Cases	72				

Killed =- 132295.7108 + 3582.6123 * Disaster + 6585.1076 * Alert level + 20422.7124 * Magnitude + 0.0010 * Affected population within 100km - 42058.2760 * Country's HDI - 630.3661 * Country's DRI + 0.0000 * Population + 43.2947 * Population density

ANOVA

	d.f.	*SS*	*MS*	*F*	*p-level*
Regression	8.	1.394	1,743,222,936.61	1.844	0.089
Residual	53.	5.008	944,911,729.805		
Total	61.	6.402			
	Coefficients	*Standard Error*	*t Stat*	*p-level*	*H0 (1%) rejected?*
Intercept	-132,295.710	66,842.629	-1.979	0.053	*No*
Cause	3,582.612	8,417.926	0.425	0.672	*No*
Alert level	6,585.107	9,147.703	0.719	0.474	*No*
Magnitude	20,422.712	7,024.004	2.907	0.005	*Yes*
Affected population within 100km	0.001	0.001	0.944	0.349	*No*
Country's HDI	-42,058.276	32,984.913	-1.275	0.207	*No*
Country's DRI	-630.366	1,255.469	-0.502	0.617	*No*
Population	0.000	0.000	0.542	0.589	*No*
Population density	43.294	57.243	0.756	0.452	*No*

Table **5-5** shows that the H0 is rejected. Therefore the relationship between the number of fatalities and magnitude is not accidental, and the relationships between fatalities and other criteria are accidental. By deleting one variable at the time, the model has been refitted. Where

H0: The regression coefficient $\boldsymbol{\beta_i} = \mathbf{0}$

H1: At least one coefficient $\neq \mathbf{0}$

Table 5-5 Regression analysis of fatality based on HDI, DRI and population

Regression analysis

R	0.36
R Square	0.129
Adjusted R Square	0.129
Standard Error	0.7311
Total Number Of Cases	4252

Fatality =- 1.429 – 1.465 * Country's HDI + 0.141 * Country's DRI + 0.264 * Population + 0.094 * Population Density

ANOVA					
	d.f.	*SS*	*MS*	*F*	*p-level*
Regression	4	339.487	84.872	158.78	0.000
			4		
Residual	4,271.00	2,282.89	0.535		
Total	4,275.00	2,622.37			
	Coefficients	*Standard Error*	*t Stat*	*p-level*	*H0 (1%) rejected?*
Intercept	-1.429	0.12657	-11.94579	0.000	*Yes*
Country's HDI	-1.465	0.11	-13.276	0.000	*Yes*
Country's DRI	0.141	0.056	2.495	0.013	*No*
Population	0.264	0.016	16.919	0.000	*Yes*
Population Density	0.094	0.025	3.79	0.000	*Yes*

Table **5-5** reveals that the individual factors can explain up to 12.9% of the number of fatalities and ANOVA reveals that this relationship is not accidental because at a 99% confidence level the H0 is rejected for all factors except a country's DRI, which is insignificant. Because the hypothesis about DRI has been rejected, the model is refitted again without DRI. The result shows that the model is improved slightly to explain 13.3% of deaths (Table **5-6**).

Table 5-6 Regression analysis of the relations between fatality and five remaining variables

Regression Statistics					
R	0.366				
R Square	0.134				
Adjusted R Square	0.133				
Standard Error	0.735				
Total Number Of Cases	4252				
Fatality =- 1.412 – 1.709 * Country's HDI + 0.257 * Population + 0.102 * Population Density + 0.316 * Type rank					
ANOVA					
	d.f.	SS	MS	F	p-level
Regression	4	250.749	62.687	115.88	0.000
			3		
Residual	2,994.00	1619.608	.541		
Total	2,998.00	1870.357			
	Coefficients	Standard Error	t Stat	p-level	H0 (1%) rejected?
Intercept	-1.412	0.140	-10.107	0.000	*Yes*
Country's HDI	-1.709	0.133	-12.888	0.000	*Yes*

Population	0.257	0.017	14.680	0.000	*Yes*
Population Density	0.102	0.027	3.722	0.000	*Yes*
Type	0.316	0.056	5.616	0.000	*Yes*

This analysis shows that the number of fatalities can be explained by a combination of variables including type, population, population density, HDI, and an intercept of up to 36.6%. However, the adjusted R-squared in this case is very small and generally is not considered explanatory. The author argues that because of the high number of observations (4252) as was explained before in the law of large numbers and Morrison and Henkel's (1970) assumption, the estimated error basically does not exist and therefore the R-SQUARE which has been calculated based on the error, is not very meaningful either. Therefore, the small R-SQUARE here could not be interpreted,therefore the dependent variable (fatality) may not be explained by the independent variables. To that end, the author asserts that the regression analysis cannot be used for finding a pattern between fatality and independent variables. However, it also means that it cannot be argued that a relationship does not exist. Therefore, the independent variables that were available at the time of the disaster were used to find a pattern between fatality and other variables using techniques other than regression as will be explained later in the chapter.

5.1.3 DEVELOPING DSA TECHNIQUE

To that end, in this research the DSA method has been defined, which shares the principle of disaster severity assessment methods (DeBoer, 1990; Ferro, 2005; Gade-El-Hak, 2007) Rodriguez et al. (2011). The difference between the DSA method and the existing frameworks is that it uses the criteria based on available data, and the socio-economic characteristics of the affected region/population. These criteria are partly borrowed from

Peduzzi et al. (2002) who utilised DRI, and Rodriguez et al. (2011) who utilised HDI in their framework. The results gives rise to the Disaster Severity Assessment (DSA) framework (

Table 5-7).

Table 5-7 Disaster severity assessment framework

Measurement	The categories	Rank
Disaster type	Storm/Flood/Volcano/Cyclone/Flash flood, Tsunami/Earthquake	1/2/3/4/5/6
HDI	Under 0.466/between 0.466 to 0.64/between 0.64 to 0.75/more than 0.759	3/2/1/0
DRI	Under 3.65/between 3.65 to 5.72/between 5.72 to 7.44/between 7.44 to 10.59/More than 10.59	0/1/2/3/4
Population	Under 0.0009/between 0.0009 to 0.009/between 0.009 to 0.09/between 0.09 to 0.9/more than 0.9	0/1/2/3/4
Population Density	Under 0.0009/between 0.0009 to 0.009/between 0.009 to 0.09/between 0.09 to 0.9/more than 0.9	0/1/2/3/4
Total		1-20

In the DSA framework, five measures are presented including type, HDI, DRI, population and population density. The higher the HDI, and the lower the DRI, the more likely a country is to cope with the situation and less likely to need international assistance. Categories for HDI and DRI are identical with the categories defined in their UN-published reports in the World Risk Reports and UNDP report for HDI. To that end

Table 5-7 shows that the HDI can be ranked from 3 if the human development is under 0.466 to 0 more than 0.759. That means in the countries with more than 0.759 the coping capability is high and they are less likely to be devastated as a result of a disaster compared to a country with lower HDI. It is noteworthy to mention, that the formula for calculating HDI was dramatically changed in 2010, which affected the calculation of HDI in 2011. The HDI before this date assumed there is no inequality within a nation, whilst the new HDI added the Inequality-adjust measures, which is closer to the real situation. Thus, the same principle goes for HDI. Meaning for the years before 2011, the HDI for 2011 was used and for the dates after 2011, the data for 2012 were used.

DRI was also launched in 2011, so for the years before that, the DRI for 2011 was used, and for the days after that, the data for 2012 were used. DSA shows that DRI can range from under 3.65 to over 10.59, and can rank from 0 to 4, showing the lowest risk to highest. This means that a country where DRI is ranked as 0, the risk for destruction by disaster is the lowest.

The population of the countries in the database ranges from 5,6000 (Americal Samoa, 2009) to 1,350,000 (China, 2013). This shows a wide and skewed distribution, where a simple percentile is not representative of its distribution. To overcome this obstacle the logarithmic values of the records were calculated and then the percentile was considered for categorising. The categories for population and population density were based on the 20%, 40%, 60%, 80% and 100% of their logarithmic values. For example, the Mongolian population at the time of the 2009 flood was 2,672,223 people, with the logarithmic value equal to 0.00193684505965476. It fits in between 20% and 40% of the logarithmic value of the data range and takes rank (1). The density of the population of that year in that country has also been added to the model because the author believes the population by itself is not an adequate measure of the potential number of people exposed to the disaster. The categories for disaster type are chosen based on a measure introduced in this paper as fatality ratio.

Table **5-7** shows that a disaster can be ranked based on their type from 1 for storm (due to its lowest destructive capability) and earthquake for the highest. These ranks have been defined based on the fatality ratio and the calculations made in chapter 4.

DSA ranking has been calculated for 4252 records (Appendix **6**) and has been used as the basis for defining the disaster scenarios (there are 102 scenarios =17 level of severity * 6 types of disasters) and also consequently for recognising a pattern of fatalities in different disaster scenarios as is explained in the next part.

5.1.4 APPLICATION OF DSA

Theoretically, in the DSA model, there are 102 scenarios, however some theoretical scenarios such as disasters rank 1, and 2 does not exist in the database of real previous disasters. This might be because they have yet to happen, or because their severity has been so low that it did not seem necessary for the humanitarian sources to record them. These scenarios will be explained later in detail.

The DSA ranked in combination with the criteria mentioned earlier to produce a standard diagnosing tool with the capability of comparing the impact of the disaster on the different countries with different coping capabilities. An example of this comparison between some areas affected by the Indian Ocean Tsunami is presented in Table **5-8**.

Table 5-8-An example of the calculated disasters' DSA rank

Country	Killed	Population	DSA rank
Indonesia	165,708	221293797	16
India	16,389	1110626108	14
Sri Lanka	35,399	19435000	13
Thailand	8,345	65087400	12
Malaysia	80	25365089	11
Seychelles	3	82500	7

Table **5-8** shows the DSA calculated for the countries who faced the Indian Ocean Tsunami (2004). It shows that Indonesia had the highest severity (DSA=16) and the Seychelles had the least (DSA=7). The significance of this framework is that, without knowing any data about the disaster itself and in seconds after the disaster strike, the DSA predicted that Indonesia needed more aid than India, even though its population is less than India. In reality weeks after the disaster, the reports showed that Indonesia sustained the highest human and material loss (News.BBC.co.uk, 2005). This indication in the early hours of a disaster is highly valuable because it signals the country most in need for channelling the humanitarian aid.

5.1.5 APPLICATION OF DSA IN PREDICTING

The significance of the DSA rank is that it standardises the various disasters and makes them comparable to each other. When all the disasters have a reference point to be measured against, it is possible to find a pattern between them. This pattern helps to develop a technique to predict the human impact of the disaster before the MIRA report releases (This report is released before 72 hours of the disaster strike). The challenge is to find a way to recognize a pattern in the human impact of the disaster such as number of fatalities, which is unknown until days or even weeks have passed the aftermath. DSA is further used to predict the impact of a disaster as follows.

5.1.5.1 PREDICTION BASED ON REGRESSION ANALYSIS

A regression analysis (Table **5-9**) on 4,252 cases reveals that the DSA rank can explain 6.6 % of the number of fatalities. If it is compared to the R-squared of the criteria used to calculate DSA it shows that regression analysis is not a good predictive method in this data set (Table **5-9**).

Table 5-9 Comparison between the explanation powers of candidate variables

Variables	Adjusted R- square
DSA rank	0.066
HDI, DRI, Population, Population density, Disaster type	0.134
Magnitude, potential affected Population within 100km, HDI, Population, Population density	0.99

Table **5-9** shows that the DSA rank can explain 6.6% of the fatalities whilst all original nine determinants explain up to 99% of the fatalities. When the determinants that were unavailable for all records (magnitude and population within 100km of the disaster) were omitted from the model, the adjusted R-SQUARE increased to 13.4%. However, there are two reasons why the author did not use regression analysis for prediction. From one point of view, the R-SQUARE is too low to be explanatory. In addition, based on the rule of large numbers as explained before, in the specific case of this research R-SQUARE is not meaningful. To that end, the author looked into other mathematical and statistical methods for prediction as is explained in the next part.

5.1.5.2 PREDICTION BASED ON MA RULE

As discussed previously, the result of the regression was rendered inaccurate. Therefore, the author looked into the literature that is similar to this research, in an attempt to predict the variables in the future based on a stream of data. These searches were an attempt to recognise patterns in the stream of data. Some examples of these, are the pattern recognition methods used in the highly volatile environments such as stock markets. In these pattern recognition methods, classification is used for the analysis of data streams, in a sense that the objects are assigned to classes based on their observed features (Hastie et al., 2001; Ross et al., 2012). Its relation to this research is the fact that the fatalities for a particular disaster can be assigned to the classes of fatality based on their DSA rank. In this method, the classification rule(s) need(s) to be learned from the database and the optimal classification rule may change over time due to changes in the stream dynamics, which is called a concept drift (Widmer and Kubat, 1996). This is exactly what happens in disaster situation where due to the chaotic changes in the climatic and socio-economic characteristics of the countries, the trends of disaster impacts changes. When concept drift occurs, it is important to design classifiers, which can adapt to changes in the stream (Ross et al., 2012). One of the commonly used classifiers in pattern recognition, which adapts to changes in the data stream, is Moving Average (MA). It is frequently used for prediction in finance and econometrics for purposes such as predicting security returns (Gencay, 1996; Zhu and Zhou 2009) or detecting changes in stock price trends (Brock, Lakonishok, and LeBaron, 1992; Gencay, 1996; Neely et al., 2013; Marshall, 2014). It has also been used for pattern recognition in consumer product markets (Ross et al., 2012). In this capacity, MA is used for detecting an increase in the mean of a sequence of variables (Roberts, 1959, Ross et al., 2012). For example, imagine the observed data are independent variables of X1, ..., Xn and their moving average is constantly under 10. Then as the stream of data progress, suddenly the MA changes to 11. This is basically an updated estimate on the stream with older data being down weighted (Rosse et al., 2012). One of the applications of MA in finance is the MA rule, which is used to generate a trade (buy/sell) signal by comparing two MA (Neely et al., 2013) when a price moves above/below a MA in a historical period (Gencay, 1996, Marshall, 2014). It is based on the assumption that MA determines the general direction of a market by examining its history (Marshall, 2014). Which is exactly what we need to do in this research (e.g. determining the direction of the disaster impact by examining its history). With one difference in that the disaster database in this research is not necessarily time-series, even though they indirectly depend on time as the socio-economic characteristics of the country or the climate changes during that time. This is similar to the MA rule method, which utilises the past information (prices) to predict incomplete information or private data (Marshall, 2014) which are unobtainable for the market. The author argues that the MA rule in the role of a classifier can be used for this research for two reasons. First, it can deal with the highly volatile environment of the stock market, which resembles the highly chaotic disaster situation. Second, it predicts the unknown or unobtainable information based on historic data, as is the case in disaster response. To adapt the MA rule to the disaster response, this rule can be redefined as "when the fatalities of a new disaster moves below or above MA it signals a change" and this can define a new class. To that end MA is calculated as

Equation 1- Moving Average

$$\boldsymbol{MAF_{i,n}} = \frac{\boldsymbol{F_{i-n+1} + F_{i-n+2} + \cdots + F_i}}{\boldsymbol{n}}$$

where $\boldsymbol{MAF_{i,n}}$ is the moving average of the fatality in disaster *i* with the length of *n*

n is the length of the moving average

Fi is the fatality in disaster *i*

This is because in the prediction of fatalities we are more concerned about the signals that show the rise in fatalities rather than the fall in the disaster impact trend (in this research). A signal is generated when $\boldsymbol{F_i - MAF_{i,n}} > 0$. This means that a signal (change in direction of the pattern) is generated when the fatalities in a disaster *i* become bigger than the moving average (Table **5-10**).

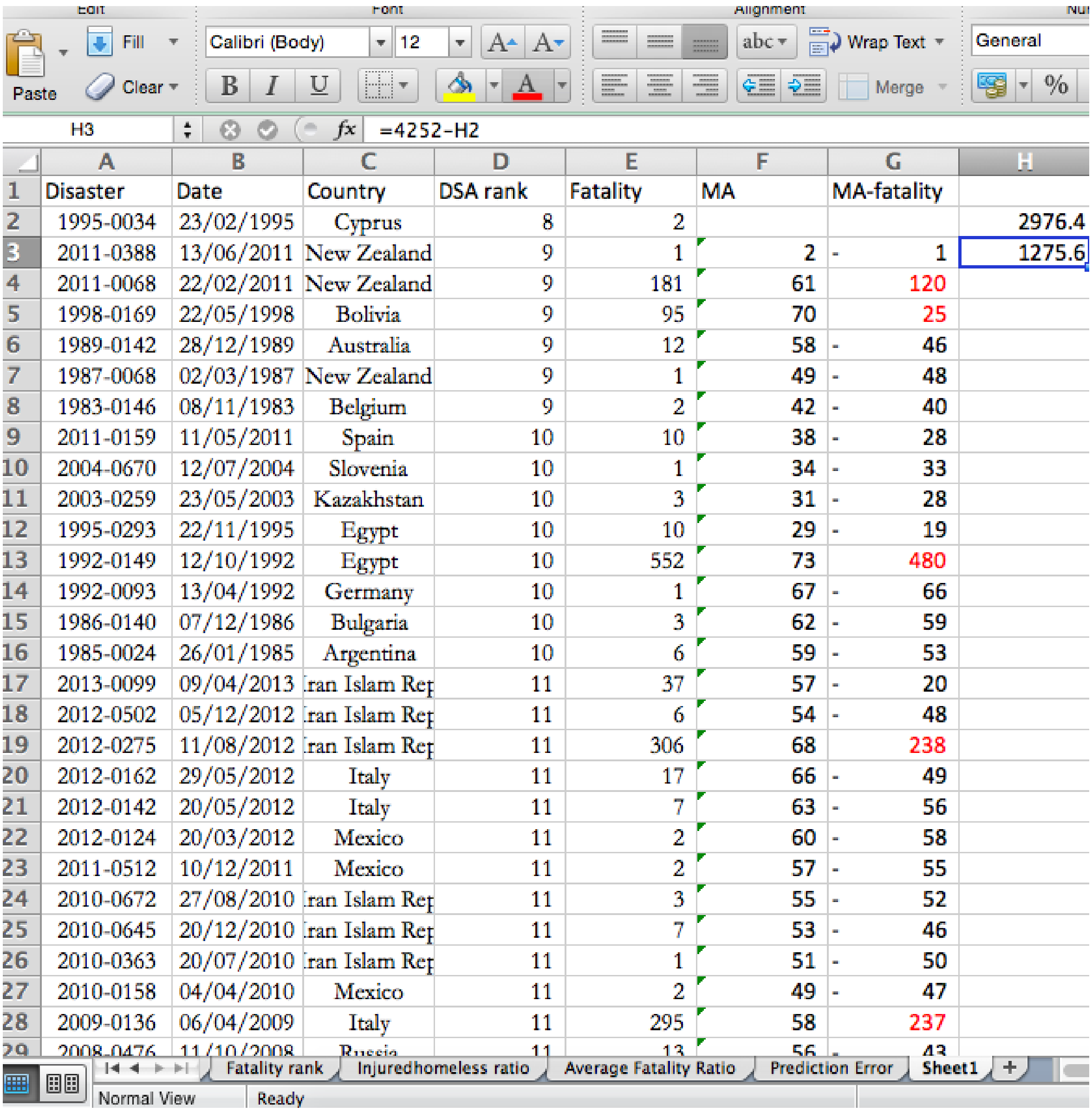
Table 5-10 Examples of changes in MA in different earthquake with different DSA ranks

Date	Country	DSA Rank	Fatality ($\boldsymbol{F_i}$)	$\boldsymbol{MAF_{i,n}}$	$\boldsymbol{F_i - MAF_{i,n}}$
22/02/2011	New Zealand	9	181	61	120
22/05/1998	Bolivia	9	95	70	25
28/12/1989	Australia	9	12	58	-46
02/03/1987	New Zealand	9	1	49	-48

08/11/1983	Belgium	9	2	42	-40
11/05/2011	Spain	10	10	38	-28
12/07/2004	Slovenia	10	1	34	-33
23/05/2003	Kazakhstan	10	3	31	-28
22/11/1995	Egypt	10	10	29	-19
12/10/1992	Egypt	10	552	73	480
13/04/1992	Germany	10	1	67	-66
07/12/1986	Bulgaria	10	3	62	-59
26/01/1985	Argentina	10	6	59	-53
09/04/2013	Iran Islam Rep	11	37	57	-20
05/12/2012	Iran Islam Rep	11	6	54	-48

In Table **5-10**, the first three rows give information about the earthquake, including its geographical and temporal data, in addition to its DSA rank. The fourth column shows the fatalities caused by that particular disaster and the fifth column calculates the MA for that stream of data. The last column simply shows the changes in the moving average. When the new moving average is higher than before, the last column is positive and signals a change in the trend, otherwise it is negative and trends stays the same. A snap shot of the cacluation process is presented in FIGURE **5-2**.

FIGURE 5-2 A SNAP SHOT OF MA RULE CALCULATIONS



H3 =4252-H2

	A	B	C	D	E	F	G	H
1	Disaster	Date	Country	DSA rank	Fatality	MA	MA-fatality	
2	1995-0034	23/02/1995	Cyprus	8	2			2976.4
3	2011-0388	13/06/2011	New Zealand	9	1	2	- 1	1275.6
4	2011-0068	22/02/2011	New Zealand	9	181	61	120	
5	1998-0169	22/05/1998	Bolivia	9	95	70	25	
6	1989-0142	28/12/1989	Australia	9	12	58	- 46	
7	1987-0068	02/03/1987	New Zealand	9	1	49	- 48	
8	1983-0146	08/11/1983	Belgium	9	2	42	- 40	
9	2011-0159	11/05/2011	Spain	10	10	38	- 28	
10	2004-0670	12/07/2004	Slovenia	10	1	34	- 33	
11	2003-0259	23/05/2003	Kazakhstan	10	3	31	- 28	
12	1995-0293	22/11/1995	Egypt	10	10	29	- 19	
13	1992-0149	12/10/1992	Egypt	10	552	73	480	
14	1992-0093	13/04/1992	Germany	10	1	67	- 66	
15	1986-0140	07/12/1986	Bulgaria	10	3	62	- 59	
16	1985-0024	26/01/1985	Argentina	10	6	59	- 53	
17	2013-0099	09/04/2013	Iran Islam Rep	11	37	57	- 20	
18	2012-0502	05/12/2012	Iran Islam Rep	11	6	54	- 48	
19	2012-0275	11/08/2012	Iran Islam Rep	11	306	68	238	
20	2012-0162	29/05/2012	Italy	11	17	66	- 49	
21	2012-0142	20/05/2012	Italy	11	7	63	- 56	
22	2012-0124	20/03/2012	Mexico	11	2	60	- 58	
23	2011-0512	10/12/2011	Mexico	11	2	57	- 55	
24	2010-0672	27/08/2010	Iran Islam Rep	11	3	55	- 52	
25	2010-0645	20/12/2010	Iran Islam Rep	11	7	53	- 46	
26	2010-0363	20/07/2010	Iran Islam Rep	11	1	51	- 50	
27	2010-0158	04/04/2010	Mexico	11	2	49	- 47	
28	2009-0136	06/04/2009	Italy	11	295	58	237	
29	2008-0476	11/10/2008	Russia	11	13	56	- 43	

Fatality rank | Injuredhomeless ratio | Average Fatality Ratio | Prediction Error | Sheet1

As is seen in Table **5-10** and FIGURE **5-2**, the signal in earthquakes appears in DSA rank 9 for the New Zealand earthquake (2011) which signals the changes in the direction of the prediction pattern when the MA jumps 120 points. The next change is signalled in the Bolivian earthquake (1998), with a DSA rank of 10, when the MA jumps 25 points, and the next change is in the Egyptian earthquake (1992) when the MA jumps 480 points. These signals and moving averages were calculated for each disaster type and rank in our 4252-size population. For example, in the category of Tsunami under 11, the number of fatalities is below 400 for 52 records, then there is a signal (jump in MA) to 30,000 fatalities when it comes to the severity 11, which changes the moving average from 50 to 2,120. The calculation was continued and the moving average for each degree of severity (DSA rank) was calculated. The result is shown in Table **5-11**.

Table 5-11 - The average and maximum human loss in previous disaster scenarios

Disaster type	DSA rank	Average Fatality	Max fatality
Earthquake	Under 10	18.6667	95
	11 to 14	1,039.2558	40,000
	15-17	1,632.85	87,476
Tsunami/ Flash flood	Under 11	43.22	412.00
	11 to 14	154.04	8,345.00
	Over 15	401.38	19,846.00
Cyclone	Under 7	15.3889	88
	8 to 10	46.5679	1,833
	11 to 14	82.1111	1,619
General flood /Mudslide	Under 7	17.3103	161
	8 to 9	41.0785	921
	Over 10	77.5862	2,665
Eruption		32.4615	192
Storm	Under 7	14.7500	240
	7 to 11	35.5818	2,000
	Over 11	120.5123	3,682

Table **5-11** shows a set of rule based scenarios where for example "If an earthquake's DSA is under 10, the fatalities are less than 200". However, because the extreme cases in the record show (As a cautionary factor, the outliers were still considered in the data set as an example of extreme cases or worst case scenarios), it is wise to keep a surge capacity as a contingency plan that can support up to 1,000 fatalities as a risk factor based on the extreme cases. Therefore, to be more precise the rules can be defined as "If the DSA is under 10, fatalities are more likely to be under 200, however in rare cases fatalities can be almost, 1000". This concept will be discussed in detail in the future for the needs assessment, and partner configuration process.

The next step is to use the above fatality prediction framework to predict the fatalities for the whole population. A randomly selected sample size of 2,976 (70% of the population) was selected out of 4,252 records of data to develop the framework. The created framework was tested on the remaining records of 1,275 (30% of the population) disasters for prediction. An example of the predicted fatalities and actual fatalities with this method is presented in Table **5-12**.

Table 5-12- Example of predictions

Name	DSA rank	Actual fatality	Predicted Average Fatality	Predicted Max fatality
Flood	4	5	17	161
Tropical cyclone	6	4	15	88
General flood	4	4	17	161
Tsunami	7	3	50	412
Tropical cyclone	9	483	47	1,833
Local storm	4	2	15	240
Earthquake	15	2323	1,632	87,476
Earthquake	15	1	1,632	87,476
Earthquake	12	1186	1,039	40,000

Table **5-12** shows that in a flood rank 4, the actual fatality was 5, which means that it was almost successfully predicted within the range, because based on Table **5-11**, a flood rank 4 is a severe flood with fatalities between 17 to 161. Another example is the tropical cyclone rank 9, where the fatalities were predicted to be between 47 and 1833 and the actual fatalities were 483, which is within the range. The result of the whole prediction set can be found in Appendix **6**.

5.1.5.3 EVALUATING THE RESULT OF FATALITY PREDICTION

At first glance, the DSA can be successfully used for predicting the number of fatalities using the MA rule. However, it fails to predict the fatalities accurately using regression analysis. In order to confirm these predictive capabilities further, the normalised root mean squared error (NRMSE) has been used. This is basically the root square variance (standard deviation), which quantifies the typical size of the error in the predictions, in absolute units (Equation **2**).

Equation 2- Normalised root mean squared error

$$NRMSE= \frac{\sqrt{\frac{\sum_{}^{n}{}_{=1}(Qobserved-Qpredicted)^2}{n}}}{X\ obsereved\ max - X\ obsereved\ min}$$

In Equation **2**, *n* is the number of cases in the fitness group, *i* is the number of observations, *Q-observed* are the actual fatalities, *Q-predicted* are the predicted fatalities and *X-observed max* and *X-observed min* are respectively the maximum and minimum number of actual fatalities in the data set.

NRMSE has been used in similar studies for validating the predictive power of the model (Rogers and Vledder, 2013; Juszczak, 2013). Employing the above measure in calculating the error in the above prediction methods provides a comparison as shown in Table **5-13**.

Table 5-13-The comparison between various prediction methods' error

Prediction error	MA	Multi-Layer NN	Regression
NRMSE	3.10%	30.2%	53,157.48%

Table **5-13** confirms the preliminary observation about the accuracy of the models. It shows that the prediction error for the fatalities using the MA rule is the lowest (3.10%) and it is the most accurate model for predicting fatalities in this research. The prediction error for regression analysis is 53,157%.

However, some might argue that based on the rule of large numbers, the NRMSE for the whole population might not be accurate. To tackle this problem the author also compared the NRMSE based on the type of the disaster to identify if this method is a better predictor for any of them. This is done using a much smaller sample (a random selection of 15 % of the population equal to 663 disasters). This might be more plausible because the sample is not equal to the whole population and therefore the error does not fall below 3% as was explained earlier in the chapter. The result (Table **5-14**) shows that almost in all of the records except for storms, the MA rule is a better predictor than regression analysis.

Table 5-14 Comparing the NRMSE of predicted fatality based on the disaster type

	Fatality average %	Regression analysis %
76 earthquake	8.16	50,445.15
128 Cyclone	7.68	3,063,927.69
71 Flash flood	8.46	55,412.20
64 Storm	12.50	38,451,465.45
320 Flood	8.55	6,257,415.76
4 Volcanic eruption	41.56	24,490,866.49

Table 5-14 shows that the NRMSE calculated based on the average fatalities in the majority of disaster types is less than 10%. The exceptions are volcanic eruptions, which due to the low number of observations (34) cannot be supported by evidence.

For a more sceptical reader, who might not rely on NRMSE at all, the author can still argue that the predictions are a good fit. The reason is that out of 4252 records of prediction, 625 of them (14.6%) were fully within the range (average to maximum fatalities) and the majority of the observed values were under the predicted maximum fatality. In fact only 29 predictions fall further than the predicted values. These are related to the extreme cases of disasters, which are articulated in Table 5-15.

Table 5-15 - The list of inaccurate predictions form the record of 4252 population

End date	Country	Name	Total Rank	Killed	Average predicted fatality	Maximum predicted fatality
04/12/2012	Philippines	Tropical cyclone	13	1,901	82.00	1,619.00
11/03/2011	Japan	Tsunami	14	19,846	154.00	8,345.00
24/10/2010	Indonesia	Volcanic eruption	14	322	120.00	192.00
12/01/2010	Haiti	Earthquake	16	222,570	1,039.00	40,000.00
12/05/2008	China P Rep	Earthquake	15	87,476	1,039.00	40,000.00
19/11/2007	Bangladesh	Tropical cyclone	16	4,234	82.00	1,619.00
08/10/2005	Pakistan	Earthquake	15	73,338	1,039.00	40,000.00
08/10/2005	Pakistan	Earthquake	15	73,338	1,039.00	40,000.00
19/09/2005	United States	Tropical cyclone	9	1,833	82.00	1,619.00
26/12/2004	India	Tsunami	14	16,389	154.00	8,345.00
26/12/2004	India	Tsunami	14	16,389	154.00	8,345.00
26/12/2004	Indonesia	Tsunami	16	165,708	154.00	8,345.00
26/12/2004	Sri Lanka	Tsunami	13	35,399	154.00	8,345.00
18/09/2004	Haiti	Tropical cyclone	14	2,754	82.00	1,619.00
20/12/1999	Venezuela	Flash flood	11	30,000	154.00	8,345.00
30/10/1999	India	Tropical cyclone	13	9,843	82.00	1,619.00
08/11/1998	Honduras	Tropical cyclone	12	14,600	82.00	1,619.00
08/11/1998	Nicaragua	Tropical cyclone	12	3,332	82.00	1,619.00
11/06/1998	India	Tropical cyclone	13	2,871	82.00	1,619.00
30/08/1998	China P Rep	General flood	11	3,656	77.00	2,665.00
04/11/1997	Viet Nam	Tropical cyclone	14	3,682	82.00	1,619.00
26/07/1996	China P Rep	General flood	11	2,775	77.00	2,665.00
08/11/1991	Philippines	Tropical cyclone	13	5,956	82.00	1,619.00
22/06/1991	Philippines	Volcanic eruption	12	640	120.00	192.00
10/05/1991	Bangladesh	Tropical cyclone	15	138,866	82.00	1,619.00
25/08/1986	Cameroon	Volcanic eruption	11	1,746	120.00	192.00
13/11/1985	Colombia	Volcanic eruption	9	21,800	120.00	192.00
28/05/1985	Bangladesh	Tropical cyclone	15	15,000	82.00	1,619.00
10/06/1980	China P Rep	Flood	10	6,200	77.00	2,665.00

Table **5-15** shows the occasions where the predicted value falls below the actual observed value. There were 29 occasions of failure out of 4,252 records. This shows a 1% (0.68%) failure in prediction. In other words in 99.3% of the time the decision maker can be sure that if s/he follows the maximum number of predictions in the PREDIS model there is a minimal chance of not being able to meet the requirements of the affected population.

5.1.6 PREDICTING THE HOMELESS AND INJURED

The numbers of injured, and homeless in previous disasters are not clearly stated in our database, for each record. Instead, in the EM_DAT database the accumulated numbers of these data are available based on region, disaster type, etc. Therefore, the accumulated number is used to recognise a pattern between the number of fatalities, injured and homeless. The data about the human impact are gathered based on the country (Table **5-16**).

Table 5-16 Example of the accumulated number of human impact

Disaster subtype	Country	Occurrence	Deaths	Injured	Homeless	Casualty ratio	Homeless ratio
Earthquake	Afghanistan	0.0340	0.3870	0.0340	0.3870	0.0340	0.3870
Flash flood	India	0.0054	6.8216	0.0054	6.8216	0.0054	6.8216
General flood	Congo	0.4279	324.5192	0.4279	324.5192	0.4279	324.5192
Local storm	Norway	12.5000	0.0000	12.5000	0.0000	12.5000	0.0000

Table **5-16** shows that during the past 30 years, 28 earthquakes have happened Afghanistan, causing 9,277 deaths, 8,826 injuries and 100,535 homeless. Therefore, it is possible to say that in general during this time, the injured/fatality ratio in Afghanistan earthquakes is 0.95 and homeless ratio is 10.8. The ratios can be calculated based on Equation **3** and Equation **4**.

Equation 3- Injured ratio

$$\boldsymbol{Injured\ ratio} = \frac{i_d^c}{f_d^c} \div o_d^c$$

Equation 4-Homeless ratio

$$\boldsymbol{Homeless\ ratio} = \frac{\boldsymbol{h_d^c}}{\boldsymbol{f_d^c}} \div \boldsymbol{o_d^{\square}}$$

Where

$\boldsymbol{i_d^c}$ Represents the accumulated number of injured in country (c) for the disaster type (d)

$\boldsymbol{h_d^c}$ Represents the accumulated number of homeless in country (c) for the disaster type (d)

f_d^c Represents the number of fatality in country (c) for the disaster type (d)

o_d^c Represents the number of occurrences of the disaster type (d) in country (c) since 1980

Using the above methods, we can predict and compare the number of injured and homeless. The calculation of these ratios for all countries is exhibited in Appendix 8. An example of these ratios is presented in Table 5-17.

Table 5-17 Examples of calculated injured and homeless ratio

Disaster subtype	Country	Occurrence	Fatality	Injured	Homeless	Injured ratio	Homeless ratio
Earthquake	Afghanistan	28	9277	8826	100535	0.0340	0.3870
Storm	Afghanistan	2	63	5	0	0.0397	0.0000
Tsunami	Afghanistan	17	838	356	4910	0.0250	0.3447
Flood	Afghanistan	45	2584	634	48285	0.0055	0.4152
Earthquake	Brazil	2	2	6	8000	1.5000	2000.0000
Cyclone	Brazil	1	3	0	1600	0.0000	533.3333
Tsunami	Brazil	5	145	276	0	0.3807	0.0000
Flood	Brazil	63	3146	2203	490345	0.0111	2.4740
Storm	Brazil	9	68	1180	8190	1.9281	13.3824
Flash flood	France	9	87	5	0	0.0064	0.0000
General flood	France	11	73	25	0	0.0311	0.0000
Cyclone	France	8	84	82	0	0.1220	0.0000
Local storm	France	15	91	153	800	0.1121	0.5861
Earthquake	Philippines	17	2884	5151	3995	0.1051	0.0815
Tsunami	Philippines	36	1139	262	6978	0.0064	0.1702
Flood	Philippines	53	786	333	85762	0.0080	2.0587

Storm	Philippines	4	9	4	4600	0.1111	127.7778
Cyclone	Philippines	201	35547	59509	4899284	0.0083	0.6857

5.1.6.1 EVALUATING THE INJURED/HOMELESS PREDICTION

In order to evaluate how the above predictions could be trusted, they need to be compared with the actual observed data. However, as mentioned above the actual observed data are published in the accumulated form as the total affected population. Total affected population is defined as the sum of injured and homeless (Equation **5**).

Equation 5 Total affected population

$$Total\ affected\ \approx homeless + injured$$

Where the injured population is defined as the people suffering from physical injuries, trauma or an illness requiring medical treatment as a direct result of a disaster. In addition, the homeless population is defined as the people needing immediate assistance for shelter. Therefore the predicted results were accumulated to make them comparable to the accumulated observed data (Table **5-18**).

Table 5-18 Example of predictions

	Observed data		Predicted data			
Disasters	Killed	Injured+homeless	Fatality		Injured + Homeless	
			Average	Maximum	Average	Max
			Using Table **5-12**		Using Equation **3** and Equation **4**	
Nigeria Flood Rank 12	19	81,506	77	2,665	151	5,194
Philippines Cyclone	6	262,884	82	1,619	160	3,155

	Observed data		Predicted data			
Disasters	Killed	Injured+homeless	Fatality		Injured + Homeless	
			Average	Maximum	Average	Max
			Using Table **5-12**		Using Equation **3** and Equation **4**	
Rank 13						
China earthquake Rank 15	3	538,050	1,039	40,000	2,025	77,945
Indonesia earthquake Rank 17	48	55,935	1,039	40,000	2,025	77,945
China storm Rank 10	11	50,000	120	3,682	234	7,175

Table **5-18** shows an example for the data predicted by this method. It also indicates that in some scenarios the equations resulting from the regression are better predictors (such as Philippines cyclone rank 13) whilst in others the equations resulting from ratios are better predictors (Nigeria flood rank 12). NRMSE for these predictors is compared in Table **5-19**.

Table 5-19 NRMSE for overall predictions

Fatality		Accumulated number of injured and homeless	
Average	Maximum	Average	Max
Using Table 5-11		Using Equation **3** and Equation **4**	
0.0171	0.0448	0.0241	0.0241

Table **5-19** shows that the average fatality (1.7% error for 4252 observations) is a better predictor than maximum fatality (4.4% error for 4252 observations). In addition, the error in the prediction of the accumulated number of injured and homeless is 2.41%. For a better picture, the number of successful and failed predictions is presented in Table **5-20**. The success of the prediction here is defined as the percentage (out of 4252) of accurately predicted values within the range.

Table 5-20 the number of success and failures of prediction (n=4252)

	Within average range	Within maximum range	Out of the range	Success percentage
Fatality	631	3589	35	99%
Injured+homeless Using Equation **3** and Equation **4**	649	1,179	2,424	43%

Table **5-20** shows that on average the fatalities predicted for 3,589 occasions is within the range of actual observation. On the other hand, for 631 occasions, the observations conform to the maximum fatalities predicted. Finally, for 35 occasions the prediction was totally inaccurate. Overall, the observed fatalities conform to the prediction range in 99% of cases. The framework predicts the homeless+injured correctly in 43% of the cases. Although, the injured+homeless (affected) population, is accurately calculated in fewer than half of the instances, just under 3% of NRMSE predictions in total show that the inaccurate predictions are not far from the average, and therefore their inaccuracy is not dramatic.

The discrepancies between the observed and predicted numbers of injured+homeless can be explained in two ways. First, that there is no evidence whether the accumulated number of affected population counts the injured people who are also homeless twice. This might cause the discrepancies. The author asked for a non-accumulated account of homeless and injured from Munich RE, and CRED databases (on 21 June, 2014), however these data were not available from any of the two sources. In addition, it should be taken into account that the observations are reported months after a disaster strike and do not necessarily comply with the early hours of the disaster. For example, some of the injured people in early hours of the disaster might unfortunately be reported as dead later on, when medical help fails to save them. Some of homeless people in early hours after the disaster might be relocated to other cities with their family and friends later on, when the panic of the early hours' has passed. Furthermore, some disasters such as floods could last months, whilst some disasters such as earthquakes happen in a matter of seconds. When a disaster lasts a long time, the number of affected people in the population could increase over the following weeks, and therefore there is a huge discrepancy between the reported number in the early hours after the disaster strike and the numbers reported months later. Therefore, this model should be applied taking into consideration of all the above limitations.

5.1.7 SUMMARY OF THE PREDICTION STUDY

The first study (The PREDICTION of human impact) in the research is an attempt to recognise a pattern in the human impact of historical disasters, in order to use the results to predict the approximate number of fatalities, injured and homeless for future disasters. The predictions are based on the severity calculated in DSA technique.

The model could predict the fatalities within the range in 99% of cases. The homeless and injured are correctly predicted in 43% of the times. The root-squared error for the above prediction (when normalised based on the maximum and minimum of the data) is less than 3%. The results of this model will be further used in combination in the ESTIMATION framework (developed in the second study in this chapter), to assess the needs in early hours of the disaster strike. The final goal is to use the assessed needs to configure a virtual organisation of potential humanitarian partners based on their capabilities and resources.

5.2 THE SECOND STUDY- ESTIMATION

Based on the definition of the United Nations Disaster Relief Organisation (UNDRO), the overall aim of the disaster relief operation is to ensure the survival of the maximum possible number of victims and keep them in the best possible health. In addition, the aim is also to re-establish self-sufficiency and essential services as quickly as possible for all population groups, with especial attention to the most vulnerable, to repair, or replace damaged infrastructure and regenerate viable economic activities. All these activities are required to benefit the affected community’s development and reduce the vulnerability of the population to future hazards (UNDRO, 1992). In the days and weeks immediately following a sudden onset disaster, the basic relief supplies and services are provided free of charge to save and preserve human lives and enable families to meet their basic needs for medical and health care, shelter, clothing, water, and food. Currently, in sudden onset disasters there are typically many different needs occurring during the first three days before the preliminary MIRA report is released. In fact, some activities need to be done so quickly that the action has to precede the detailed assessments. This may be possible by using strategies determined during preparedness planning on the basis of previous emergencies (UNDRO, 1992). Therefore, a solution is required to address the needs in the early hours after the disaster onset before any official report is released. For example, during the recent UK flood in 2014, even though good warning systems were in place (Maps.environment-agency.gov.uk, 2014) the lack of decision-making tools, led to the death of seven people and the destruction of 1,700 homes. It is critical to understand that these negative effects happened in the presence of the exact knowledge of where and when the storm/flood would strike, in a developed country with a sufficient budget for prevention.

The present research is based on the assumption that the scenario-based decision-making would help in decreasing the negative effects of the disasters, by pre-designing the possible outcomes and providing a hypothetical response for each DSA rank disaster, should it then ever happen. To that end, the present model is an attempt to provide a framework to estimate the disaster needs hours after the disaster strike, based on the evidence drawn from previous disasters.

5.2.1.1 DATA COLLECTION FOR THE SECOND STUDY (ESTIMATION)

This second study (ESTIMATIOPN) uses meta-analysis to generate a framework in order to draw a minimum standard of needs for each unit of human impact based. The research is based on the existing records of standards, which are published by various humanitarian organisations. The internal reports and working papers include ECB (2009), GHC. (2012), Hartwell-Naguib, and Roberts (2014), IFRC (2000,2009), Morgan et al. (2006), OCHA (n.d, 2012a, 2012b, 2012c, 2013a, 2013b, 2013c, 2014), OXFAM (2012), Patrice (2008), FEMA (2007), AHRMM.org (n.d), Sphere project (2011), UNDRO (1982,1992), UNHCR (2010), UNICEF (2005), VOAD (2011) and WHO (2011,2013). The list of these publishers and the title of reports are articulated in Table **5-21**.

Table 5-21- The data source for the second study

Title of the report	Publisher
A Case Study: Joint Needs Assessment after the West Sumatra Earthquake	ECB (2009)
Global Health Cluster Partners' survey	GHC. (2012),
Winter floods 2013/14	Hartwell-naguib and Roberts (2014)
Disaster emergency needs assessment	IFRC (2000)
IFRC shelter kit	IFRC (2009a)
World disaster report	IFRC (2009b)
Mass fatality management following the South Asian tsunami	Morgan et al. (2006)

Title of the report	Publisher
disaster: case studies in Thailand, Indonesia, and Sri Lanka	
Multi/cluster-sector initial and rapid assessment (MIRA) Community level assessment	OCHA (n.d)
MIRA report - Pakistan Floods	OCHA (2012a)
MIRA report -In preparedness for disasters and emergencies A joint initiative between Government and the humanitarian community	OCHA (2012b)
MIRA Report Pakistan Floods	OCHA (2012c)
The Philippines second-phase MIRA report for tropical storm WASHI (Sending)	OCHA (2012d)
Inter-agency initial rapid needs assessment preliminary report, (October).	OCHA (2013a)
Joint Rapid Damage and Needs Assessment Report,	OCHA (2013b)
MIRA report Philippines typhoon Haiyan.	OCHA (2013c)
Central African republic multi-cluster/sector initial rapid assessment	OCHA (2014)
Sylhet phase 1 rapid emergency assessment	OXFAM (2012)
Emergency Relief Logistics : Evaluation of Disaster Response Models Based on Asian Tsunami Logistics Response.	Patrice (2008)
Target capabilities list	U.S department of homeland security (2007)
Medical-surgical supply formulary by disaster scenario.	AHRMM and HIDA and HIGPA (n.d)
The sphere project	Sphere project (2011)
Shelter after disaster	UNDRO (1982)
An Overview of Disaster Management.	UNDRO (1992)
Shelter project	UNHCR (2010)
Emergency handbook	UNICEF (2005)
National voluntary organisations active in disaster	VOAD (2011)
Management of dead bodies after disasters	WHO (2011)
Classification and minimum standards for foreign medical teams in sudden onset	WHO (2013)

The data sources in Table **5-21** were used to consolidate a needs assessment for disaster situations. These data enable the setting of priorities for each group of needs based on the type of disaster, and the socio-economic factors of the affected area. The detailed procedure for the analysis of this data is elaborated in the following section.

5.2.2 ESTIMATING THE LEVEL OF THE NEEDS

By identifying the focus of the study as key life-saving activities, the evidence of previous practices can be used to define the minimum standards of needs in each humanitarian cluster. The clusters are defined in the sphere project as Shelter, Nutrition, WASH (water and sanitation), and Health. The result would give rise to designing scenarios based on the assumption that the disaster's needs could be estimated based on the evidence of previous experiences, economic aspects of the affected region and the type of the disaster. The process to define the minimum standard of needs is described in detail as follows. The author also further explains how two more determinants including the type of disaster, and the economic characteristics of the affected region could affect the priorities of where the humanitarian clusters are the most needed in the response operations.

5.2.3 EVIDENCE FROM PREVIOUS EXPERIENCE IN ESTIMATING NEEDS

Evidence from previous practices is used to define the minimum standard of needs in each humanitarian cluster. The significance of this method is that by knowing the number of people affected in the population, and based on the minimum standard, the required units of aid can be calculated. This data is obtained from three major sources. The data on the four clusters are obtained from Sphere project (2011), which is a combination of humanitarian non-governmental organisations (NGOs) and the International Red Cross and Red Crescent Movement. In addition to that the data on the Shelter and food cluster are obtained from IFRC (2009) and the data concerning the Health cluster are obtained from WHO (2013). Minimum standard needs are defined by these organisations based on the right of the affected population to live with dignity and therefore getting assistance. To that end, all possible actions should lead to alleviating the human suffering as a result of the disaster (Sphere project, 2011). The minimum standards are evidence-based, and represent sector-wide consensus on best practice in a humanitarian response. The result of this accumulation is articulated in Table **5-22**.

Table 5-22- Minimum standards for key life-saving activities

Humanitarian Cluster	Requirements	Specification	Amount required
WASH	Hygiene equipment needs	10–20 litre capacity water container for transportation	One per household
		10–20 litre capacity water container for storage	One per household
		250g bathing soap	One per person per month
		200g laundry soap	One per person per month
		Acceptable material for menstrual hygiene, e.g. washable cotton cloth	One per person per month
		Blanket-	One per person per month
		75ml/100g toothpaste	One per person per month
		One toothbrush -	One per person per month
		250ml shampoo	One per person per month
		250ml lotion for infants and children up to 2 years of age	One per person per month
		One disposable razor	One per person per month
		Underwear for women and girls of menstrual age	One per person
		One hairbrush and/or comb	One per person
		Nail clippers	One per household
		Nappies (diapers) and potties (dependent on household need).	
	Water requirements	Survival needs: water intake (drinking and food)	2.5–3 litres per day
		Basic hygiene practices	2–6 litres per day
		Basic cooking needs	3–6 litres per day
		Total basic water needs	7.5–15 litres per day
		Health centres and hospitals	5 litres per outpatient 40–60 litres per inpatient per day Additional quantities may be needed for laundry equipment, flushing toilets, etc.
		Cholera centres	60 litres per patient per day 15 litres per career per day
		Therapeutic feeding centres	30 litres per inpatient per day 15 litres per career per day
		Reception/transit centres	15 litres per person per day if stay is more than one day 3 litres per person per day if stay is limited to day-time

Humanitarian Cluster	Requirements	Specification	Amount required
		Schools	3 litres per pupil per day for drinking and hand washing (Use for toilets not included: see Public toilets below)
		Mosques	2–5 litres per person per day for washing and drinking
		Public toilets	1–2 litres per user per day for hand washing 2–8 litres per cubicle per day for toilet cleaning
		All flushing toilets	20–40 litres per user per day for conventional flushing toilets connected to a sewer 3–5 litres per user per day for pour-flush toilets
		Anal washing	1–2 litres per person per day
		Livestock	20–30 litres per large or medium animal per day 5 litres per small animal per day
	Hygiene facilities (water point is accessible for approximately eight hours a day only and water supply is constant during that time)	Water tap	Every 250 people (based on a flow of 7.5 litres/minute)
		Hand Pump	Every 500 people (based on a flow of 17 litres/minute)
		Open well	Every 400 people (based on a flow of 12.5 litres/minute)
		Toilets	1 toilet to 50 stalls, individual, outpatients
		Demarcated defecation area (e.g. with sheeted-off segments)	
		Trench latrines,	
		Simple pit latrines,	
		Ventilated improved pit (VIP) latrines	
		Ecological sanitation with urine diversion,	
		Septic tanks	
Nutrition and food	Food (Example food parcel)	SALT, iodised edible	1
	2,100 kcals per person per day	SUGAR, white	1
	10-12% of total energy provided by protein	YEAST, dried, package 11 gr	8
	17% of total energy provided by fat (Sphere project)	FISH, canned, sardines, veg oil, 150g	2
		PASTA, durum wheat meal	1
		RICE, white, long grain, irri6/2	1
		OIL, rapeseed	1
		BEANS, white, small	1
Shelter and settlement	Shelter	Tarpaulin (4mX6m)	2
		Rope (30 m)	30 m

Humanitarian Cluster	Requirements	Specification	Amount required
		Saw	1
		Roding, small and largo Nail (1/2 kg each)	1/2 kg each
		Shovel	1
		Hoes	1
		Machete	1
		Shear	1
		Wire (1.5 mm diameter)	25 m
		Claw hammer	1
		Woven Sack	1
Health cluster	MT Foreign Medical Team Classification	Type 1: Outpatient Emergency Care	100 outpatients/day for 2 weeks, 3 doctors (emergency and primary care) with doctor: nurse ratio = 1:3 skilled in emergency, trauma care and maternal and child health, knowledge of endemic disease management
		Type 2: Inpatient Surgical Emergency Care	1 operating theatre with 1 operating room: 20 inpatient beds; 7 major or 15 minor operations per day.
	IFRC Emergency Response Units (ERU)	Basic Healthcare	200 people/day 10–20 beds for overnight observation Supplies to treat 30,000 pops. for a month, Per 12–14 hr. shift: 1 Doctor, 1 Pharmacist/Nurse, 1 Curative/Community Health Nurse, 1 Midwife/ Nurse, 2 General Technicians
		Rapid Deployment Emergency Hospital	20–70 inpatient beds, essential medical and surgical care 300 people/day, 50–100 OPD/day, First level mobile hospital or field hospital, its services include an OT, intensive observation, anaesthesia, x-ray, laboratory, maternal-child health, pharmacy, sterilization, and outpatient clinics. Provides safe medical and surgical interventions, while offering limited medical/surgical care
	EU European Civil Protection Modules	Advanced Medical Post	Medical team per 12 hour shift: triage: 1 nurse and or 1 doctor; intensive care: 1 doctor and 1 nurse; serious but not life threatening injuries: 1 doctor and 2 nurses; evacuation: 1 nurse; specialised support personnel: 4
		Advanced Medical Post with Surgery	Triage at least 20 patients per hour, Surgical team capable of damage control surgery for 12 patients per 24 hours, working in 2 shifts, Supplies to treat 100 patients with minor injuries per 24 hours, Amen as above + Surgery: 3 surgeons, 2 operating nurses, 1 anaesthetist, 1 anaesthetist nurse

Humanitarian Cluster	Requirements	Specification	Amount required
	UN	Level 1: Primary health and emergency care	Treatment of 20 OPD/day, holding capacity of 5 patients for up to, 2 medical officers, 6 paramedic/nurses, 3 support staff
		Level 2: Basic field hospital	3–4 operations per day, hospitalisation of 10–20 sick/ wounded for up to 7 days, 40 OPD per day, 1 OT, 1 or 2 ward with, 2 surgeons, 1 anaesthetist, 1 internist, 1 general physician, 1 dentist, 1 hygiene officer, 1 pharmacist, 1 head nurse, 2 intensive care nurses, 2 OT assistants, 10 nurses/paramedics, 1 radiology assistant, 1 laboratory technician, 1 dental assistant, 2 ambulance drivers, 8 support staff
	Civil Protection Proposal, Region Marche, ANA, CRI, GCU	Advanced Medical Post (AMP)	Medical supplies to treat 150 patients per 24 hours (50 Red/ Yellow tag and 100 Green as per the Medical Triage colour tags, START), 6 Doctors (2 surgeons, 2 emergency, 2 anaesthetist, 2 emergency medical first aid); 10 critical care nurses, 4 logisticians, 1 medical team leader and 1 deputy medical leader or nurse with proven experience and training
		Advanced Medical Post Surgery (AMP-S)	Medical supplies to treat 150 patients per 24 hours (50 Red/ Yellow tag and 100 Green as per the Medical Triage colour tags, START), 12 doctors (6 surgeons, 4 anaesthetists, 2 emergency room), 14 nurses (10 critical care and 4 peril operative), 4 logisticians, 1 team leader, 1 deputy leader, 1 radiology technologist

Table **5-22** articulates the generic minimum standard of requirements for each life-saving /mass care cluster. However, there is no agreement between the humanitarian organisations over the health cluster and as is presented above, each of them define their own requirements and minimum standards. Therefore, the average of health cluster requirements is calculated and shown in Appendix 9.

In this calculation, the text has been used to draw the number, and then the number obtained from different resources has been used to provide an average number. For example, IFRC (Cited by WHO, p.48-49) states: “200 people/day 10–20 beds for overnight observation, Supplies to treat 30,000 pops. For a month, Per 12–14 hr. shift: 1 Doctor, 1 Pharmacist/Nurse, 1 Curative/Community Health Nurse, 1 Midwife/ Nurse, 2 General Technicians” from this statement, we can conclude that for 200 people/ day we require a maximum of 20 beds, 1 doctor, 3 nurses and 2 other medical personnel and 1000 units of treatment supplies (30,000 for 30 days). The same principle has been applied to the all five sources indicated in Table **5-22**. The result is exhibited in Table **5-23**.

Table 5-23 the average medical resources required for the health cluster

Required resource/day	Patient	Doctors	Nurse	Other personnel	Bed
Average	133	4	7	6	20

Table **5-23** shows that for an average of 133 patients per day the health cluster requires 4 doctors, 7 nurses, 6 other medical personnel and 20 beds for overnight observations. However, for simplification of the calculation, if we calculate the requirements for 100 patients instead of 133, the health cluster in

Table **5-24** is obtained.

Table 5-24 the minimum requirements for life saving activities

Humanitarian cluster	Specification	Per person	Per household
WASH	Transportation containers (10-20 lit)	N/a	1
	Storage containers (10-20 lit)	N/a	1

Humanitarian cluster	Specification	Per person	Per household
	250g bathing soap, 200g laundry soap	1	
	Acceptable material for menstrual hygiene	1	
	Blankets	1	
	75ml/100g toothpaste	1	
	250ml shampoo, 250 lotion	1	
	250ml lotion for children up to 2 years old	1	
	Underwear for women and girls	1	
	Hairbrush, razor, toothbrush	1	
	Nail clippers	1/ household	1
	Total basic water needs	7.5–15liter/ day	
	Patients	60 litter /day	
	Livestock	30 lit/animal	
	Water taps	1/250	
	Hand pumps	1/500	
	Open wells	1/400	
	Toilets	1/50 people	
	Trench latrines,		1
Nutrition and food	Salt, iodised edible	1	1
	Sugar, white	1	1
	Yeast, dried, packets 11 gr	8	1
	Fish, canned, sardines, veg oil, 150g	2	1
	Pasta, durum wheat meal	1	1
	Rice, white, long grain, irri6/2	1	1
	Oil, rapeseed	1	1
	Beans, white, small	1	1
Shelter and settlement	Tarpaulins (4mx6m)	2	1
	Ropes (30 m)	30 m	1
	Saws	1	1
	Roding, small and largo nail (1/2 kg each)	1/2 kg each	1
	Shovels	1	1
	Hoe	1	1
	Machete	1	1
	Shear	1	1
	Wire (1.5 mm diameter)	25 m	1
	Claw hammer	1	1
	Woven sack	1	1
Health cluster	Doctors	4.57	100
	Nurses	5.9	100
	Others	6	100

Table **5-24** specifically provides numbers as the minimum requirements for each cluster based on the person or household needs. A household in disaster literature is defined as a group of people who eat from a common pot, and share a common stake interpreting, and improving their socio-economic status from one generation to the next (Baas et al., 2008). There are many options available for food as long as it provides the 2,100 kcal required for each person (Sphere, 2011) and complies with the cultural norms of the affected society. However, the food packages in

Table 5-24 are one of the examples provided by the Red Cross (Procurement.ifrc.org, 2014).

5.2.4 EFFECT OF THE DISASTER TYPE ON THE NEEDS OF THE DISASTER

The demand also may vary based on the type of the disaster. As was explained in the previous sections the type of disaster influences the extent of the effects. For example, Table 5-25 shows that the number of deaths in an earthquake is higher than other disasters. In addition, the Sphere project (2011) provides a set of linguistic measures for the effects of different disasters. For example, based on these data, it is unlikely that the affected population suffers from the food scarcity in the aftermath of earthquakes or winds, whilst it is quite probable in after a tsunami. By adding to the effects of the different types of disasters, Table 5-25 is created. The following ranks are applied to the situation If Small = 1, Rare = 2, Few = 3, Moderate = 4, Many = 5, Common = 6, High = 7. It is noteworthy that the ranks need to be considered as priorities and not the actual numbers. Therefore, we started the priorities from 1 for simplification. It is possible to start it from any other number such as

0.57, 0.58, 0.59, or even start from 1000, 1100, 1200, as long as it makes it possible to show higher priorities.

Table 5-25 Weights of the effects in various types of disasters

Effect	Task group and Cluster	Complex emergencies	Earthquakes	High winds	Floods	Flash floods/ tsunamis	Eruptions
Deaths	Fatalit management	5	5	3	3	5	Varies*
Severe injuries	Health Cluster	Varies*	5	4	3	3	4
Increased risk of communicable diseases	WASH cluster	7	Varies*	1	Varies*	Varies*	5
Food scarcity	Food cluster	6	2	2	Varies*	6	5
Major population displacements	Shelter cluster	6	2	2	6	Varies*	6

Adapted from the Sphere project (2011) and author

* The word varies is transferred from its orginial table in Spehere project and implies that the different records and scholars never agreed on a number on the specific disasters.

Table **5-25** explains that for example when earthquakes strike, fatality management, and medical mass care require the highest level of resources followed by food and shelter. Another conclusion is that after floods, the most required resources are shelter whilst after a flash flood and tsunami the highest priority is a food cluster. Because the data set was void of information about the eruptions, the definition from IFRC (2014b) was used for this disaster type. It suggests that in eruptions the population displacement is often a consequence. Therefore, in general the eruption response prioritises temporary shelter materials; safe water and basic sanitation; food supplies; and the short-term provision of basic health services and supplies.

Using this data, decision makers could know roughly that when an earthquake strikes fatality management needs more participants than food supplying partners. However, this rule does not indicate prioritising people, and in applying this rule, it should always be taken into consideration that the live population has a higher priority. As a result, the mass care needs of the live population should be dealt with first before fatality management is put into place.

5.2.5 EFFECTS OF THE ECONOMIC CHARACTERISTICS ON ESTIMATING THE NEEDS

In addition, the economic characteristics of the affected regions could influence the priority of needs. Typically, the events that result in the highest numbers of fatalities are located in regions with increased risk and vulnerable populations. This is often compounded by limited infrastructure and poor integration of the health system into disaster preparedness, response, and recovery (WHO, 2011). For example, more foreign medical care is required for a disaster, which strikes in Sub-Saharan Africa, than a disaster in the Middle East, due to the capabilities of medical infrastructure. Therefore, different levels of attention are required for various clusters in different types of disasters. For example after an earthquake, the food cluster in Japan and Philippines require different levels of attention, due to their different level of infrastructures. To address this issue the indicators of economic development have been included in the model. These indicators were drawn from the medical capabilities, and sanitation/nourishments are annually calculated by the United Nation (World Risk Report, 2011, 2012). These indicators include the ‘coping capability’ indicators, which were calculated, based on (amongst other criteria) the number of physicians and hospital beds /per

10000 inhabitants by UN. This indicator has been added to the model by the author or as a weight, to signal the health cluster capability of the country. Furthermore, a 'susceptibility' indicator based on (amongst other criteria) access to the water sanitation and nourishment calculated by the UN is has also been added to the model by the author as a weight to signal the food and WASH cluster. These weights signal the criticality of the situation on a specific cluster in a particular country. It also provides an opportunity for comparison between different disasters. This is depicted in Table **5-26** in detail.

Table 5-26 Comparing two different disasters with their weights

Year	Origin	Cluster weight	Lack of Coping capability	Susceptibility	Cluster weights for earthquake	Cluster priority
2005	Pakistan	FOOD		38.84	5	=38.84 x 5=194.2
		WASH		38.84	5	=38.84 x 5=194.2
		Health	87.39		Varies	87.39
		Shelter			2	=100 x 2=200
		Other (Fatality)			2	=100 x2=200
2011	New Zealand	FOOD		16.19	5	=16.19 x5=80.95
		WASH		16.19	5	=16.19x 5=80.95
		Health	39.79		Varies	39.79
		Shelter			2	=100 x2=200
		Other (Fatality)			2	=100 x2=200

Table **5-26** shows that by comparing the 2005 disaster in Pakistan with the 2011 disaster in New Zealand, without knowing any other information, including what type of disaster it is, we can tentatively claim that the health cluster (in terms of hospital beds and physicians) in Pakistan is almost two times less likely to cope with the disaster effects than New Zealand. The reason is that Pakistan's lack of coping capability is 87.39% compared to New Zealand's lack of coping capability, which is 39.79%.

The same principle can be used to interpret the susceptibility based on access to food and nourishment. It shows that Pakistan (38.84% susceptibility) is three times more likely to suffer from mal-nourishment, lack of water, and sanitation than New Zealand (with 16.19% susceptibility) would, after a typical disaster.

It is noteworthy, that these numbers should also be considered as probabilities or risk factors and not actual numbers. Furthermore, they are only to be used for signalling what areas of needs should be prioritised.

Combining the criteria affecting the needs in a disaster situation (including evidence from previous experiences, the type of disaster, and economic aspects of the affected region), the priority for each task can be calculated. Assume we have to choose between disaster response clusters in both Pakistan and New Zealand at the same time. Based on the data in Table **5-26** the priorities would be shelter and fatality management in both counties because their priorities are higher than other clusters and equal to 200. The next priority is food and WASH for Pakistan (both 194 points for priority), followed by the Health cluster for Pakistan (87.39 points for priority), then food and WASH for New Zealand (80.95 points for priority), followed by the Health cluster for New Zealand (30.79). This data is obtainable and calculated without knowing any other information about the disaster including its type. This principle feeds into the priority settings in the AHP model (as described in chapter 4) when it comes to the partner selection decision-making.

5.2.6 SUMMARY OF THE SECOND STUDY (ESTIMATION)

The results of this study have led to a list of minimum standard requirements for a disaster situation. This list contains four main clusters for the key lifesaving activities including WASH, health, nutrition, and shelter cluster. Fatality management has been omitted from the list because it is not a “life-saving” activity and here the focus is life saving. In addition, the type of the disaster and the coping capabilities of the affected country would affect the priority of the needs required. This study addresses the above issues and provides a framework for needs estimation and prioritisation of the needs. This framework combined with the human impact predictive framework provided in the first study gives rise to the total needs estimation in each disaster. The third study (OPTIMISATION) discusses the process of partner selection in a disaster situation based on the above frameworks (PREDICTION including DSA, ESTIMATION including priority settings).

5.3 THIRD STUDY- OPTIMISATION

As was explained in earlier chapters, the objective of the current research is to reduce the proliferation problem in a disaster-affected area by suggesting a method to configure the suitable partners. It was suggested in previous chapters that disaster response networks need to be redesigned into a pool of potential partners within a long-term virtual breeding environment (Ermilova and Afsarmanesh, 2007; Romero at al., 2010). This VBE can quickly generate a VO when the disaster strikes. In this part, we explain how to use the predictions generated in the first and second study (PREDICTION and ESTIMATION) described earlier in the chapter to identify the number of people in need of help, the number of units of resources required in each cluster and their priorities. In order to configure a VO after a disaster strikes a combination of Analytical hierarchy process (AHP) is applied within the concept of Multi-attribute utility theory. The reasoning behind the selection of these methods and theories are explained in the third and fourth chapter. This procedure is explained as follows.

5.3.1 HYPOTHETICAL MODEL

CHAPTER 5 PREDICTION, ESTIMATION & OPTIMISATION

A Virtual Breeding Environment (VBE) should be created based on the competency or value system (Ermilova and Afsarmanesh, 2007; Romero at al., 2010). To that end, a database needs to be created containing the required data for each potential partner. For example, their type, their sector, their size, and resources they are able to provide, and how fast they can mobilise their resources, etc. However, the process of obtaining this data is very time consuming, and requires the commitment of the whole humanitarian community. Besides, it is out of scope of one single PhD research study. To that end, the list of partners used in this research is a hypothetical list of partners (Appendix 10) generated from randomly allocated weights. Obviously, for the actual decision-making in the disaster situation, the list of real partners needs to be replaced. The beauty of this model is that every decision maker can provide their own criteria and create their favourite VO based on their preferences, budgets, limitations, ethical grounds, etc.

For example out of one VBE with *n* number of potential humanitarian partners, at the time of a flood in Thailand, various VOs could be created. For example, the Thai government could create a VO with 1000 partners, whilst the embassy of Denmark in Thailand, who is interested in assisting, creates their own version of the VO with 200 partners. Furthermore, a religious NGO that needs a few partners to channel their own operation, might choose a VO of five partners with whom they intend to work. Various studies exist instructing the theoretical and practical methods for creating a VO (Lau et al., 2001; Afsarmanesh and Camarinha-Matos, 2003; Bernus and Tolle, 2003; Fischer et al., 2004; Ip et al., 2004; Jarimo et al., 2007; Wu and Su, 2009; Romero et al., 2010). However, the challenge facing a disaster response network is from a political and moral point of view as it is impossible to choose a limited number of partners through optimisation and prevent the rest of the volunteer organisations and individuals who are eager to help from doing so.

The final decision on choosing partners belongs to the decision makers, who will do so based on their own agenda. For example, even if a military organisation ranked the first in our model but a government prefers to avoid military partners, they can simply ignore this option in their VO or adjust the criteria used in analysis to get different options. To that end, the present research provides a technique for using the estimated needs and the priorities to rank the partners in VBE by Analytical Hierarchy Process (AHP). In addition, these ranked partners could be further shortlisted based on the optimisation of Utility theory, which will be explained later.

5.3.2 RANKING THE POTENTIAL PARTNERS IN A VBE

The present research suggests ranking potential partners in a VBE in two steps; the first step predicts the needs required for a particular disaster, based on minimum standard requirement for disaster. The second step is to organise the decision maker's preferences and the disaster needs priorities into an AHP model. Combining the priorities obtained from the AHP model with the resources available to each partner, it is possible to rank the partners based on their utility (value) for the decision maker.

The employment of AHP for partner selection in collaborative networks is common practice (Liberatore, 1987; Lin and Chen, 2004; Li et al., 2008; Erkayman et al., 2012; Kara et al., 2012,). In addition, Multi-attribute utility theory, which is the standard decision-making methodology, is used under uncertain conditions, in various studies for partner selection (Lavra, 2008; Chen et al., 2007; Wu et al., 2009; Zhao and Fu, 2011; Kannan et al., 2013). Some scholars have also used linear programming (LP) for partner selection before

(Ghoudsypour and O'Brien, 1998; Ustun and Demirtas, 2008; Jarimo et al., 2009; Serban et al., 2008; Rolland et al., 2010). In the present study, the partners are ranked based on their utility for decision makers using AHP. The reason for using these decision-making techniques has been explained in the third and fourth chapter where the various decision techniques (including mathematical programing, evolutionary algorithms, and MCDM) were explored. The suitable techniques are adapted based on their compliance with the specific situation in the disaster situation including the lack of time, uncertainty of information, and subjective criteria of the decision maker.

5.3.3 ESTIMATING THE REQUIRED RESOURCES _An example

The first step is to estimate the required resources in order to rank the partners accordingly. Imagine the following case study of a flood in Afghanistan (Table **5-27**).

Table 5-27- The estimated human impact for Afghanistan Flood 2013

Disaster	Actual impact	Predicted impact	Calculated based on
Afghanistan Flood 2013 Rank 11	Fatality: 63 Total affected: 2,221	Fatality: 77-2,665 Injured: 1-15 Homeless: 32-1,107	Table **5-11** Equation **3** Equation **4**

Table **5-27** is built upon the principle described in the first and second study (PREDICTION and ESTIMATION). It shows that based on the PREDIS model 77 fatalities are expected and in extreme cases this number can go up to 2,665.

Based on this estimation the injured can be calculated using Equation **3**. The Afghanistan injured ratio based on Appendix **8** is 0.0055, therefore because $Injured = Fatality * \ injured\ ratio$ the range of injured can be predicted as:

Lower range of expected injured = 77 * 0.0055 = 0.41 ≈ 1

Higher range of expected injured = 2665 * 0.005 = 14.5 ≈ 15

Based on this estimation the homeless can be calculated using Equation **4**. Afghanistan homeless ratio based on Appendix **8** is 0.4152, therefore because $homeless = Fatality * homeless\ ratio$ the range of homeless can be predicted as:

Lower range of expected homeless = 77 * 0.4152 = 31.97 ≈ 32

Higher range of expected homeless = 2665 * 0.4152 = 1106.63 ≈1107

This shows that the predicted total affected (injured+homeless) is between 33 to 1,122. The actual affected population in Afghanistan flood was 2,221.

Using this prediction there are four prominent categories of needs, one for each humanitarian cluster including health, nutrition, WASH and shelter. In the second study, 43 needs were described in total, which are distributed between four humanitarian clusters. Multiplying the needs for one person in the estimated number of people in need of that particular help, would provide the total number of needs required for that cluster as is presented in Table **5-28**.

Table 5-28 Need estimation for Afghanistan flood 2013

Humanitarian Cluster	Specification	Needs for Lower level impact		Needs for Higher level impact	
WASH	Transportation container (10-20 lit)	6.4	221.4	17.4	597.2
	Storage containers (10-20 lit)	6.4	221.4	17.4	597.2
	250g bathing soap	32	1107	87	2986
	200g laundry soap	32	1107	87	2986
	Acceptable material for menstrual hygiene	32	1107	87	2986
	Blankets	32	1107	87	2986
	75ml/100g toothpaste	32	1107	87	2986

Humanitarian Cluster	Specification	Needs for Lower level impact		Needs for Higher level impact	
	One toothbrushes -	32	1107	87	2986
	250ml shampoo	32	1107	87	2986
	250ml lotion for children up to 2 years	32	1107	87	2986
	One disposable razor	32	1107	87	2986
	Underwear for women and girls of menstrual age	32	1107	87	2986
	One hairbrush and/or comb	32	1107	87	2986
	Nail clippers	6.4	221.4	17.4	597.2
	Nappies (diapers) and potties	Dependent on household need.			
	Total basic water needs	480	16605	1305	44790
	Patients	1920	66420	5220	179160
	Water tap	0.128	4.428	0.348	11.944
	Hand Pump	0.064	2.214	0.174	5.972
	Open well	0.08	2.7675	0.2175	7.465
	Toilets	0.64	22.14	1.74	59.72
	Trench latrines,	6.4	221.4	17.4	597.2
Nutrition and food	SALT, iodised edible	6.4	221.4	17.4	597.2
	SUGAR, white	6.4	221.4	17.4	597.2
	YEAST, dried, package 11 gr	51.2	1771.2	139.2	4777.6
	FISH, canned, sardines, veg oil, 150g	12.8	442.8	34.8	1194.4
	PASTA, durum wheat meal	6.4	221.4	17.4	597.2
	RICE, white, long grain, irri6/2	6.4	221.4	17.4	597.2
	OIL, rapeseed	6.4	221.4	17.4	597.2
	BEANS, white, small	6.4	221.4	17.4	597.2
Shelter and settlement	Tarpaulins (4mX6m)	12.8	442.8	34.8	1194.4
	Ropes (30 m)	192	6642	522	17916
	Saws	32	1107	87	2986
	Roding, small and largo Nail (1/2 kg each)	3.2	110.7	8.7	298.6
	Shovels	32	1107	87	2986
	Hoes	32	1107	87	2986
	Machetes	32	1107	87	2986
	Shears	32	1107	87	2986
	Wire (1.5 mm diameter) meters	160	5535	435	14930
	Claw hammers	32	1107	87	2986
	Woven Sack	32	1107	87	2986
Health cluster	Doctors	0.0341	0.5115	2.1824	75.2587
	Nurses	0.0585	0.8775	3.744	129.1095
	Others	0.0481	0.7215	3.0784	106.1567

Table **5-28** is calculated by combining the impacts predicted in Table **5-27**. For example, WASH and Nutrition are required for both injured and homeless population, whilst the health cluster and shelter are just required for the injured

So the need for each cluster is calculated as:

[Total unit required for a cluster = Minimum standard requirement * Predicted impact]

For example in the health cluster the need for a doctor in Afghanistan flood 2013, based on a lower level of prediction, 1 doctor is needed, however the decision maker needs to be prepared in case the higher prediction happens where 75 doctors are needed. Another example is that 16,605 litre water/day are needed, however if higher prediction happens it might need up to 44,790 litre water/day. At this point, which level of impact prediction we choose, depends on the decision maker's preference. If a decision maker is a risk taker or has limited resources s/he might consider the lower level for partner selection. However, a more cautious decision maker with more resources might go for the unlikely event of extreme cases in the higher level.

5.3.4 BUILDING AHP MODEL BASED ON DECISION MAKERS' PREFERENCES

Imagine that there are two different kinds of decision makers the first being ones who would like to avoid military partners as much as they can and they prefer NGO based or governmental organisations to international organisations and volunteers. This decision maker also prefers to use big partners which have expanded internationally (such as the UN) and who have had experience in more than 10 previous disasters. They also prefer organisations that can extend their surge capacity more than 30% if necessary. The preferences of this hypothetical decision maker are entered and can be quantified using AHP. The result of the AHP weights is presented in Table **5-29**.

Table 5-29- AHP priorities for decision maker 1

Level 1	P (L1)	Level 2	P (L2)	Level 3	P (L3)	Total Priority
Type	0.1667	Governmental	0.1098			0.0000
		NGO	0.1108			0.0076
		Military	0.0001			0.0001
		Volunteers	0.0016			0.0008
		International	0.0006			0.0108
Size	0.1667	Under 50 employees	0.0800			0.0109
		Under 100 employees	0.0800			0.0009
		Under 500 employees	0.0800			0.0009
		Over 500 employees	0.7500			0.0050
International Expansion	0.1667	Yes	0.9000			0.1500
		No	0.0000			0.0067
Experience	0.1667	Under 10 times	0.0800			0.0109
		Under 300 times	0.0800			0.0009
		Under 500 times	0.0811			0.0019
		Over 1000 times	0.7500			0.0050
Surge capacity	0.1667	None	0.0833			0.0139
		Under 10%	0.0833			0.0139
		Under 30%	0.0833			0.0139
		Over 30%	0.7500			0.1250
Humanitarian Cluster	0.1667	WASH cluster	0.0794	N1	0.0500	0.0007
				N2	0.0500	0.0007
				N3	0.0500	0.0007
0.3789				N4	0.0500	0.0007
				N5	0.0500	0.0007
				N6	0.0500	0.0007
				N7	0.0500	0.0007
				N8	0.0500	0.0007
				N9	0.0500	0.0007
				N10	0.0500	0.0007
				N11	0.0500	0.0007
				N12	0.0500	0.0007
				N13	0.0500	0.0007
				N14	0.0500	0.0007
				N16	0.0500	0.0007
				N17	0.0500	0.0007
				N18	0.0500	0.0007
				N19	0.0500	0.0007
				N20	0.0500	0.0007
				N21	0.0500	0.0007
		Nutrition Cluster	0.0794	N22	0.1250	0.0017
				N23	0.1250	0.0017
				N24	0.1250	0.0017
				N25	0.1250	0.0017
				N26	0.1250	0.0017
				N27	0.1250	0.0017
				N28	0.1250	0.0017
				N29	0.1250	0.0017

Level 1	P (L1)	Level 2	P (L2)	Level 3	P (L3)	Total Priority
		Shelter Cluster	0.6554	N30	0.0909	0.0099
				N31	0.0909	0.0099
				N32	0.0909	0.0099
				N33	0.0909	0.0099
				N34	0.0909	0.0099
				N35	0.0909	0.0099
				N36	0.0909	0.0099
				N37	0.0909	0.0099
				N38	0.0909	0.0099
				N39	0.0909	0.0099
				N40	0.0909	0.0099
		Health Cluster	0.1857	N41	0.3333	0.0103
				N42	0.3333	0.0103
				N43	0.3333	0.0103

The other decision maker is an organisation that welcomes donations, and help from everyone and assumes that all needs are equally important. The AHPs calculated for this decision maker are presented in Table **5-30**.

Table 5-30 AHP built upon preferences of decision maker 2

Level 1	P (L1)	Level 2	P (L2)	Level 3	P (L3)	Total Priorities
Type	0.16666	Governmental	0.2			0.033333
		NGO	0.2			0.033333
		Military	0.2			0.033333
		Volunteers	0.2			0.033333
		International	0.2			0.033333
Size	0.16666	Under 50 employees	0.25			0.041667
		Under 100 employees	0.25			0.041667
		Under 500 employees	0.25			0.041667
		Over 500 employees	0.25			0.041667
International Expansion	0.16666	Yes	0.5			0.083333
		No	0.5			0.083333
Experience	0.16666	Under 10 times	0.25			0.041667
		Under 300 times	0.25			0.041667
		Under 500 times	0.25			0.041667
		Over 1000 times	0.25			0.041667
Surge capacity	0.166667	None	0.25			0.041667
		Under 10%	0.25			0.041667
		Under 30%	0.25			0.041667
		Over 30%	0.25			0.041667
Humanitarian Cluster	0.16666	WASH cluster	0.25	N1	0.06666	0.002778
				N2	0.06666	0.002778
				N3	0.06666	0.002778
				N4	0.06666	0.002778
				N5	0.06666	0.002778
				N6	0.06666	0.002778
				N7	0.06666	0.002778
				N8	0.06666	0.002778

Level 1	P (L1)	Level 2	P (L2)	Level 3	P (L3)	Total Priorities
				N9	0.06666	0.002778
				N10	0.06666	0.002778
				N11	0.06666	0.002778
				N12	0.06666	0.002778
				N13	0.06666	0.002778
				N14	0.06666	0.002778
				N15	0.06666	0.002778
				N16	0.06666	0.002778
				N17	0.06666	0.002778
				N18	0.06666	0.002778
				N19	0.06666	0.002778
				N20	0.06666	0.002778
				N21	0.06666	0.002778
		Nutrition Cluster	0.25	N22	0.125	0.005208
				N23	0.125	0.005208
				N24	0.125	0.005208
				N25	0.125	0.005208
				N26	0.125	0.005208
				N27	0.125	0.005208
				N28	0.125	0.005208
				N29	0.125	0.005208
		Shelter Cluster	0.25	N30	0.090909	0.003788
				N31	0.090909	0.003788
				N32	0.090909	0.003788
				N33	0.090909	0.003788
				N34	0.090909	0.003788
				N35	0.090909	0.003788
				N36	0.090909	0.003788
				N37	0.090909	0.003788
				N38	0.090909	0.003788
				N39	0.090909	0.003788
				N40	0.090909	0.003788
		Health Cluster	0.25	N41	0.333333	0.013889
				N42	0.333333	0.013889
				N43	0.333333	0.013889

These two sets of preferences could give rise to the decision-making using the principle of Utility theory as was explained before in the research design chapter. The details of this process are further elaborated as follows.

5.3.5 CALCULATING MAUT FOR EACH PARTNER

Based on the above priorities calculated by AHP, the MAUT produced for each partners can be calculated as follows.

$U_i(x)$ is a single utility function or preference function associated with candidate i, which represents the utility values the decision maker attaches to each candidate and is obtained by using the AHP process. To aggregate the scores of each attribute in the MAUT process, the linear additive utility form is the frequently simplified assessment procedure as given by Equation **6**.

Equation 6– Utility function of the candidates based on the available resources

$$V(y_i) = \sum_{i=1}^{n} \boldsymbol{r_{ij}} . \boldsymbol{u_i(x)}$$

Where r_{ij} represents the resource j available to candidate i. The $V(y_i)$ will be the value of the candidate i because of the resource j they have available. $V(y_i)$ for each partner is calculated in appendix 5, for two scenarios for each partner. An example of the chosen partners is presented in Table **5-31**.

Table 5-31 An example of the result of a resource-based decision-making

		Total resources	Available	Required resources	Utility	Partner 1	Partner 2,	Partner 300
Transportation container	N1	20.5065		221.4	0.0007	0.1324	0.1185	0.1087
Storage containers	N2	108.1904		221.4	0.0007	0.1467	0.0147	0.2348
250g bathing soap	N3	108.2418		1107	0.0007	0.4328	0.0000	0.1687
Toilets	N4	21.0673		1107	0.0007	0.0411	0.0675	0.0675
Menstrual hygiene	N5	21.6865		1107	0.0007	0.0103	0.1203	0.1423
Blankets	N6	22.3937		1107	0.0007	0.0235	0.0895	0.0205
Toothpaste	N7	21.4371		1107	0.0007	0.0015	0.0029	0.0719
Toothbrushes -	N8	23.0159		1107	0.0007	0.0851	0.0279	0.0088
Shampoo	N9	20.4921		1107	0.0007	0.0646	0.0176	0.0866
Lotion for infants	N10	22.1516		1107	0.0007	0.1086	0.1247	0.0088
One disposable	N11	21.4752		1107	0.0007	0.0426	0.1042	0.1233

		Total resources	Available	Required resources	Utility	Partner 1	Partner 2,	Partner 300
razor								
Underwear	N12	23.9417		1107	0.0007	0.0895	0.0455	0.0954
One hairbrush and/or comb	N13	21.9697		1107	0.0007	0.0528	0.0719	0.0514
Nail clippers	N14	21.8596		221.4	0.0007	0.0249	0.1115	0.1159
Total basic water needs	N16	110.1125		16605	0.0007	0.3155	0.2421	0.6309
Water for Patients	N17	1.4999		66420	0.0007	0.0005	0.0062	0.0054
Water tap	N18	28.3749		4.428	0.0007	0.0661	0.0717	0.1170
FISH, canned, sardines, veg oil, 150g	N19	5573.1222		2.214	0.0007	23.1098	30.4462	12.8388
200g laundry soap	N20	10930.5533		2.7675	0.0007	16.1402	42.5513	56.4905
Water for patients	N21	9245.0809		22.14	0.0007	31.6934	39.9102	42.8448
RICE, white, long grain, irri6/2	N22	1074.4942		221.4	0.0017	3.0079	6.2360	5.0621
SALT, iodised edible	N23	107.6255		221.4	0.0017	0.0440	0.6309	0.5722
SUGAR, white	N24	108.7846		221.4	0.0017	0.7116	0.5282	0.3815
YEAST, dried, package 11 gr	N25	115.2554		1771.2	0.0017	0.4915	0.6750	0.2714
Hand Pump	N26	13.7558		442.8	0.0017	0.0128	0.0394	0.0174
PASTA, durum wheat meal	N27	54.8545		221.4	0.0017	0.1541	0.2788	0.0734
Trench latrine	N28	113.1792		221.4	0.0017	0.2494	0.5722	0.7043
OIL, rapeseed	N29	114.2209		221.4	0.0017	0.2421	0.6016	0.4915
BEANS, white, small	N30	114.9399		221.4	0.0099	0.2201	0.6750	0.3301
Tarpaulins	N31	109.3716		442.8	0.0099	0.6823	0.4989	0.1687
Ropes (30 m)	N32	55.6266		6642	0.0099	0.1264	0.3233	0.1003
Saws	N33	3.6562		1107	0.0099	0.0107	0.0193	0.0111
Roding	N34	21.3230		110.7	0.0099	0.0862	0.1442	0.1011
Shovels	N35	232.2283		1107	0.0099	0.4906	0.8176	1.4122
Hoes	N36	22.5286		1107	0.0099	0.0535	0.0416	0.1100
Machetes	N37	21.6605		1107	0.0099	0.0981	0.0937	0.0937

		Total resources	Available	Required resources	Utility	Partner 1	Partner 2,	Partner 300
Shears	N38	21.8671		1107	0.0099	0.1249	0.0491	0.1189
Wire (1.5 mm diameter) meter	N39	23.0296		5535	0.0099	0.0372	0.0550	0.0074
Claw hammer	N40	4.4225		1107	0.0099	0.0196	0.0134	0.0268
Woven Sack	N41	22.9344		1107	0.0103	0.1085	0.1204	0.1219
Doctors	N42	0.0372		0.5115	0.0103	0.0112	0.0133	0.0038
Nurses	N43	32.3130		0.8775	0.0103	25.3685	30.1751	2.6237
Other staff	N44	43.02		0.7215	0.0103	25.3685	30.1751	2.6237

Table **5-31** shows that for example, in this scenario the total available resources N42=Doctors, are 0.0372 for each 100 people. However, the number of required doctors is more than 0.515 for 100 people. Although due to the scarcity of this resource, and the fact that the decision maker needs all the helps s/he could get, it is still possible to rank the partners based on the decision maker's preference. As you see, the utility of the doctors that partner 2 can provide (0.133) is greater than the number doctors that partner 1 can provide (0.0112). In addition, as can be seen in this case the utility of the health cluster (0.103) is more than the other clusters. The utility of the shelter cluster is 0.099, whilst the utility of the nutrition is 0.017 and WASH is 0.0007. Therefore, if a decision maker has to decide which need to prioritise, s/he should first consider choosing the partners who can provide the doctors, nurses, etcetera, rather than the partners who can provide, food, water, or shelter.

5.3.6 RANKING PARTNERS BASED ON THEIR MAUT

To get a better understanding about how the partners in different scenarios for different decision makers may differ, an example is presented in Table **5-32**.

Table 5-32 An example of the partners ranked based on MAUT

Scenario1, Decision maker 2		Scenario 2, Decision maker 2		Scenario 1, Decision maker 1		Scenario 2, Decision maker 1	
Partner	MAUT rank	Partner	MAUT rank	Partner	MAUT rank	Partner	MAUT rank
Partner 153	1.132760063	Partner 211	9.145249183	Partner 41	0.633921855	Partner 284	1.729714766
Partner 41	1.093820533	Partner 156	9.040183495	Partner 2	0.627643924	Partner 211	1.718802656
Partner 103	1.091799078	Partner 284	9.018674079	Partner 34	0.626474797	Partner 2	1.701977126
Partner 49	1.087162067	Partner 57	8.936134347	Partner 147	0.624785592	Partner 29	1.691246352
Partner 34	1.074618739	Partner 238	8.92111127	Partner 188	0.624258076	Partner 238	1.690334061
Partner 89	1.05959383	Partner 43	8.817729406	Partner 89	0.619832194	Partner 59	1.683764898
Partner 147	1.045494784	Partner 29	8.813827688	Partner 128	0.618894191	Partner 221	1.665627368
Partner 47	1.042460701	Partner 132	8.809210021	Partner 49	0.61852712	Partner 158	1.657652558
Partner 258	1.041537843	Partner 158	8.665270492	Partner 103	0.614151747	Partner 16	1.635904691
Partner 2	1.038680511	Partner 47	8.611684923	Partner 64	0.605774312	Partner 57	1.628361564

Table **5-32** shows the ranking of the partners based on the highest utility to the lowest for this example. Based on the preferences of decision maker 2 and the needs predicted in scenario 1, Partner 153 with a total utility of 1.13 is the best option followed by partner 41 with 1.09 utility, etc.

5.3.7 SUMMARY OF THE THIRD STUDY

The present research has been designed to provide a technique for partner ranking/selection in disaster response VO. The model in previous chapters was created to diagnose the severity of the disaster and predict their human impact. This model enables the estimation of required needs for each cluster. The third study provides a technique for ranking the partners based on their utility for decision maker and the priorities of the tasks. It also provides a technique for partner selection based on optimisation of the decision makers' utility. In other words the importance of the partner and the product/service they can offer, in the eye of the decision maker is the basis for partner selection in a humanitarian VO in this research. The combination of the first, second and third study is called PREDIS model or Predictive Disaster response model. To further verify this model, the fourth study was designed which will be explained as follows.

5.4 SUMMARY OF THE CHAPTER

The aim of this chapter was to outline the PREDIS model developed in the process of three separate yet interrelated studies following a soft-system approach to the complex problems as defined in the methodology chapter.

The first study (PREDICTION) provides a predictive model for the human impact of the disaster including the fatality, injured and homeless people. This part investigates the 4252 previous disasters in different types and locations and concludes that there is a relationship between the criteria defined in the methodology chapter and the impact of the disaster. At this stage, a disaster severity assessment technique (DSA) was developed which is capable of classifying the disasters based on their type and socio-economical characteristics of the affected country. The findings in the next part confirm that DSA and the criteria used to calculate it could explain the disaster fatalities to some extent. Using this principle the study used methods, including regression analysis and comparison of averages to predict the fatality based on DSA. The result shows that the latter, which is the simplest way amongst the three, could predict the fatalities within the range with a 3.10% error. In addition, by comparing the accumulated data about the injured and homeless population (the only available data) the predictions could be made with 42.93% accuracy. The discrepancies between the observed and predicted injured+homeless could be because the accumulated number of affected people in the population counts the injured people who are also homeless twice. This could not be confirmed because none of the above sources can provide the separate number for injured and homeless. Furthermore, because the observations are reported months after a disaster, the number of affected people in the population could develop over the weeks, and therefore there is a huge discrepancy between the numbers reported in the early hours after the disaster strike with the reported number months later. Therefore, this model should be applied in consideration of all the above limitations.

The second study (ESTIMATION) provides a technique for estimating the needs in a disaster situation. In this stage, various humanitarian guidelines and official reports were used to argue that it is possible to outline a minimum standard requirements for each disaster type and based on the affected countries' socio-economic characteristics. This gives a list of requirements in disaster situation for each injured, homeless with priorities. This list however is a suggestion and each decision maker may alter the requirements based on their own preferences/specialty.

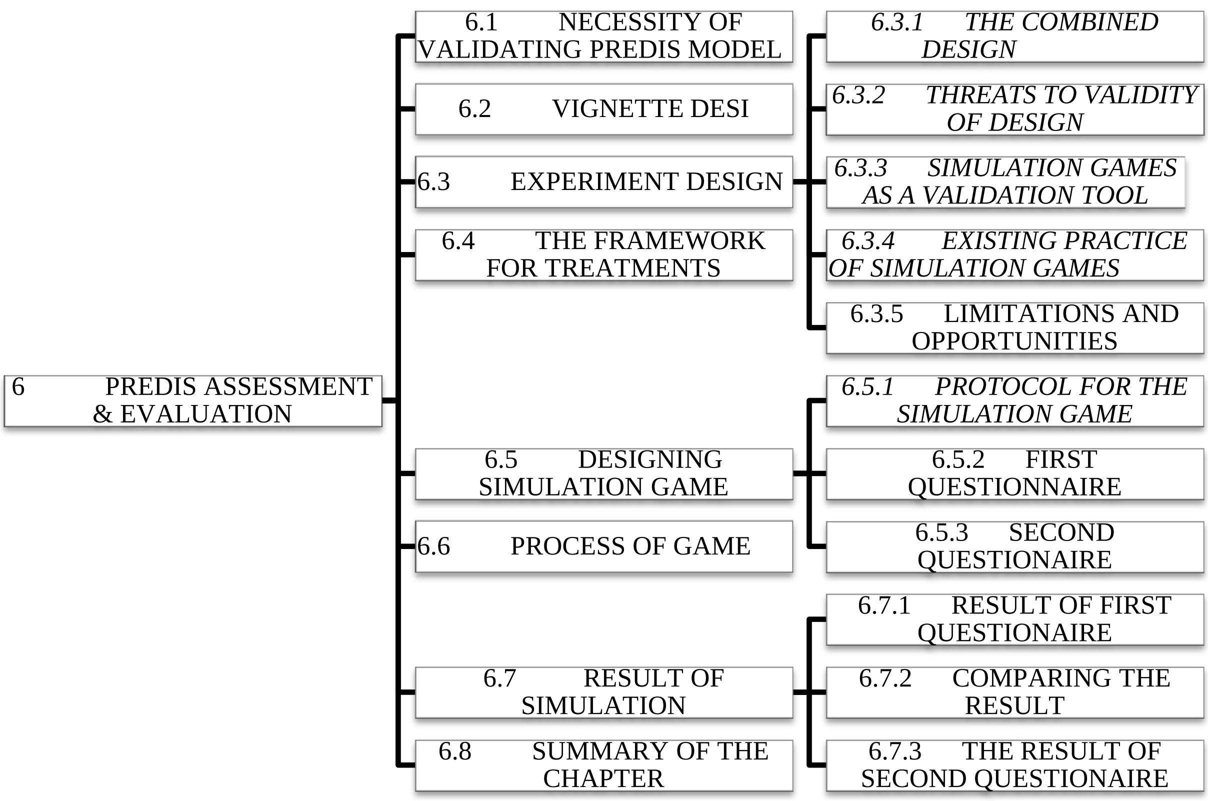
The third study (OPTIMISATION) suggests a hypothetical list of partners with their hypothetical resources, which can then be optimised, based on the principles of Utility theory and Resource-dependency theory as explained in the research design chapter.

CHAPTER 6 PREDIS ASSESSMENT & EVALUATION

6 PREDIS ASSESSMENT & EVALUATION

The decision support model presented in this research - PREDIS (PREdictive model for DISaster response partner selection), needs to be further validated. As was mentioned before, the data on the human impact of the disaster are unavailable up to 72-hours after the disaster strike when the MIRA report is released. Therefore, any decision made about the needs and the partners during this time are based on limited data including the decision maker's experiences, restrictions, and preferences. The author believes that the present model can be used to bridge the 72-hour gap before receiving data from the MIRA report. FIGURE 6-1 outlines the components of this process.

FIGURE 6-1- OUTLINE OF THE CHAPTER 6



CHAPTER 6 PREDIS ASSESSMENT & EVALUATION

6.1 NECESSITY OF VALIDATING THE PREDIS MODEL

For any modelling paradigm, validation is vital for the acceptance by the users of the model (Anand, 2013). It is often too costly and time consuming to determine whether a model is absolutely valid over the complete domain of its intended applicability. Instead, tests and evaluations are conducted until sufficient confidence is obtained that a model can be considered valid for its intended application (Sargent, 2011).

Many scholars have addressed the validation issue of decision support models. For example, Olewnik (2005) believes that a decision support tool should first be logical. It means it should originate from a model that makes sense with the intuition. Testing for this can be accomplished by using test cases for which the results are intuitive and checking if the model results agree with intuition. Second, it should use meaningful, reliable information. The information that is incorporated into the model should be meaningful in the sense that it provides insight into interdependencies among system variables, and is reliable in the sense that the information originates from appropriate sources in order to reduce the level of uncertainty with which it is associated. Finally, it should have an unbiased designer, meaning the preferences of the designer utilising the methodology should not be set by the method itself to avoid influencing the outcome of the decision.

Yeh and Chang (2008) suggest measuring the inconsistency of decision-making models from the decision maker's view with a series of interviews. The same principle is suggested by Saaty (2005) who puts forward a sensitivity analysis to examine the effect of varying the influences on the stability of the outcome of a decision-making tool. A series of interviews, which ask about what the decision makers like, and what they think about the durability and satisfaction they would get from their decision when it is influenced and altered by resistance and opposition from many directions. He also tests the validity of a widely used decision-making tool (AHP in particular) by providing evidence from various practices exhibiting its strengths and weaknesses.

Another suggestion provided by Mohan et al. (2014) is to measure the retest reliability (similar result in the repetition of the test), internal consistency (Comparing the result of the decision tool with the real practice), known-groups performance (comparing performance of various groups of decision makers), and criterion validity (correlation between the result in decision tool and practice) of the decision-making tool. Zebda (2003) identifies predictive validity as the most widespread validity tests. Predictive validity type one examines the validity of the model in predicting the behaviour of decision makers, whilst predictive validity type two investigates how the solution obtained by the model corresponds to the behaviour of the system. Because the study of decision makers' behaviour is out with the scope of this research, the latter is the subject of the current study. Zebda (2013) denotes that it is possible to validate the solution derived from a model empirically by comparing it to the real performance of the system.

TABLE 6-1 EMPIRICAL VALIDATION OF A MODEL

Compliance of the behaviour Of the model with	Type of validity	Weaknesses
Past performance	Replicative validity	Time and cost consuming Not necessarily predictive
Future performance	Predictive validity	Not generalisable
Simulation performance	Predictive validity One of the validation tools is simulation.	Assumption based, time and cost consuming Subjective

Adapted from Zebda (2013)

TABLE **6-1** suggests that, if the comparison complies with the past performance, the decision model has replicative validity. If it complies with future performance or simulated performance, it has predictive validity. Based on Zebda's account, it seems that the PREDIS decision model needs to comply with simulated performance, because it requires to be validated based on predictive validity.

Another reason for choosing a simulation is that the majority of the validity testing tools compare the performance of the model with the real system. However, sometimes such as in this research, the creation of the real system is costly or impossible. It is practically impossible and morally unjustifiable to create a disaster in order to observe how the decision makers decide. Instead, due to the non-existence of the real world system to compare the result with, a simulation can create such a system. In other words, in the lack of real world, the analysts use the simulation model as a surrogate because it is impractical to construct multiple prototype versions of the real system, or because costs or other constraints prohibit experimentation with the real system. The insight provided by the simpler model (simulated disaster situation) may be used for verification and validation of the complex parent model (real disaster situation). In order to design this simulation model for validating the PREDIS, a combination of two methods including a vignette study and simulation game has been considered as follows.

6.2 VALIDATING THE PREDIS MODEL

To validate the PREDIS model a series of hypotheses need to be considered to evaluate the contributions. One hypothesis is that the combination of partners chosen by decision makers after the release of a MIRA report about the disaster impact is not significantly different from the combination of partners chosen using the PREDIS model, which is usable within minutes after the disaster strike. If this hypothesis is confirmed, it can be said that the PREDIS could bridge the 72-hour delay in receiving data and would make the whole process more time efficient. The other hypothesis is that the result of the decision in a test group of experts is not significantly different from the control group of non-experts. If this hypothesis is confirmed, it can be said that the PREDIS model not only helps the experts to decide faster but also helps the non-experts in making decisions as well as the experts. To that end, the two hypothesis are put forward to examine the model from the decision-making point of view :

Hypothesis (Hb) : 'The PREDIS model assists the decision makers in making the same decisions faster'

Hypothesis (Hc) : 'The PREDIS model assists the non-experts in making decisions as well as experts'

To test the above hypothesis two designs were considered. The first option was to put forward a series of questions in the frame of a vignette study. The second option was to use an experiment and practically see how the model works in the real life. These options are reviewed as follows.

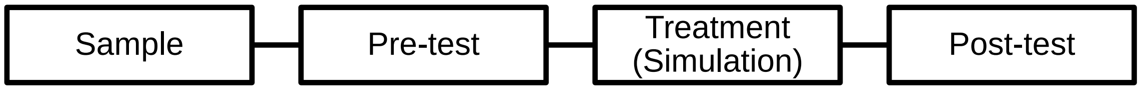
6.3 VIGNETTE DESIGN

One of the techniques used for putting forward a set of questions to examine the people decision-making process is the vignette technique, where the people are faced with a set of scenarios and are asked how they decide if they face with these situations (Brymana and Bell, 2003). The advantages of this method are that it reduces the possibility of an unreflective response, and it is very useful when the questions are sensitive because the respondents answer the questions about the hypothetical characters and not themselves. However, this technique could not facilitate a hands-on experience for the participants where they can actually try the PREDIS platform. In addition, it does not provide a setting where the experts and non-experts could be compared. It also could not take into account the learning effect associated with being exposed to the PREDIS model in the process of decision-making.

6.4 EXPERIMENT DESIGN

Another method that the author could use was an experiment design, where the respondents could be exposed to the PREDIS model, and their actual actions are registered and compared. The latter had the capability of comparing the experts' and non-experts' decisions and observing the effect of being exposed to the PREDIS model by comparing the results of the decision-making before and after. In the pre-test phase the disaster scenario (e.g. Indian Ocean Tsunami, 2004) was provided to the participants. This information is the first available official data and probably closer to the reality than the other official data which would be reported months after the strike. The respondents were then asked how they would decide about the partners. At this point, the participants were exposed to the PREDIS model and were asked to 'learn' the procedure (treatment) in order to apply that in the post-test where the PREDIS model is used to make the decisions. This introduces the elements of experiments to the design where the groups are 'treated' with the exposure to the PREDIS method. The process follows a simple quasi-experimental design (FIGURE **6-2**) where the simulation game is observed as the treatment to a quota sample selected equally from a mixed population of experts and non-experts. This experiment was designed in the form of a quasi-experiment because not all the factors in human decision-making process could be controlled.

FIGURE 6-2 THE QUASI-EXPERIMENTAL DESIGN OF THE SIMULATION GAME



Adapted from Campbell and Stanley (1963) and Bell (2010)

The basic premise behind the pre-test/post-test design involves obtaining a pre-test measure of the outcome of interest (here decision-making in disaster situation) prior to administering some treatment (exposure to PREDIS model) followed by a post-test for the same measure after treatment occurs. Pre-test–post-test designs are employed in both experimental and quasi-experimental research (Bell, 2010). For the treatment, a simulation (Bryman and Bell, 2003) is used which involves representing the situation by creating an artificial setting (here the hypothetical disaster scenario) in which individuals are observed. Simulations create a large amount of data in a short period of time and enable access to the issues that may not be amenable to observation in real life such as problem-solving and decision-making. They also enable the researcher to create and later observe the situation in order to examine the effect of an intervention (Bryman and Bell, 2003).

6.4.1 THE COMBINED DESIGN

Although the elements of a vignette study such as scenario making, survey questions and human judgment are present in this study; a pure vignette study is not appropriate. The reason is that the elements of experiments are also present in the study, where the participants are exposed to the PREDIS model and are asked to 'learn' the procedure in order to apply that in their second round of the game. This introduces the elements of experiments to the design where the groups are 'treated' with exposure to the PREDIS method. The details of defining the experiment will be described later in the chapter.

The use of the experimental design in simulation games is popular due to its resemblance to the laboratory conditions (Simon, 1961; Norris and Snyder, 1982; Ben-Zvi, 2010; Musshoff, 2011; Croson et al., 2014). Experimental approaches are used in various studies including laboratory experiments with hypothetical decision-making situations such as purposefully designed business simulation games, in which participants have to make entrepreneurial decisions within the systematically controlled rules of the game (Longworth, 1969, 2008; Tanner, 1975; Keys and Wolfe, 1990; Musshoff and Hirschauer, 2014). The process follows a quasi-experimental design, where the simulation game is observed as the treatment to a quota sample selected from two equal sized samples from a mixed population of experts and non-experts.

The basic premise behind the pre-test–post-test design involves obtaining a pre-test measure of the outcome of interest (here decision-making in disaster situation) prior to administering some treatment (exposure to PREDIS model) followed by a post-test on the same measure after treatment occurs. Pre-test/Post-test designs are employed in both experimental and quasi-experimental research (Bell, 2010).

The design adapted in this part is a simple quasi-experiment, which can be further explained as a non-equivalent group counterbalanced design (Abowitz and Toole, 2010) as depicted in FIGURE **6-3**.

FIGURE 6-3 SCHEMATIC OF THE COUNTERBALANCED DESIGN

Group	Time 1	Time 2
A	X1 O	X2 O
B	X1 O	X2 O

FIGURE 6-3 shows that the group A (here non-experts) and B (here experts) are a combination of non-equivalent participants distributed in two groups. The design implies that each group is exposed to the treatment X1 (here the preliminary disaster data report), which is observed followed by being exposed to the treatment X2 (here the PREDIS model) and is observed. Treatment X1 comprises of providing the participants with a disaster scenario and asking them to choose from a list of hypothetical partners based on their knowledge and the data in a preliminary disaster data report. Treatment X2 comprises of providing the participants with the PREDIS model and asking them to choose from a list of hypothetical partners based on the predictions in the model. The above steps are explained in detail in the following section. However, there are some limitations associated with this design, which are addressed as follows.

6.4.2 THREATS TO THE VALIDITY OF THIS SIMULATION GAME DESIGN

There are validity threats associated with this design (Campbell and Stanley, 1963), which affect the interpretation of the results as follows (TABLE **6-2**).

TABLE 6-2 THREATS TO THE VALIDITY OF THIS SIMULATION GAME DESIGN

Design validity	Threats to the design validity	Addressed

Internal validity	History	Unlikely
	Maturation	Reduced
	Testing	Not applicable
	Instrumentation	Reduced
	Regression	Yes
	Selection	Reduced
	Mortality	Unlikely
External validity	Interaction of testing and experiment	Reduced
	Interaction of selection and experiment	Reduced
	Reactive arrangement	Yes
	Multiple treatment interference	Yes

TABLE **6-2** shows that the internal validity can be affected by various factors. History can be a threat when some events occur between the pre-test and post-test which changes the course of the result. The effect of history is kept to a minimum by executing the process on one occasion. Therefore, the chance of events occurring which might lead to the change in measurements is reduced. Another threat is maturation, where the passage of time causes the responders to change (e.g. grow older, or get hungrier). This is also kept to a minimum by keeping the procedure short (45 to 90 minutes depending on the participants' requirements) and by also offering breaks during the sessions. The testing effect occurs when the test is being taken is added to the scores of the previous tests. This is not applicable in this research because taking the second experiment does not depend on the score on the first experiment. The instrumentation effect happens when the changes in instruments or calibration of measuring happens. This is also kept to a minimum because the author runs all sessions herself and uses the same excel files, data case, presentations and computer systems. However, in some cases the sessions are held virtually on Skype, whereas in others the sessions are held in person. This is due to the geographical dispersion of the humanitarian workers involved, which made the in person sessions impossible. The statistical regression occurs when people are selected based on their high scores. This might be present in the research because the respondents are partly contacted based on their experience in the humanitarian field. However, measuring this effect is one of the secondary objectives of the study. So the presence of this threat will be measured later in the chapter. Any other discrepancies in the skills and capabilities of the respondents are non-intentional and therefore the selection biases are kept to the minimum. Selection biased happens when the groups are being selected based on different unequal measures. The loss of respondents during the sessions (experimental mortality threat) is unlikely during a 90-minute session and therefore the mortality effect is kept to the minimum.

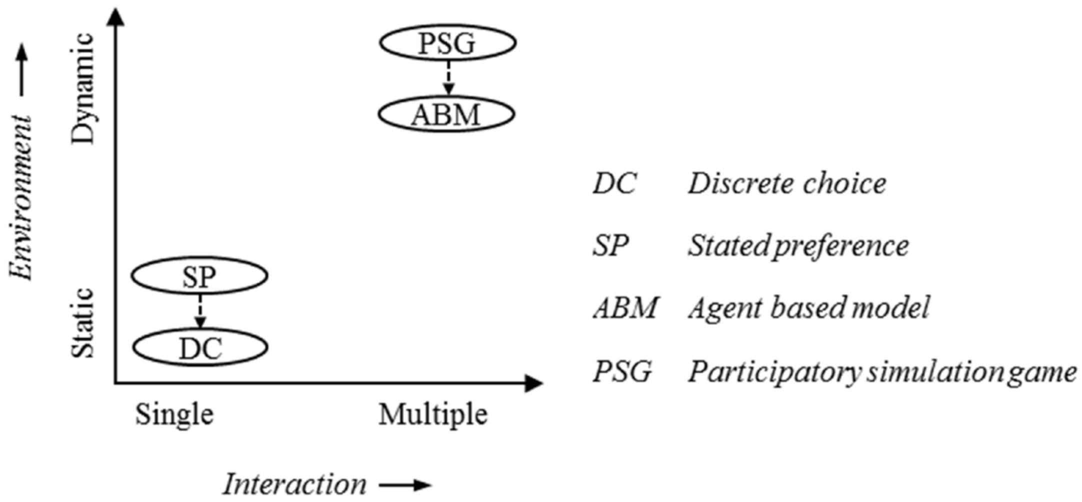
The external validity associated to this design includes multiple treatment and reactive/interactive effects effect of testing. Multiple exposures to treatments interfere with each other and the experience is not erasable from the mind of the participants. This is present in this research due to the design, which makes the participants exposed to the data of disaster in pre-test and post-test. Attempts have been made to even out both groups by switching the timing of the experiments and the Latin-square arrangement. This as Stanley and Campbell (1963) denote, keeps this threat from contaminating the main effects of experiments. However, the author is aware of this threat as a limitation of the study. The reactive/interactive effect of testing occurs when the participants are exposed to pre-test and this changes their sensitivity for the test variables and makes it unrepresentative of the untested group of participants. The reactive effects of experimental arrangements are also kept to the minimum by exposing the respondents to the treatments only in the experimental setting and not giving away data about the procedure of the experiment to the respondents before the sessions.

To summarise, the threats associated with the simulation game design in this research affect the internal and external validity as follows. Internal validity, which is present in this research, is regression biased, because the experts are selected based on their high level of experience in the disaster situation and this makes them unequal to the non-expert group. However, the difference in decision-making in these two groups is the subject of hypothesis (Hc) and therefore it will be discussed in detail. The external validity is threatened by the reactive arrangement of experiments in addition to the multiple treatment interference. This is one of the most important limitations of the present design, which makes its generalisability difficult.

6.4.3 SIMULATION GAMES AS A VALIDATION TOOL

Simulation is defined as a representation of a real-world environment, system or process used for scientific purposes, when the real system may not be observed directly because of the inaccessibility, cost, danger (Barton, 1994). In other words, it is the imitation of the operation of a real-world process or system over time (Banks, 1998). Simulation approaches include system dynamics, discrete event modelling and agent based modelling. By taking the simulation off the computer screen and bringing it into the experiential world of the players (Colella, 2000), participatory simulation or simulation games are born. In this method, an environment is created where players take decisions based on underlying rules that are consistent with the real world and comprehensible (Anand et al., 2013). The reason is it supports the understanding of complex social phenomena by a generative approach, which involves reduction, performance, training, proof, and discovery in social science (Gentile et al., 2014). In this context, the main goal of the game is to simulate the actors' decision-making processes. This leads to the demonstration of the consequences within social systems where the users have to cope with difficulties arising from the complex nature of these systems (Westera, 2008). Some researchers believe that simulation games are the third research methodology in line with induction and deduction (Axelrod, 1997). As is shown in FIGURE **6-4**, simulation games are more dynamic than other decision-making simulated models (including discrete choice, stated preference, and agent based modelling) because multiple agents are interacting with each other for decision-making and the choice of one agent affects (and is affected by) decision of other agents (Anand, 2013). FIGURE **6-4** compares different decision-making tools with a simulation game.

FIGURE 6-4 -POSITIONING SIMULATION GAMES WITHIN DECISION TOOLS



Source: Anand et al., 2013.

FIGURE **6-4** uses an arrow to show that the dynamic nature in the agent based modelling tools decreases towards less dynamicity in comparison to the simulation game. However, the use of multiple decision makers remains at the same level as the simulation games. Conversely, both dynamicity and the use of multi- decision makers change when it comes to the tools with stated preference, which use a single decision maker in a static environment. The arrow shows that although the use of a single decision maker remains the same in the discrete choice tools; their environment is even more static than the stated preference tools.

These tools include the judgmental tasks, in which the decision makers based on or certain attributes rank a particular choice context.

The multi-agent simulation games explicitly describe the decision processes of simulated agents at the micro level that lead to the emergence of structures at the macro level as a result of those decisions (Gentile et al., 2014). These simulation games are well suited to modelling and investigating systems with heterogeneous, autonomous, and proactive actors, such as human-centre systems including social and biological systems (Lopez-Paredes, 2012). Complex computer simulation models of proposed or existing real systems are often used to make decisions on changes to the system design. The insight provided by the simple model may be used for verification and validation of the complex system. Since it uses fewer resources, the model can run iteratively many times for repeated 'what if' evaluation for multi-objective systems (Barton, 1992).

6.4.4 THE EXISTING PRACTICE OF SIMULATION GAMES

Simulation games have been used for validating decision-making models in medical treatment (Reichlin et al., 2011), where they aim to investigate how increasing the knowledge of the patient would change their decision about cancer treatment processes. Another example is for entrepreneurial scheme (Gentile et al., 2014) where they use agent-based model for designing a serious game, which helps in developing an entrepreneurial mind in the user. Their goal is to design a tool to determine whether their model is clear and comprehensible to the user. It has also been used for cross-cultural decision-making (Madni, 2013) in the settings where globalisation renders ad-hoc decision-making on the concepts such as distribution, supply chain and operations. It has also been used to validate a model about city logistics (Anand et al., 2013) where the players (decision makers) are responsible for deciding about the profit margin, supply partners. The aim is to collect information about the behaviour and beliefs of the decision makers in the real settings, in order to validate their model. Another research study is related to the application of a simulation game to validate a model about land use (Villamore, 2013). They tried to analyse the decisions made by the households with a quasi-experiment to see if they would change their decision about land use if they were rewarded for eco-friendly behaviour or if they were given financial subsidies for profit-based behaviour.

Operations management in particular (Lewis and Maylor, 2007) employs a wide variety of games (Riis and Mikkelsen, 1995), ranging from simple table top (Robinson and Robinson, 1994) and red bead experiments (Deming,1986), to system simulations like the Beer game (Forrester 1961, 1990) and Cuppa Manufacturing games (Ammar and Wright, 1999), to much more complex interactive environments such as a training factory (Haapsato and Hyvönen, 2001). Although the simulation games are performed in various disciplines, scholars (Elgood, 1997; Lewis and Maylor, 2007) identify 572 simulation games in which almost half (222 games) are related to operations management. This signals the success of the simulation games in capturing the nature of operations management.

In the field of humanitarian disaster, a number of simulation games have been launched to raise awareness and assist in decision-making about various disasters. For example, FloodSim (Playgen.com, 2014) is a simulated game where the player is in charge of all flood related policy-making decisions for the next three years in the UK. FoodForce (foodforce2.com, 2014) is another game in which players take on missions to distribute food in a famine-affected country. In ‘Stopthedisaster game’, the players are in charge of making decisions leading to the reduction of disaster risk (Stopdisastersgame.org, 2014). In Darfurisdying (Darfurisdying.com, 2014), players make decisions about surviving in a refugee camp. Planning with Large Agent-Networks Against Catastrophes (Plan-C) software is a simulation program with the ability to cover 1,000,000 injured, and which provides statistical outcome data at medical, emergency responder and community levels. This model is tested on food poisoning and terrorist attack modelling (Mysore et al., 2005, 2006). Although these games are useful for planning, and familiarising decisions makers with the decision-making process in disaster situation, they are void of predictive elements. This is the factor that the present research is trying to address.

In the present research a non-computer, based simulation game has been designed for implementing the decision-making model for partner selection in disaster situations, in a simulated process by the experts in the field. The results should highlight the strengths and weaknesses of the model and justify its usage in the real-world situations. Keeping the above examples of simulated games, the author believes that the presented framework is capable of being developed into a computer based decision tool, in the eventuality of acquiring the required funding in the future.

6.4.5 LIMITATIONS AND OPPORTUNITIES IN SIMULATION GAMES

Although the simulation game is subjective, some researchers believe it is the only method or only viable way to study populations of agents who are rather than fully rational (Axelrod, 1997). The reason is while people may try to be rational in their decision-making; they seldom have the all information required for a rational model (Simon, 1955; March, 1978). In the end, when the person makes a decision, it is subjective to the person's viewpoint. One argument against simulation games is that it uses human judgment to validate the decision models designed to improve human judgment. The response to this criticism is that simulations provide a relatively flexible and realistic representation for complex problem, and major decisions are made based on the simulation results (Horn, 1986). Considering all the above limitations, the author relies on two grounds for choosing the simulation game for this stage of the research.

The first reason is the numerous experimental studies in the non-management areas of research, where scholars use human judgment in hypothetical situations including vignette studies and economic experiments. These two methods are elaborated further as follows.

One of the vastly used methods is vignette, which involves presenting participants with a hypothetical scenario, and asks how participants would think, feel, and act in the depicted situation (Barter and Renold, 2000). Vignettes are generated from a range of sources including previous research findings (Carlson, 1996; McKeganey et al., 1995), in collaboration with other professionals working in the field (Kalafat et al., 1993; Kalafat and Gagliano 1996), or based on real-life case histories (Rahman 1996). Participants are typically asked to respond to these scenarios by answering what they would do in a particular situation or how they think a third person would respond (Hughes, 1998).

The simulation game presented here is not a vignette study, but the vast acceptance of human judgment as a laboratory-like tool in validating hypothetical scenarios, and thus signalling the power of similar tools. An example of these tools is a simulation model that replicates the decision-making process in disaster response networks. The author believes that this offers participants distance and space to provide a discursive interpretation within the context by constant interactions between the decision makers and the real-like scenarios. This has also an educational effect on the decision makers in the long run, as they will learn from their own experience by repeating the process of decision-making in a simulated environment of disaster response. Where this ‘snap-shot’ of disaster scenarios does not offer enough information for an individual to make a decision or provide an explanation, the situated context of a simulation model could work similarly to a vignette, which can be used to explore the main influencing factors. Although vignette studies are more popular in the study of decision-making in medical practices such as critical care decision-making (Thompson et al., 2003) or the end of life decision-making (Ruppe et al., 2013),the author believes that there is a similar nature of pressure and sensitivity to the decision-making at the time of the disasters. Therefore, if the analysis of hypothetical scenarios of decision-making during medical practices can be justified by a vignette study, it is possible to verify the decision-making model in a disaster situation by bringing in a well-designed simulation game.

The second reason for relying on simulation game as an appropriate design for this part of the research, is the exponentially increasing use of the simulation games among scholars as exhibited in TABLE **6-3**. It lists a number of simulation game designs used in previous studies published in peer-reviewed journals.

TABLE 6-3- SIMILAR SIMULATION GAME BASED DESIGNS

Scholar	Subject	Objective	Participants
Laine et al (2012)	Servitisation enhancement	Understanding the customer needs and define the scope of servitisation	140 business units and customers
Oderanti and Wilde (2010)	Decision-making under uncertainty	Strategic policy formulation	Not implemented yet
Lopes et al. (2013)	Leadership development	Literature review	N/A
Anand et al. (2013)	City logistics	Validating the propose framework	
Mohan et al. (2014)	Medical decision-making	Understanding the decision-making process	28 Trauma surgeon, 26 Physicians
Ben-Zvi et al. (2010)			
Musshoffa and Hirschauerb (2014)	Agricultural policy	Analysis of the impact of a policy	190 students (38 in each scenario group)
Musshof et al. (2011)	Economic behaviour	Analysing the Bounded Rational Behaviour	105 students
Dufty (1961)	Organisation theory	Confirming the hypothesis	Two groups of 9 students

Scholar	Subject	Objective	Participants
Thavikulwat et al. (2013)	Merger and Aquisition	Understanding in what economy the merger and acquisition takes place	180 undergraduate students
Thompson et al. (1995)	Strategic decision	Manufacturer	12-80
Laine et al. (2012)			140
Ben Zvi (2010)	Decision support system	Efficacy of simulation game	58-520
Sterman et al. (2014)	Policy negotiation	World climate	3 rounds of 43 and 100 and 173 students/ teachers
Croson et al. (2014)	Supply chain management	Effect of coordination risk on bullwhip effect	4 groups of 40 students

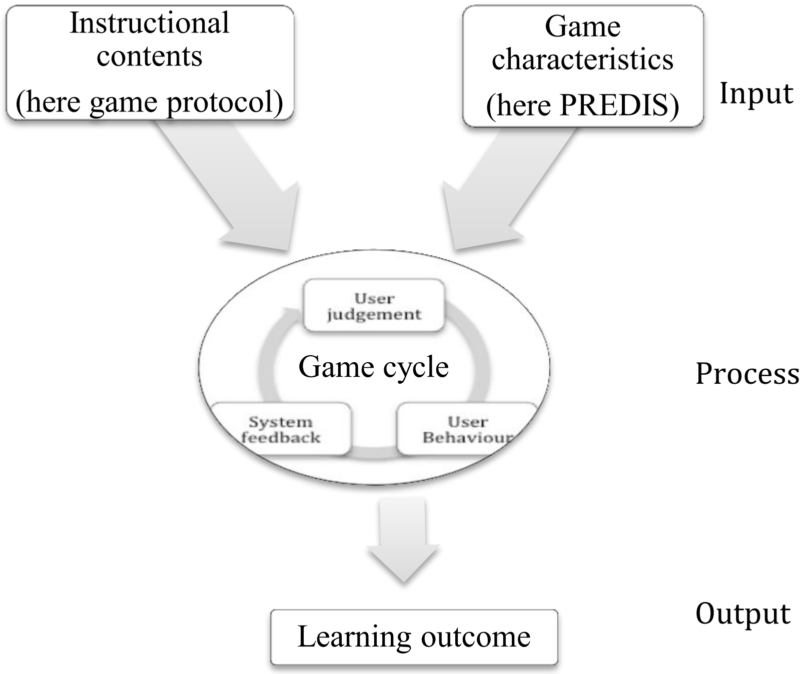
TABLE **6-3** shows that the simulation game has been used in different areas of studies using a 12-to 520-sample size. The noteworthy point is that out of 15 articles only one has explicitly used the experts (surgeons and physicians) as the participants. The reason might lie in the difficulty of reaching enough experts to guarantee the statistical accuracy required for generalisation (minimum sample size of 30). To that end, the present simulation game has been designed using a mixed population of participants to determine the effect of experience on the decision-making as well as the effects of exposure to the PREDIS model in decision-making.

6.5 THE FRAMEWORK FOR TREATMENTS (SIMULATION GAME)

Simulation games are constructed, tested, and revised (Saunders, 1995) to include real world–like responses by participants in the simplified simulated experiential environment. The environments contain enough verisimilitude, or illusion of reality (Keys and Wolfe, 1990; Crookall et al., 1987). In the lack of an authentic task, a constructive process is designed to simplify the task (Lainema, 2008) in order to make the participants use their personal interpretation of experience and build an internal representation of knowledge

(Bednar et al., 1992). These games include actors (here decision makers), rules (here the PREDIS model principles), and resources (here calculating software, experiences of the decision makers) interacting in an input-process-outcome game model (Klabbers, 1999, 2001) as exhibited in FIGURE **6-5** INPUT-OUTPUT-PROCESS MODEL.

FIGURE 6-5 INPUT-OUTPUT-PROCESS MODEL



Adapted from: Garris et al. (2002)

FIGURE **6-5** shows that the input of instructional contents (here game protocol) and game characteristics (here PREDIS) triggers the process of the game cycle that includes user judgments or reactions such as enjoyment or interest, user behaviours such as persistence or time, and system feedback. This leads to the achievement of the outcomes (here decision).

6.6 DESIGNING A SIMULATION GAME FOR THE PROPOSED MODEL

VanSickle (1978) defines the simulation game design in three groups of participants' characteristics, game administration factors and game structural characteristics. Following the Van Sickle (1978) definition, the design of the game can be characterised as follows:

(1) Participant characteristics prior to game play

   a. Conceptual pre-requisite (here they need to be conceptually decision makers participating in disaster decision).
   b. Skill pre-requisite (here their skill set should fit within two groups of experts and non-experts).

(2) Game administration factors.

   a. Group versus-individual decision-making (here individual decision-making)
   b. Intermittent and structured discussion (here the discussion after simulation game)
   c. Pacing (here the time for each session is between 45 to 90 minutes)
   d. Group size (here group size is two groups of 22 participants)

(3) Game structural characteristics

   a. Written decision-making records (here excel files showing all the process
   b. Predictive accuracy feedback (here the predictions are compared to the actual impact of disaster, and the decisions are compared to each other in

both groups. This is discussed in detail in the result of the simulation game, answering hypothesis Hc).

c. Similarity of problem and data presentation (here the data about the decisions taken by participants are presented in the same units (of aid required) and partners (selected for the response) as was presented in the problem provided at the beginning of the game.

d. Decision-making procedure specificity: The steps for decision-making are specified in the procedure of PREDIS model followed by the participants in two phases of pre-test and post-test design. First the simulation games and their background in addition to the participant manuals are distributed. The second period is used for interviewing. The options are laid out and the decision maker in two rounds decides about the partners. Once using their own method and the second time using the proposed model. Some breaks are taken and the differences are analysed. For example, in terms of the ease of use, the time consumption, selection criteria, and other aspects which might come to the participant's mind during the process. In the second interview, the decision maker who has read the report reflects on that and evaluates the value of the model in a questionnaire. The steps which are outlined in detail in the following section, are briefly mapped in relation to the previous studies in FIGURE **6-6**.

FIGURE 6-6 - MAPPING THE PROCESS IN RELATION TO THE EMPIRICAL STUDIES

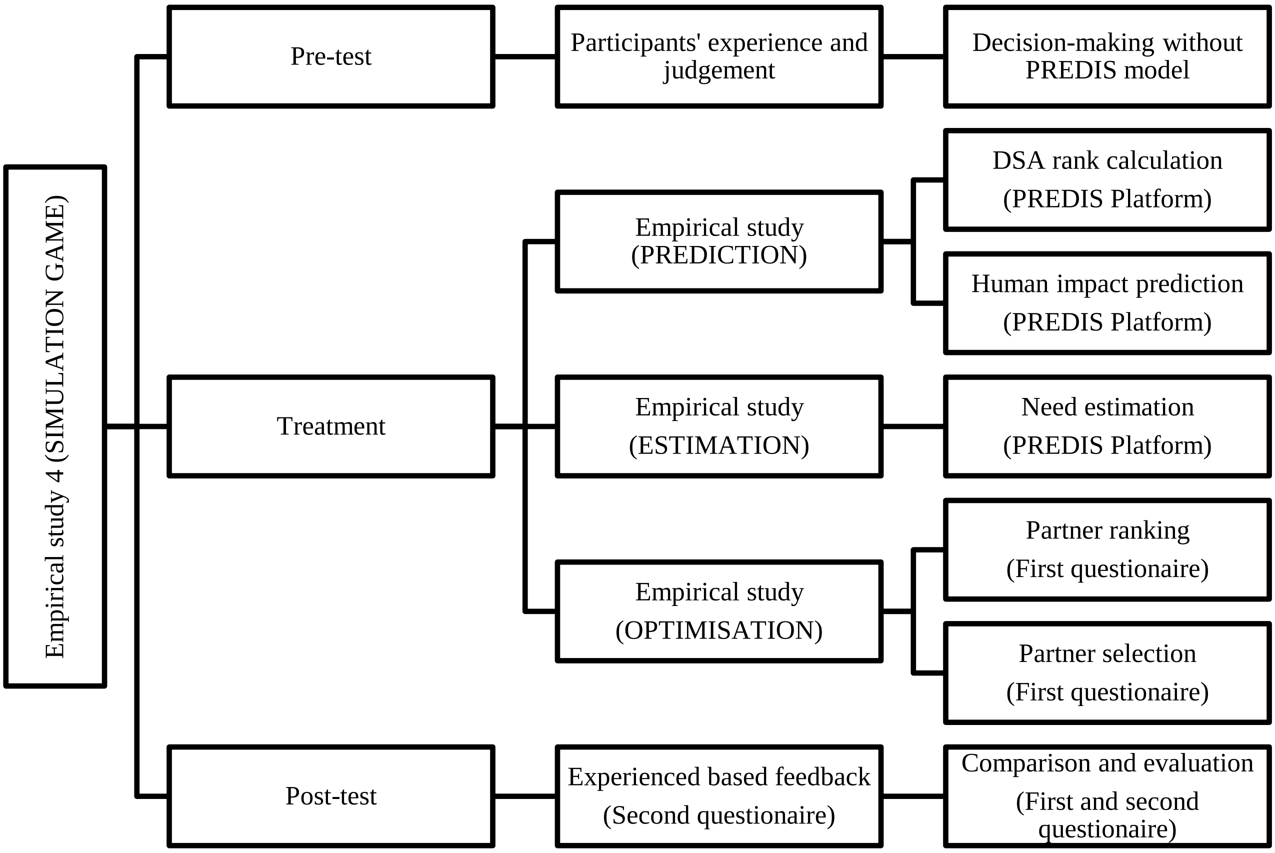


FIGURE **6-6** shows that the empirical study 4 (Simulation game) contains three phases of the quasi-experiment design. It starts with the pre-test where the participant chooses the disaster case s/he wants to proceed with. Accordingly, an example of the data in the early hours after the disaster strike, is presented to the participant. This is in addition to a summarised list of partners containing 20 partners (Appendix 11). The participant then needs to decide based on their own judgement and experiences which partners they want to choose for this particular disaster. The second step is the treatment where it uses the principles of the three studies embedded in the PREDIS template (Appendix 12) . As soon as the participant chooses the disaster cases the DSA rank IS calculated and the human impact is predicted based on the principles outlined in the first study (PREDICTION). The needs are also calculated based in the principals of the second study (ESTIMATION). The treatment continues with the first questionaire which gives rise to the calculation of AHP weights for each participants. Using these weights in combination with the principals of the third study (OPTIMISATION) it is possible to rank and select the partners. An example of the result of this process is presented in Appendix **14**.

In the post-test phase the results of the questionaire is used to compare the decision-making before and after exposure to the PREDIS model.

6.6.1 PROTOCOL FOR RUNNING THE SIMULATION GAME

This section outlines the protocol for the partner selection in disasters, developed to verify the suitability of the proposed model in the eye of the experts and non-experts. In addition, Sterman's (1987) example of a simulated game such as a beer game is used for designing the instructions, strategies and debriefing questionnaires. The logic behind the segregation between expert and non-expert participants is that in many cases in disaster situation, the people who are forced to decide about relief aid, in NGOs or voluntary organisations, amongst others, are non-experts. If the model can produce a comparable result of decisions between experts and non-experts, it is possible to argue that the model can help the non-experts to decide like experts. To that end, two groups of players separately participate in this simulation game.

The prerequisite of group one is that the participants have at least one experience in decision-making in a disaster situation. These participants are summoned from various specialised humanitarian groups and voluntarily participated in the game.

CHAPTER 6 PREDIS ASSESSMENT & EVALUATION

The prerequisite of group two is that the participants have no experience in disaster response and voluntarily participated in the game.

1. Purpose

   a. Introduce and evaluate the model

   b. Identify the weakness of the model in a real-world-like situation

2. Overview of the simulation game

   a. Identify the roles: Facilitator and Decision maker (players).

   b. Although the multiple decision makers can exist, they all decide individually without interaction with others. The reason is that this research would like to measure the efficiency of the model itself and is not equipped to isolate the effect of player's interaction (which may cause synergy) on the decision-making process.

   c. At least one country and one type of disaster is the subject of a hypothetical disaster

3. Basic rules

   a. Each decision maker should highlight their preferences for partner selection by answering the related questionnaire. For example if they prefer to use NGO partners to military partners, or if they just would like to address the medical needs. These data will be used to calculate the AHP by the facilitator or in the designated cells in the excel sheet.

   b. The objective of the game is to compare the results of the existing partner selection method of decision makers with the results obtained from the propose model.

4. Steps of the Game. The game leader should call out the steps, as the game progresses. In addition, a booklet (Appendix **13**) is provided explaining the process and an excel sheet embedding all the formulas, accompanies the process.

a. First step- PRE-TEST

i. The preliminary disaster data report of a particular disaster in addition to the list of the available partners and their resources are provided to the players.

ii. The decision maker is asked to choose between the partners using their own method.

iii. The time to come up with the decision is registered.

b. Second step – TREATMENT

i. The participants fill in the first questionnaire (DECISION PREFERENCE)

ii. The PREDIS model is explained to the decision maker.

c. Third step- POST-TEST

i. The facilitator can help with the calculation of the result of the model.

ii. The chosen partners are finalised (using PREDIS).

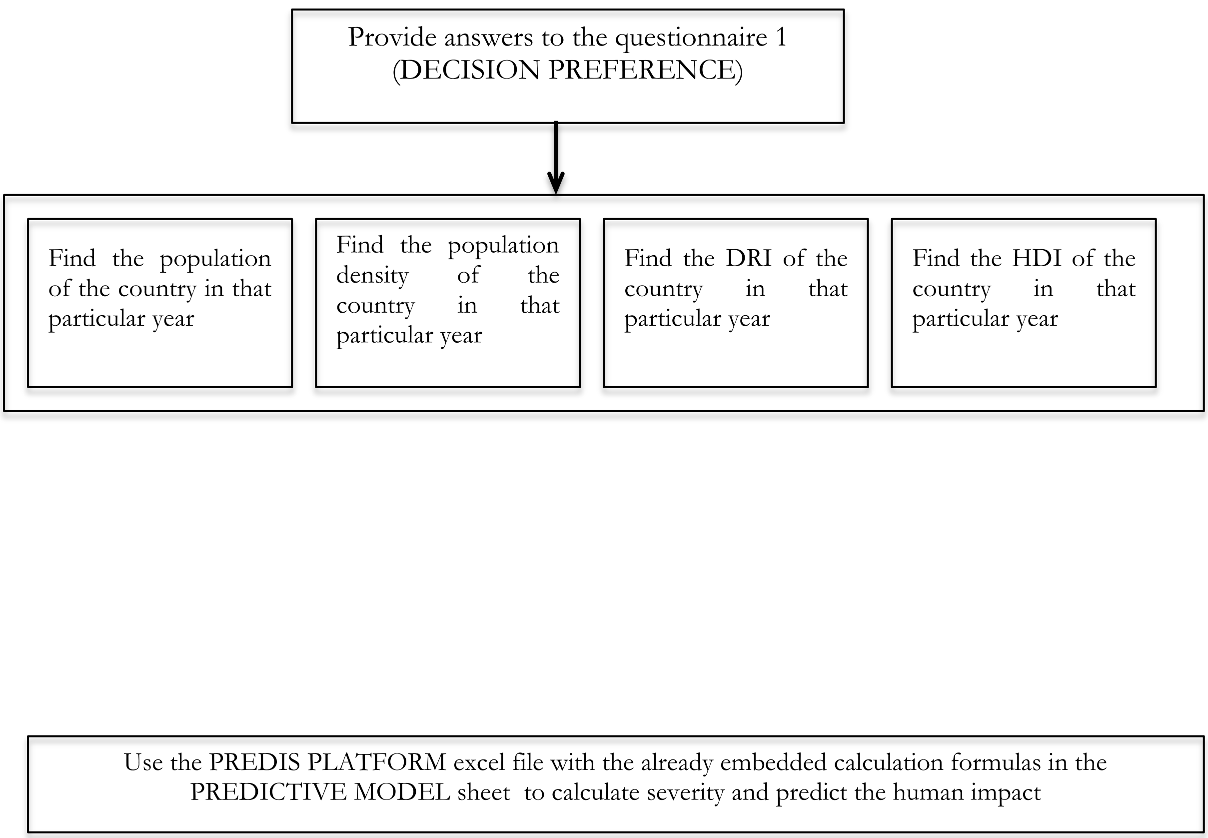
d. Fourth step- DEBRIEFING AND ANALYSIS

i. The results are compared and analysed first by comparing the characteristics of the chosen partners in addition to statistical analysis.

ii. The experts answer the second questionnaire (EXPERIENCE BASED FEEDBACK) in order to provide feedback on the suitability of the PREDIS for the disaster situations in which they have been involved. The non-expert's procedure is finished at this stage because their pre-requisite for participation implied that they have no experience in disaster response and therefore they are unable to give feedback on the suitability of the PREDIS in a real disaster situation.

To facilitate the use of the model, the instructions for the process are illustrated in a chart as exhibited in FIGURE **6-7**.

FIGURE 6-7 THE PROCESS OF SIMULATION GAME FOR THE PLAYERS



Use the PREDIS PLATFORM excel file with the already embedded calculation formulas in the NEEDS sheet to estimate the disaster needs

Ask the facilitator to calculate the preference weights based on the data declared in the questionnaire 1 (DECISION PREFERENCE)

Put the values extracted from preference weights in the designated area in the PARTNERS sheet to calculate the utility rank of the hypothetical partners.

Use the optimisation add-in the PREDIS PLATFORM excel file to calculate the final partners in the OPTIMISATION sheet (ask for the facilitator's help if necessary)

No

Are you an expert?

Yes

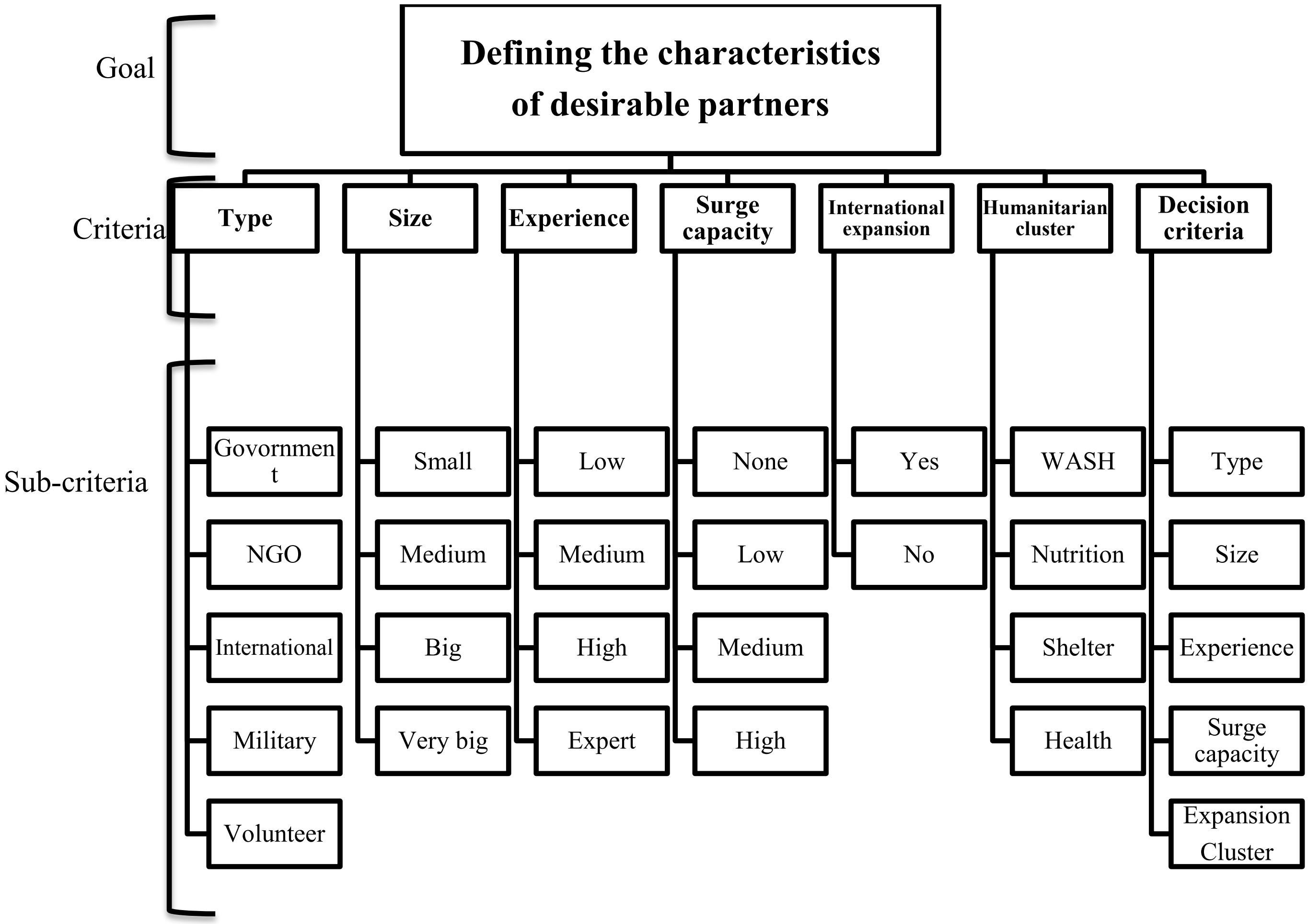
Your session is finished. Thank you
Any feedback about the process?

Please answer the questionnaire 2 (EXPERIENCE BASED FEEDBACK)

6.6.2 FIRST QUESTIONNAIRE- DECISION PREFERENCE

This section outlines the process of calculating weights of the decision makers' preference towards the partner selection criteria. This questionnaire is handed out before the start of the face-to-face simulation game or is sent out to the players who are participating on Skype. At this stage the players are asked to identify in respect to each one, the criteria for partner selection which criterion is more important and how much more important on a scale of 1 to 9. This is the basis for questionnaire 1 (DECISION PREFERENCE). These criteria include the type of partners (Government, NGO, Military, International organisations such as Red Cross and UN and volunteers), size, experience of the partners, their surge capacity (the ability to rapidly expand beyond normal capacity to meet the increased demand) and their cluster (WASH, nutrition, health, shelter). The first questionnaire is given to both groups of participants in order to identify their preferences. The goal, criteria, and sub-criteria considered in this questionnaire are articulated in FIGURE 6-8.

FIGURE 6-8- COMPONENTS OF FIRST QUESTIONNAIRE (DECISION PREFERENCE)



The first row of FIGURE 6-8 shows that the goal of this questionnaire is to define the characteristics of the desirable partners in the view of each decision maker. The second row gathers the data about the characteristics of the desired partner in terms of the following criteria.

- Type of the partner in respect of being governmental, NGO, International, Military or Volunteer organisation as sub criteria.

- Size of the partners based on ANLAP's (2012) categories for humanitarian organisations, being Small (under 10 million USD expenditure), Medium (between 10-49 million USD expenditure), Big (between 50-99 million USD expenditure) and Very big (more than 100 million USD expenditure).
- Experience of the partners being Low (Under 5 disasters), Medium (Under 10 disasters), High (under 50 disasters) and Expert (more than 50 disasters)
- Partner's surge capacity (the ability to rapidly expand beyond normal capacity to meet the increased demand) being None (0% of the total capacity), Low (under 10% of the total capacity), Medium (under 30% of the total capacity) and High (over 30% of the total capacity)
- Partner's international expansion being Yes (expanded internationally such as UN), No (expanded only locally such as local charities).
- Partner's ability to address the needs for humanitarian cluster being WASH, Nutrition, Health, and Shelter.

Finally, to give numerical preferences for the above decision criteria being type, size, experience, surge capacity, expansion and cluster. The first questionnaire is exhibited in TABLE 6-4.

TABLE 6-4 FIRST QUESTIONNAIRE- DECISION PREFERENCE

1. In respect to the type of the partners:

	How much more important								Equal	How much less important								
Government	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	NGO
Government	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Military
Government	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	International
Government	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Volunteers
NGO	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Military
NGO	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	International

NGO	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Volunteers
Military	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	International
Military	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Volunteers
Volunteer	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	International

2. In respect to the size of the partners being (based on ANLAP, 2012)

Small=under 10 million USD expenditure

Medium= between 10-49 million USD expenditure

Big= between 50-99 million USD expenditure

Very big= more than 100 million USD expenditure

	How much more important								Equal	How much less important								
Small	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Medium
Small	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Big
Small	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Very big
Medium	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Big
Medium	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Very big
Big	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Very big

3. In respect to the experience of the partners being

Low=under 5 disasters

Medium= Under 10 disasters

High= under 50 disasters

Expert= more than 50 disasters

	How much more important								Equal	How much less important								
Low	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Medium
Low	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	High
Low	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Expert
Medium	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	High
Medium	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Expert
High	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Expert

4. In respect to the partners' surge capacity (the ability to rapidly expand beyond normal capacity to meet the increased demand)

None=0% of the total capacity

Low= under 10% of the total capacity

Medium= under 30% of the total capacity

High= over 30% of the total capacity

	How much more important								Equal	How much less important								
None	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Low
None	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Medium
None	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	High
Low	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Medium
Low	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	High
Medium	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	High

5. In respect to the partners' international expansion

	How much more important								Equal	How much less important								
Yes	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	No

6. In respect to the humanitarian clusters of the needs, do you prefer the partners to provide any particular need to the other clusters?

	How much more important								Equal	How much less important								
WASH cluster	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Nutrition cluster
WASH cluster	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Shelter cluster
WASH cluster	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Health cluster
Nutrition cluster	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Shelter cluster
Nutrition cluster	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Health cluster
Shelter cluster	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Health cluster

7. In respect to the above decision criteria, which one is more important to you?

	How much more important								Equal	How much less important								
Type	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Size
Type	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Experience
Type	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Surge capacity
Type	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	International Expansion
Type	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Cluster
Size	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Experience

Size	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Surge capacity
Size	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	International Expansion
Size	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Cluster
Experience	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Surge capacity
Experience	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	International Expansion
Experience	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Cluster
Surge capacity	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	International Expansion
Surge capacity	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Cluster
International Expansion	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Cluster

The data gathered in this questionnaire was then used to calculate the preference weights using AHP. This questionnaire was provided to the participants in the simulation game session, which overall took three weeks to complete for 42 expert and non-expert participants.

6.6.3 SECOND QUESTIONAIRE (EXPERIENCED BASED FEEDBACK)

Expert participants were asked to fill in this questionnaire about their opinion regarding the PREDIS model in comparison to the models they currently use. The non-expert participants currently do not have a model for partner selection and therefore cannot compare it with the PREDIS model. However, they were asked their opinion about the process of decision-making they experienced during the simulation game. The details of this questionnaire are elaborated in TABLE 6-5. The goal is to analyse the effect of expert's background on their evaluation of the PREDIS model. The components of the second questionnaire (feedback), is articulated in TABLE 6-5.

TABLE 6-5- COMPONENTS OF SECOND QUESTIONNAIRE (DECISION BASED FEEDBACK)

Goal	Question category	Criteria	Sub criteria	Expected response
Analysing the effect of expert background on their evaluation of the PREDIS model	Participant's characteristics	Age	< 35	It was expected from the respondents who have expressed their initial interest in participation, that the respondents are experienced, meaning they are older than 35, with experience in various sectors and in both international and national disasters.
			35 to 50	
			>50	
		Sector	Public humanitarian	
			NGO	
			Government	
			Military	
			Other	
		Number of Disaster	1 International	
			1 to 5 international	
			More than 5 international	
			Just national	
	Existing framework characteristics	Existing Framework	Yes	It was expected that most of the participants have frameworks in place and it takes them less than 12 hours to decide and have enough confidence in their framework to decide.
			No	
		How long to use the existing framework	< 1 hour	
			1 to 6 hours	
			< 12 hours	
		Confidence level in the existing framework	Very	
			Enough to decide	
			Better than nothing	
			Impossible to be confident	
	PREDIS framework characteristics	Simplicity of PREDIS	Simple/time effective	It is expected that the participants find the PREDIS simple and quick to use and use it in real disaster and recommend it to others.
			Simple/Time consuming	
			Complicated/time effective	
			Complicated/time consuming	
		Use of PREDIS in real disaster	Yes, instruction	
			No due to time	
			No, use my own	
			No, other reason	
		How long it takes to implement PREDIS in real situation	<1 hour	
			< 6 hours	
			< 12 hours	

Goal	Question category	Criteria	Sub criteria	Expected response
			>12 hours	
	Possibility to expand PREDIS in practice	Future use/recommendation of PREDIS	Yes	
			Yes, recommend	
			No	
			No, recommend	
		Why yes	Better than nothing	The answer to these questions is not clear at this point, because it depends on the comparison with the previous stage.
			Quick	
			Available data	
			Preference	
			Others	
		Why no	Vague	
			Untrustworthy	
			Unrealistic	
			Complicated	
			None	
			Areas of improvement	

TABLE 6-5 shows that the questionnaire gathers data on four areas, the characteristics of the participants, existing framework, PREDIS framework, and the reasoning behind their comparison.

The characteristics of the participants (age, sector, number of disaster): The demographic data (age) and an insight about the depth of knowledge (sector of experience, the number of disasters in which s/he participated). The reason for asking these questions is that in the pilot study the participants' responses to the level of experience were unrealistic. For example, a participant stated that he had 38 years of experience in disaster operations. Later it became clear that he has been providing consultancy to the humanitarian organisations on and off during the past 38 years. To differentiate between this participant and the participants who actually have been in the first line of disaster aid, three questions were asked: How old are you? The respondents below 35 of age were more likely to have less than 10 years of experience in the field, which is considered early OR career stage (OR society, 2015). The respondents between 35 and 50 years' of age were more likely to have more than 10 years of experience and still be active (not retired). The respondents older than 50, were more likely to be highly experienced, but have less current responsibilities in the first line of aid. This was combined with the questions on how many disasters they have had experience in and what type of organisations they have worked with. For example, an expert of over 50 who has experience of working in 2 national disasters and working for consultancy firms, overall is less experienced than an expert between 35 to 50 years of age who has experience of 10 national and 5 international disasters and has worked with the UN, Military, and NGOs. It was expected that the majority of respondents (because they expressed interest in participating as experts) are mature (more than 35) have lots of experience in both national and international disasters, and have cooperated with a variety of partners.

The characteristics of the existing framework (existence, length, confidence level): The existence of a framework was asked because it was necessary to know if the experts already have a decision-making process in place to which they can compare the PREDIS. It was expected that the majority of the participants have them and these can be used further as a source of comparison and analysis of the PREDIS. The length of their current decision-making process was also asked because in the early hours after the disaster strike, the decisions regarding aid can be crucial. For example, the medical triage employs the "golden hour" rule. This is the period of time (first hour) in which the treatment of the patient in shock or with traumatic injuries is most critical (Koelher, 1996). In addition, the time for rescue can also be divided into the periods of less than 1 hour, and 1-6 hours (Rutherford, 1998; DeBoer, 1990; Ferro, 2005). In addition, time frame for providing the first action plan for providing critical resource needs is 12 hours (Molino, 2006; MAdry, 2015). Therefore, the milestones for critical decisions to be made, for saving lives by medical triage (1 hour), saving lives by rescue (6 hours), and the action plan for critical resources needs (12 hours), can be set. It was expected that the majority of the participants make their decisions under 6 hours in order to be able to perform the initial rescue operations. However this would be one of the strength of PREDIS, where the decision makers have to decide within 6 hours based on no information, PREDIS provides predicted values. The level of confidence was also asked about in order to see how much the decision makers require to rely on the PREDIS model as a source of their confidence due to the predictions it provides. It was expected that the majority of the participants would be confident enough to make decisions but not very confidant.

The characteristics of the PREDIS framework (simplicity, real disaster, length): These questions were asked to specify if the PREDIS model could compete with the actual frameworks they are using at the moment. The few important points were, whether it is simple enough to be used under pressure, and by non-technical decision makers, also to make sure that the whole process does not supersede the critical time lines (1, 6, 12 hours). In other words, make sure that the author's assumption that the PREDIS can be used quickly by the decision makers is valid. It is expected that the participants find the PREDIS simple and quick to use and would use it in a real disaster, though some training might be required. The answer to these questions may signal the opportunity for the further expansion of PREDIS in the humanitarian sector. To that end the next level of questions are asked:

Possibility to expand PREDIS in practice (recommendation, why yes, why no): At this point it is clearly asked if the participants would use PREDIS in a real disaster. The participants are prepared for this question in the previous question where they have thought about the strength and weaknesses of the model and have compared it with their existing framework. The answer to these questions was not clear at this point because it depends on the answers to the previous questions. However ideally the participants would use PREDIS and recommend it to others whilst clearly stating why. If this happens, then the author has a clear idea if the PREDIS model has met the requirements for which it was designed including being quick, using the data that are available at the time of the disaster, and taking into account the preferences of the decision maker. In addition, they might come up with some unforeseen reasons why they favour PREDIS. This would pave the way for developing PREDIS further into software and finding a market for its expansion. However, if the majority answer no, and they provide the reasoning behind their choice including that they believe PREDIS to be untrustworthy, complicated, unreal or any other reason, they would signal the necessity to revisit the model critically. This questionnaire is exhibited in TABLE 6-6.

TABLE 6-6- SECOND QUESTIONNAIRE- EXPERIENCED BASED

The respondent's information
The respondent's age: a. Under 35 b. Between 35 to 50 c. Over 50 The respondent's sector of experience: a. Public humanitarians (UN, Red Cross, Medicine sans frontier, etc.) b. NGO c. Non-military part of a government d. Military e. Others (please explain) The respondent's experience in previous disasters: a. One international disaster

b. Between one and five international disasters
c. More than five international disasters
d. Just national disasters

The questionnaire:

1. Have you had a framework for partner selection in previous disaster situations?
    1.1. Yes
    1.2. No
2. If yes, how long does it take to perform this framework in real situation?
    2.1. Less than one hour
    2.2. Less than five hours
    2.3. Less than 12 hours
    2.4. More than 12 hours
3. How confident are you about the results of the decisions from your existing framework?
    3.1. Very confident
    3.2. Confident enough to make a decision
    3.3. Not so confident but it is better than no framework.
    3.4. There is against the nature of the disaster to be confident about any decision at the time of the disaster.
4. How simple was to make yourself familiarize with the new model?
    4.1. Relatively simple and time effective
    4.2. Relatively simple but time consuming
    4.3. Complicated but time effective
    4.4. Complicated and time consuming
5. Will you be able to perform this model at the real disaster situation?
    5.1. Yes, if I have the detailed instruction.
    5.2. No, because I will not have time in the disaster situation.
    5.3. No, because I will use my own framework.
    5.4. No, for other reasons (please explain)
6. How long does it take to use the new model without the help of the facilitator?
    6.1. Less than one hour
    6.2. Less than five hours
    6.3. Less than 12 hours
    6.4. More than 12 hours
7. Do you find this model helpful?
    7.1. Yes
    7.2. Yes, and I would recommend it to the colleagues.
    7.3. No, and I would not recommend it to the colleagues.
    7.4. No, but I would recommend it to colleagues.
8. If yes, what are the reasons? (You can choose one or all the answers).
    8.1. There is finally one guideline I can use.
    8.2. It is quick to perform.
    8.3. It uses available data.
    8.4. It accommodates my preferences.
    8.5. None of the above (Please explain)
9. If no (if you will not use it), what are the reasons?

9.1. It is vague.
9.2. I can’t trust the procedure.
9.3. It is not realistic (not close to the real situation at the time of the disaster).
9.4. It is complicated to use.
9.5. None of the above (please explain)

10. Would you lend us some time and identify the areas of improvement in the model.

To summarise TABLE **6-6** helps to identify if the expert’s opinion has been affected by their sector, number of disasters in which they have participated, by comparing the results of their decisions with the other experts with different characteristics. The questionnaire also gives an idea about the existence, time effectiveness and confidence level of the existing decision frameworks they might currently use. The objective is to compare that further with the PREDIS model. To that end, the questionnaire also gathers data about the opinions of the decision maker towards the simplicity and time effectiveness of PREDIS and directly asks the experts if they will use/recommend the PREDIS model in a real situation and the reasoning behind their positive or negative answer. At the end, there is an opportunity for the decision makers to point out the areas of improvement for the PREDIS model.

6.7 THE PROCESS OF SIMULATION GAME

The information about the experiment and invitation for participation was distributed amongst various organisations (Environment agency, Crisis departments of five different embassies, Business continuity departments of Munich RE, Barclays Bank and Lloyds bank, and individuals who had connections with humanitarian organisations including UN, UNISDR, UNICEF, World Vision, Caritas International, British Red Cross, American Red

Cross, Save the children and various specialised forums and groups related to disaster management on LinkedIn (including Business Continuity and Disaster Recovery Professionals, Business Continuity Management & Risk, Business Continuity/Disaster Recovery Network, Disaster & Emergency Management, Disaster, Disaster, Disaster Management - Multi Hazard Risk Assessment, Disaster Researchers and Disaster Management Professionals, Disaster Risk Management Practitioners, Emergency Preparedness Consultants / Trainers Group, GWU Institute for Crisis, Disaster and Risk Management, Humanitarian & Disaster Response Technology Network, Innovations in Disaster Management and Emergency Response !,Natural disasters and natural hazards, Natural Hazards and Disaster Risk Management, Performance Management, Professionals in Emergency Management, World Conference on Disaster Management) in addition to humanitarian summit (2014), Risk analysis conference (2014), OR society conference (2014) and UCL IRDR society.

As a result, 68 experts initially expressed their interest in participating. Out of this number, the sum of 29, made appointments to participate out of which 22 experts actually turned up at the appointments. These experts were from various backgrounds in different governments, international humanitarian organisations, NGOs, disaster consultancy professionals and corporate continuity departments in addition to military officers and fire brigade members. To make the non-expert groups comparable to the experts, an equal number of non-experts were invited by distributing invitations to various graduate and undergraduate students (by contacting their lecturers) in various areas of studies including but not limited to management, OR, disaster management, history, actuarial sciences, law and biology. In addition, the invitations were sent to any non-students who were interested in participating including engineers, HR professionals, MDs of private companies, health care managers, legal aid, high school teachers, social activists, and carpet designers. These contacts were made through the author's personal circle of acquaintances, and they were asked to forward this information to anyone they suspect might be interested. Overall, 112 individuals contacted the author, 37 made appointments and 35 turned up. However, in order to keep the group comparable to the experts, the author randomly selected 22 sessions. The sessions were held in one to one virtual appointments, which took place on Skype. The sessions were held during August 2014, and lasted between 45 to 90 minutes, depending on the length of participants' answers and suggestions. A booklet (Appendix 13) containing an explanation of the aims and objectives, the ethical form, which needed their consent, the description of the process, in addition to a short presentation (Appendix 15) to a model was sent out to the participants. After having their consent, a power point presentation was given by the facilitator, which explained briefly, how the model works and asked if they had any questions.

6.6.1. SIMULATION SCENARIO

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The disaster Haiyan scenario was presented to the participants in two stages. In the pre-test phase, the case provided in MIRA report is presented as is exhibited in FIGURE 6-9. The reason for choosing this disaster was that at that time, it was the most recent devastating disaster (apart from Ebola) that has occurred on an international scale and many of the participants had recently worked with or had heard news about it. The author assumed that this would motivate them to be curious about the effectiveness of PREDIS in similar circumstances and to participate with more enthusiasm. Although the facilitator gave them the option of selecting any other disaster, all participants continued with the Haiyan disaster.

FIGURE 6-9 SNAPSHOT OF THE DATA IN PRESENTATION (HAIYAN, 2013)

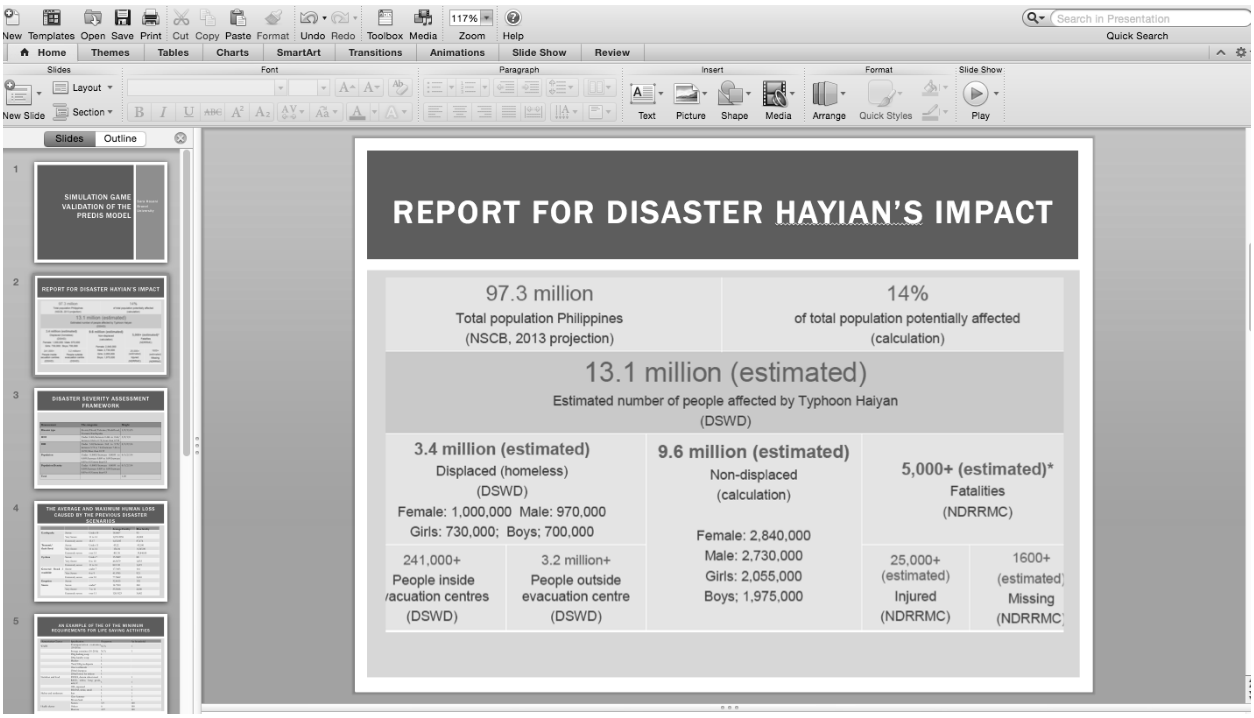

FIGURE **6-9** shows a report of the impact of the disaster regardless of what is required for the PREDIS model. The reason is to avoid disclosing any data about the PREDIS process in order to reduce the effect of pre-disposing the participants to “treatment” in the phase of “pre-test". This also helps the decision makers to use their experience and current frameworks in a way they normally use in disaster situation without being exposed to the process of the PREDIS model.

In the post-test phase the Haiyan disaster is again presented to them but in the brief format required for PREDIS model. The only information required for PREDIS model is the type, date and the country of the disaster occurance. Therefore the scenario presented at the post-test is as follows:

Type of the disaster: Tsunami
Date: 2013
Country: Philippines

The rest of the data is calculated by the PREDIS platform.

6.6.2. PARTNER SELECTION

In the pre-test phase of the simulation game, the participants were asked to rank a list of 20 partners. Due to the absence of a consolidated list of humanitarian partners, a hypothetical list of 20 partners is generated, using random number creation application on the excel office (Appendix 11). This list also was presented to the participants in two phases of post-test and pre-test in order to compare the result. This process will be explained in details further in the chapter.

During the questionaires the participants (experts) were also enquired about the frameworks they already have in place. Although a number of experts mentioned that they already have selection frameworks in place, none of them provided an actual ranking of the desired partners at this phase. For example HISS-CAM framework (FIGURE **6-10**) provided by

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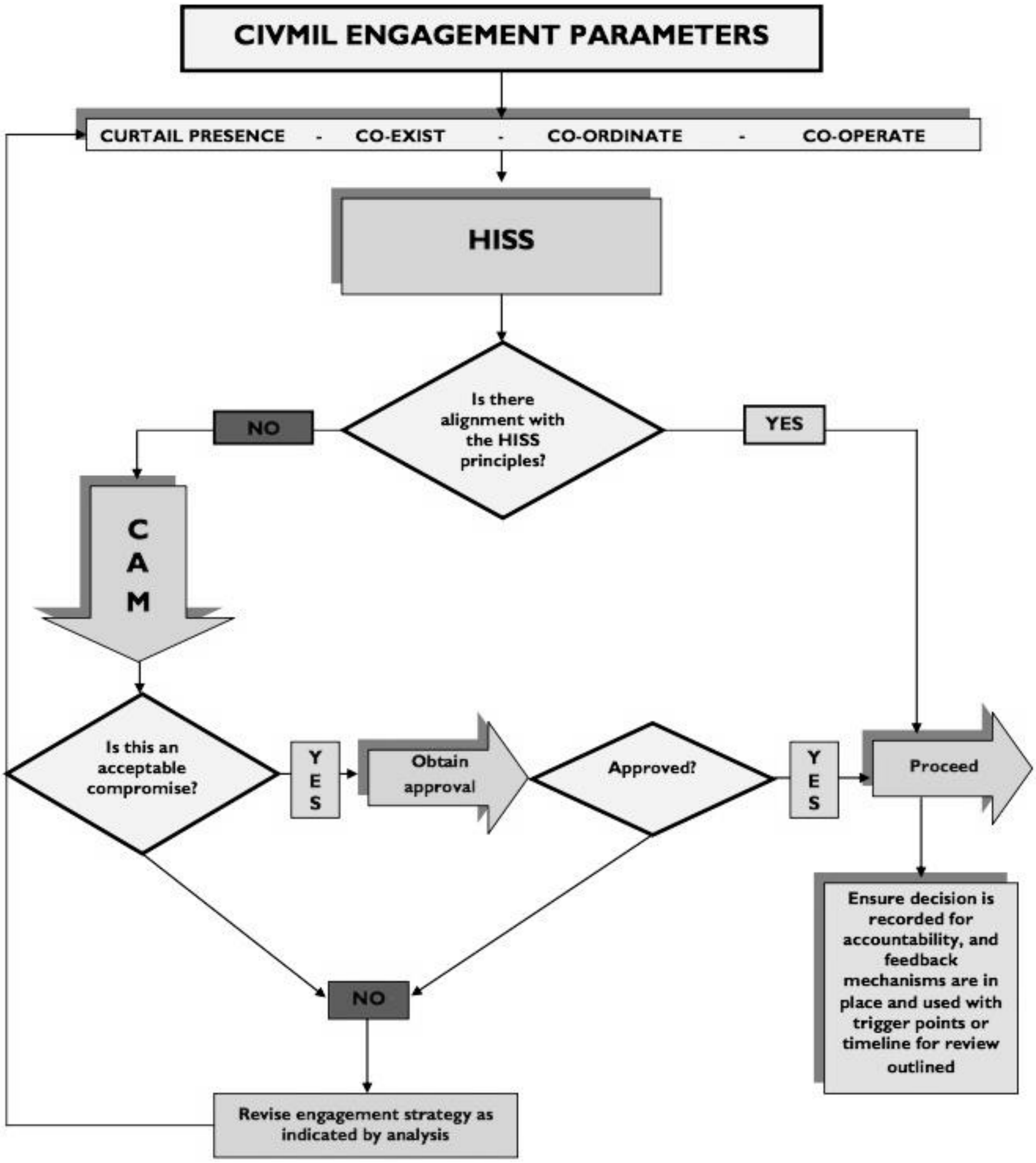
World vision organisation is designed to ensure a balance combination of civil–military (CIVMIL) partners in a disaster response.

FIGURE 6-10 FRAMEWORK FOR CHOOSING PARTNERS BY WORLD VISION



Source: The European Interagency Security Forum (2008)

In FIGURE **6-10**, HISS stands for Humanitarian, Impartiality, Safety and Sustainability) and CAM stands for Compelling aim, Appropriate information and Minimising negative impact (Odihpen.org, 2015). This framework has been used for partner selection in Afghanistan and Georgia amongst other countries, since 2008. It shows a flowchart were judgment calls need to be used to make sure the partners are aligned with the HISS principles. However, this does not provide numerical data about selecting the partners based on tasks. Another example is the American Red Cross cooperation with local churches in gathering the supplies from their warehouses (conversation with a former employee, 2014) which is done by calling the churches one by one to ensure the availability of the stock before sending out the trucks to bring their supplies. This is done on a first come first served basis and is based on the existing connections between the two entities (Red Cross and churches).

To that end, most of the existing frameworks for partner selections mentioned in the process of simulation game, were understandably based on the elements of experience-based trust or resource-based choices. Meaning if the decision maker has had previously worked with a partner and trusted them, they were first in line to be called in, regardless of their current capabilities or the specific requirements of the disaster. In addition, if the decision maker knew, based on their experience, that some partners might be able to supply few resources, they were selected for participation. The treatment part of experiment was the simulation game where the participants were exposed to the principles of PREDIS model in the presentation (Appendix 15), which is also outlined in the booklet (Appendix 13). In the post-test, participants were asked to fill out the first questionnaire (DECISION PREFERENCE) leading to the calculation of their AHP preferences by the facilitator. An example of one of this process is exhibited in FIGURE 6-11.

FIGURE 6-11 A SNAPSHOT OF THE PROCESS OF CALCULATING AHP PREFERENCE

Analytic Hierarchy Template: n=	5	Criteria

Fundamental Scale (Row v Column)	
Extremely less important	1/9
	1/8
Very strongly less important	1/7
	1/6
Strongly less important	1/5
	1/4
Moderately less important	1/3
	1/2
Equal Importance	1
	2
Moderately more important	3
	4
Strongly more important	5
	6
Very strongly more important	7
	8
Extremely more important	9

Type

Pairwise Comparison Matrix

	Govornment	NGO	Military	Volunteer	International
Govornment	1	5	7	9	8
NGO	1/5	1	9	2	3
Military	1/7	1/9	1	2	7
Volunteer	1/9	1/2	1/2	1	1
International	1/8	1/3	1/7	1	1
~~Requirement 6~~	~~1~~	~~1~~	~~1~~	~~1~~	~~1~~
~~Requirement 7~~	~~1~~	~~1~~	~~1~~	~~1~~	~~1~~
~~Requirement 8~~	~~1~~	~~1~~	~~1~~	~~1~~	~~1~~
~~Requirement 9~~	~~1~~	~~1~~	~~1~~	~~1~~	~~1~~
~~Requirement 10~~	~~1~~	~~1~~	~~1~~	~~1~~	~~1~~
~~Requirement 11~~	~~1~~	~~1~~	~~1~~	~~1~~	~~1~~
~~Requirement 12~~	~~1~~	~~1~~	~~1~~	~~1~~	~~1~~
~~Requirement 13~~	~~1~~	~~1~~	~~1~~	~~1~~	~~1~~
~~Requirement 14~~	~~1~~	~~1~~	~~1~~	~~1~~	~~1~~
~~Requirement 15~~	~~1~~	~~1~~	~~1~~	~~1~~	~~1~~
Column totals	1.5790	6.9444	17.6429	15.0000	20.0000

Cw (Normalised)					
1	0.633324956	0.72	0.396761134	0.6	0.4
2	0.126664991	0.144	0.510121457	0.133333333	0.15
3	0.090474994	0.016	0.056680162	0.133333333	0.35
4	0.07036944	0.072	0.028340081	0.066666667	0.05
5	0.07916562	0.048	0.008097166	0.066666667	0.05

FIGURE 6-11.

FIGURE 6-11 shows the preferences of one of the participants towards the type of the partners. This is calculated by a set of pairwise comparison matrices where the verbal preference (e.g. extremely less/more important) is translated into numerical values (e.g. 1/9 to 9). The AHP weight calculated for these values can get values from zero to 1.0 or from 0% to 100% (FIGURE 6-12).

FIGURE 6-12- AN EXAMPLE OF AHP VALUES CALCULATED

	AHP	
1	0.608	60.8%
2	0.168	16.8%
3	0.094	9.4%
4	0.065	6.5%
5	0.065	6.5%

For example in FIGURE **6-12**, the government had the highest value for this particular participant (60.8%) whilst the International organisations and volunteers had the lowest value (6.5%). In other words, if s/he wanted to decide based on the type of the organisation s/he would definitely choose the government over International organisations.This process gives a full set of preference for each unit of resource per partner (TABLE **6-7**).

TABLE 6-7 EXAMPLE OF AHP FOR A PARTICIPANT / UNIT OF RESOURCE PER PARTNER

Resources	AHP weight	Partner 1	Partner 2	Partner 3	Partner 4	Partner 5
Total basic water needs	0.58407534	0.46365588	0.49915368	0.60237036	0.7427232	0.6225768
Rice	0.12190161	0.09676902	0.10417772	0.12571994	0.1550128	0.1299372
Tent	0.7279017	0.5778294	0.6220684	0.7507018	0.925616	0.775884
Doctors	0.09822288	0.07797216	0.08394176	0.10129952	0.1249024	0.1046976

For example TABLE **6-7** shows that the preference for Doctors (a resource in the health cluster) for this participant is AHP= 0.98 or 9.8%; whilst s/he considered water (a resource in the WASH cluster) much more important (AHP= 0.58 or 58%). In addition, the AHP weight of each resource for each partner was calculated. For example the water provided by Partner 4 had a higher preference (74%) than the water provided by partner 2 (49%) due to the preference this participant had towards the characteristics of these partners (including type, size, expansion and so on). These AHP weights then were used to calculate the utility of each resource as well as the utility of that resource for that partner (TABLE **6-8**).

TABLE 6-8 EXAMPLE OF THE UTILITY FOR A PARTICIPANT

Resource	Utility	Partner 1	Partner 2	Partner 3	Partner 4	Partner 5
Water	25.11523962	15.30064404	42.92721648	23.49244404	13.3690176	47.3158368
Rice	4.14465474	7.54798356	10.00106112	5.40595742	15.3462672	10.7847876
Tent	67.6948581	39.2923992	14.3075732	22.521054	71.272432	51.984228
Doctors	6.77737872	4.83427392	3.44161216	6.0779712	7.7439488	8.899296

For example in TABLE **6-8**, the utility of the water provided by Partner 1 is 15.30, whilst the utility of water for all the partners is 25.11. The total utility of all the resources that each partner holds can be calculated as the accumulated values of that partner's utilities. For example, for these particular participants, the utility of partners can be calculated and be used to rank the partners as exhibited in TABLE **6-9**.

TABLE 6-9 EXAMPLE OF PARTNERS RANKED / PARTICIPANT'S PREFERENCES

Rank	Partner	Total Utility	Type	Size	Expansion	Experience	Surge capacity
1	Partner 5	1520.571854	Government	Small	Yes	Low	Low
2	Partner 14	1371.679272	Government	Small	No	Low	Low
3	Partner 18	1354.951272	Government	Small	Yes	Low	Very high
4	Partner 12	1307.893611	Government	Small	Yes	High	High
5	Partner 16	1164.387224	Government	Medium	Yes	Low	Very high
6	Partner 6	1146.227455	NGO	Small	No	Very high	Low
7	Partner 13	1052.240062	Volunteer	Small	Yes	Medium	Low
8	Partner 3	1031.564786	Volunteer	Medium	Yes	High	High
9	Partner 10	1030.562215	Volunteer	Small	Yes	High	Very high
10	Partner 9	1016.64566	Government	Medium	No	High	Very high

TABLE **6-9** shows an example of the rankings of the partners based on this participant's preferences. For example, Partner 5 is the most desirable partner with a utility of 1520. This also shows that the most desirable partners for these participants are small governmental entities. In addition, it seems that this participant does not value the experience or the surge capacity of the partners as critical requirements for a disaster response. Finally, the experts were asked to fill out the second questionnaire. An example of the accumulated data is exhibited in TABLE **6-10**.

TABLE 6-10 EXAMPLE OF ACCUMULATED DATA IN SECOND QUESTIONNAIRE

Participants information	Options	Expert 1	Expert 2
The responder's age	a. Under 35		
	b. Between 35 to 50		1
	c. Over 50	1	
The respondent's sector of experience:	a. Public humanitarians		
	b. NGO	1	1
	c. Non-military part of a government		
	d. Military	1	
The respondent's experience in previous disasters:	a. 1 international disaster	1	
	b. Between one and five international disasters		
	c. More than five international disasters		1
	d. Just national disasters/US	US	
1. Have you had a framework for partner selection in previous disaster situations?	a. Yes		
	b. No	Not a formal one	b. No (Because I am operation, they are some guidelines, specific around capabilities /radio partner with locals).
2. If yes, how long does it take to perform this framework in real situation?	a. Less than one hour		
	b. Less than five hours/ Not extremely detailed	Not extremely detailed	
	c. Less than 12 hours		

Participants information	Options	Expert 1	Expert 2
	d. More than 12 hours		1
3. How confident are you about the result of the decision from your existing framework?	a. Very confident		
	b. Confident enough to make a decision	Biased, they have a commitment biased, stick to the commitment, because they don't want to lose. Overestimate their decision capabilities.	1
	c. Not so confident but is better than no framework.		
	d. There is against the nature of the disaster to be confident about any decision at the time of the disaster.		
4. How simple were to make you familiarise with the new model?	a. Relatively simple and time effective		
	b. Relatively simple but time consuming		Understanding of your own organisation is more important, content critical; military shows how that is critical.
	c. Complicated but time effective	Completely will decrease by practice.	
	d. Complicated and time consuming		
5. Will you be able to perform this model at the real disaster situation?	a. Yes, if I have the detailed instruction	Prior to disaster	
	b. No because I will not have time in the disaster situation.	Most decision makers say	
	c. No because I will use my own framework.		
	d. No, for other reasons (please explain).		Complicated, tangible information, not interested in partner selection, predicting damage and e1trapolating the amount of needs. Range helps, 100-150,000 helps.

TABLE **6-10** shows an example of the answers two of experts have provided to the second questionnaire. For example expert 1 who is over 50 years of age and has experience in working with NGO s and the military in one International disaster and mostly national US disasters, does not have a formal framework for decision-making. Furthermore, s/he is not extremely detailed about whether s/he is confident about this informal framework enough to make decision, however s/he believes that the big partners are biased towards their decisions and because they do not want to lose, they overestimate their decision capabilities. For this reason, s/he prefers the small partners to the big ones. S/he also believes that although the PREDIS model is complicated, it is time effective, and the time required for performing it, will considerably decrease with practice. S/he is able to use PREDIS if receiving training before the disaster strikes, however s/he believes that most of the decision makers will say they will not have time to use PREDIS in a real disaster situation.

The second expert who is younger (between 35 and 50) has experience of working with NGOs in more than five international disasters. Because s/he is operational, does not have a framework for decision-making per se, but s/he uses some guidelines, specific around capabilities /radio partner with locals, which takes less than 12 hours to perform. S/he believes that PREDIS is simple but time consuming, and knowing your organisation is more important. This person is not interested in the partner selection part of the PREDIS, but very interested in the tangible information, which the predictive part of the PREDIS can provide about the amount of needs. In fact, this conversation with this expert led to a suggestion for cooperation with the author to develop PREDIS into a real time software program in the future. S/he also believes predicting a range helps a lot as long as the range, is between 100 and 150,000. This answer, which is confirmed by several other experts, is very important because it further assured the author that giving the range for the predictions, is not a limitation of PREDIS, but can be considered a strength from the experts' point of view. The overall result of the simulation game is further elaborated as follows.

6.8 THE RESULT OF THE SIMULATION GAME

First, it is noteworthy to mention that the result of the pre-test in two groups of expert and non-experts are incomparable to each other. The reason is that none of the participants could come up with an actual list of selected or ranked partners. The reason might be due to the lack of existing practical frameworks, which allow the calculation of numerical or ordinal values. This signals that most of the decisions in this area are done heuristically and as will be confirmed later in the result of the questionnaire 2 (DECISION BASED FEEDBACK) the decisions are mostly experience-based rather than evidence-based.

Therefore, only the results of the post-test for two groups of experts and non-experts are comparable here. These results (Appendix **16**) can be interpreted in two sections. The results of the first questionnaire identify how the experts and non-experts prefer one partner to another. The results of the second questionnaire identify how the experts evaluate the PREDIS model compared with their existing frameworks.

6.8.1 THE RESULT OF THE FIRST QUESTIONAIRE (DECISION PREFERENCE)

The results of the first questionnaire (DECISION PREFERENCES), exhibited inAppendix **16**, lead to the AHP preferences, which are compared for both groups of experts and non-experts in TABLE **6-11**.

TABLE 6-11 COMPARING AHP PREFERENCES / EXPERTS AND NON-EXPERTS

Level 1	Level 2	Non Expert	Expert
Type	Government	0.069	0.118
	NGO	0.019	0.045
	Military	0.081	0.042
	Volunteers	0.052	0.024
	International	0.021	0.034
Size	Small	0.036	0.625
	Medium	0.016	0.025
	Big	0.016	0.023
	Very big	0.033	0.051

Level 1	Level 2	Non Expert	Expert
International Expansion	Yes	0.06	0.653
	No	0.022	0.005
Experience	Low	0.026	0.042
	Medium	0.039	0.045
	High	0.066	0.06
	Expert	0.177	0.099
Surge capacity	Low	0.025	0.027
	Medium	0.029	0.022
	High	0.025	0.029
	Very high	0.074	0.06
WASH	Transportation container (10-20 lit)	0.086	0.097
	Storage container (10-20 lit)	0.086	0.097
	250g bathing soap	0.086	0.097
	200g laundry soap	0.086	0.097
	Acceptable material for menstrual hygiene	0.086	0.097
	Blanket-	0.086	0.097
	75ml/100g toothpaste	0.086	0.097
	One toothbrush -	0.086	0.097
	250ml shampoo	0.086	0.097
	250ml lotion for infants and children up to 2 years of age	0.086	0.097
	One disposable razor	0.086	0.097
	Underwear for women and girls of menstrual age	0.086	0.097
	One hairbrush and/or comb	0.086	0.097
	Nail clippers	0.086	0.097
	Total basic water needs	0.086	0.097
	Water for patients	0.086	0.097
	Water tap	0.086	0.097
	Hand Pump	0.086	0.097
	Open well	0.086	0.097
	Toilets	0.086	0.097
	Trench latrines,	0.086	0.096
Nutrition	SALT, iodised edible	0.036	0.035
	SUGAR, white	0.036	0.035
	YEAST, dried, package 11 gr	0.036	0.035
	FISH, canned, sardines, veg oil, 150g	0.036	0.035
	PASTA, durum wheat meal	0.036	0.035
	RICE, white, long grain, irri6/2	0.036	0.035
	OIL, rapeseed	0.036	0.035
	BEANS, white, small	0.036	0.035
Shelter Cluster	Tarpaulin (4mX6m)	0.023	0.067
	Rope (30 m)	0.023	0.067
	Saw	0.023	0.067
	Roding, small and largo Nail (1/2 kg each)	0.023	0.067
	Shovel	0.023	0.067
	Hoe	0.023	0.067
	Machete	0.023	0.067
	Shear	0.023	0.067
	Wire (1.5 mm diameter) meter	0.023	0.067
	Claw hammer	0.023	0.067
	Woven Sack	0.023	0.067

Level 1	Level 2	Non Expert	Expert
Health Cluster	Doctors	0.054	0.047
	Nurses	0.054	0.047
	Other specialties	0.054	0.047

TABLE **6-11** shows that the experts' preferences on average put more value on government (12%), and almost the same value on NGO (4.5%) and military (4.2%). On the other hand the non-experts put more value on military (8%) followed by government (7%), and volunteers (5.2%). Experts put more value on the small sized organisations (62%), whilst the non-experts gave the same value (3%) to small and very big organisations. Experts gave a high value for international expansion (65%), whilst non-experts had a low preference for international expansion (6%). Both groups had a high value for partners with more experience, however non-experts preferred experience (18%) to experts (10%). Both groups gave a higher value for the partner with higher surge capacity, 8% for non-experts, and 6% for experts. However, for the lower surge capacities both values were around 2%. The experts gave the highest value for WASH (9.7%) shelter (7%), health (5%), and nutrition (35%) whilst non-experts gave the highest value for WASH (8.6%) health (5%) nutrition (36%) and shelter (2%).

These preferences in combination with the resources available to the partners can be used to calculate the utility of each partner. An example of these data is articulated in TABLE 6-12.

TABLE 6-12 EXAMPLE OF DATA REQUIRED TO CALCULATE PREFERENCE

	Total basic water needs	Rice	Tent	Doctors

	Total basic water needs	Rice	Tent	Doctors
Decision maker preference	0.033	0.013	0.013	0.094
Partner 1	43	34	93	69
Partner 2	33	78	68	62
Partner 3	86	96	23	41
Partner 4	39	43	30	60
Partner 5	18	99	77	62
Partner 6	76	83	67	85
Partner 7	88	34	75	68
Partner 8	42	27	21	8
Partner 9	28	69	28	69
Partner 10	76	11	2	45
Partner 11	9	11	45	11
Partner 12	40	31	80	30
Partner 13	63	10	13	13
Partner 14	58	97	88	29
Partner 15	77	82	47	92
Partner 16	97	52	58	95
Partner 17	92	84	2	34
Partner 18	10	49	6	23
Partner 19	69	96	78	31
Partner 20	24	99	2	12

TABLE **6-12** shows that the decision maker's preference for the resources including water, rice, tent, and doctors respectively was equal to 0.33, 0.013, 0.013 and 0.094. In addition, the amount of available resources for the partners is exhibited. For example, the amount of water available to the partner 1 is 43 units, and partner 19 has 96 units of rice available to them. Based on the above preferences the partners' priorities (AHP weights) are calculated for each partner per resource as $U_{ni} = Ri * Pj$

Where *U* is the utility of the partner *n* for resource *i*

Ri is the units of resource *i* available to partner *n*

Pj is the weight of resource *i* from the view point of decision maker *j*

For example if the decision maker's preference for water in the Hayian disaster is calculated as 0.033 (3.3%), then the utility of partner 1 for water is calculated as: $0.33 * 43 =$

0.142. This value is calculated for all the partners/resources, a part of these utilities are calculated in TABLE **6-13**.

TABLE 6-13 UTILITIES OF EACH PARTNER RESOURCES / EXEMPLARY DECISION MAKER

Utility	Total basic water needs	Rice	Tent	Doctors
Partner 1	1.419	0.442	1.209	6.486
Partner 2	1.089	1.014	0.884	5.828
Partner 3	2.838	1.248	0.299	3.854
Partner 4	1.287	0.559	0.39	5.64
Partner 5	0.594	1.287	1.001	5.828
Partner 6	2.508	1.079	0.871	7.99
Partner 7	2.904	0.442	0.975	6.392
Partner 8	1.386	0.351	0.273	0.752
Partner 9	0.924	0.897	0.364	6.486
Partner 10	2.508	0.143	0.026	4.23
Partner 11	0.297	0.143	0.585	1.034
Partner 12	1.32	0.403	1.04	2.82
Partner 13	2.079	0.13	0.169	1.222
Partner 14	1.914	1.261	1.144	2.726
Partner 15	2.541	1.066	0.611	8.648
Partner 16	3.201	0.676	0.754	8.93
Partner 17	3.036	1.092	0.026	3.196
Partner 18	0.33	0.637	0.078	2.162
Partner 19	2.277	1.248	1.014	2.914
Partner 20	0.792	1.287	0.026	1.128

The total utility for all the needs/resources can be accumulated as ΣU_{ni} for example the utility of partner 1 is equal to $(U_{1water} + U_{1Rice} + U_{1Tent} + U_{1Doctors} + \cdots)$. This amount for the above decision maker is equal to 89.222. The utility of each partner for this decision maker is calculated and exhibited inTABLE **6-14**.

TABLE 6-14 TOTAL UTILITY OF EACH PARTNER / EXEMPLARY DECISION MAKER

Partner	Utility of each partner
Partner 1	89.222
Partner 2	107.337
Partner 3	122.526
Partner 4	88.387
Partner 5	104.817
Partner 6	100.534
Partner 7	102.338
Partner 8	95.265
Partner 9	89.72
Partner 10	96.388
Partner 11	93.269
Partner 12	87.676
Partner 13	98.831
Partner 14	98.711
Partner 15	107.361
Partner 16	108.654
Partner 17	107.002
Partner 18	96.672
Partner 19	89.998
Partner 20	99.97

TABLE 6-14 shows the total utility of partner 1, 2, 3 respectively as 89.22, 107.337, and 122.526, and so on. The least desirable partner for this decision maker was Partner 1 (89.22) and the most desirable was partner16 (108.65). This gives rise to ranking the partners as shown in TABLE 6-15.

TABLE 6-15 UTILITY OF EACH PARTNER FOR THIS PARTICULAR DECISION MAKER

Partner	Utility	Rank	Type	Size	Expansion	Experience	Surge capacity
Partner 3	122.526	1	Government	Small	No	Low	Low
Partner 16	108.654	2	Volunteer	Very big	Yes	Low	High
Partner 15	107.361	3	Volunteer	Small	Yes	High	Medium
Partner 2	107.337	4	Government	Small	Yes	High	High
Partner 17	107.002	5	Government	Medium	No	High	Very high

Partner	Utility	Rank	Type	Size	Expansion	Experience	Surge capacity
Partner 5	104.817	6	Government	Medium	Yes	Low	Very high
Partner 7	102.338	7	Government	Small	Yes	Low	Very high
Partner 6	100.534	8	International	Very big	Yes	Very high	Medium
Partner 20	99.97	9	Volunteer	Small	Yes	Medium	Low
Partner 13	98.831	10	Government	Small	Yes	Low	Low
Partner 14	98.711	11	NGO	Small	No	Very high	Low
Partner 18	96.672	12	Volunteer	Small	Yes	High	Very high
Partner 10	96.388	13	Military	Small	Yes	Low	Medium
Partner 8	95.265	14	Volunteer	Small	Yes	Very high	Medium
Partner 11	93.269	15	Volunteer	Medium	Yes	High	High
Partner 19	89.998	16	Government	Very big	Yes	Low	Medium
Partner 9	89.72	17	Government	Very big	Yes	Low	Low
Partner 1	89.222	18	Government	Big	Yes	Very high	Low
Partner 4	88.387	19	International	Big	Yes	Low	High
Partner 12	87.676	20	Military	Small	No	Low	Very high

TABLE 6-15 shows the ranking of the partners based on the preference of this particular decision maker. This shows that the favourite partner for this particular decision maker was partner 13 with a utility of 122.526, which is a small governmental entity with no international expansion, low experience, and low surge capacity. On the other hand, her/his least favourite was partner 12, with the utility of 87.676, which is a small military entity with no international expansion, low experience and very high surge capacity. This process of ranking has been repeated 44 times equal to the number of participants in both groups of experts and non-experts (Appendix 16). The result has been compared in the next section.

To take the selection of the partners and allocation of resources further, the partners utility in an optimization problem with the following restrictions.

EQUATION 7 – RESTRICTION 1

$$\sum_{i=1}^{n} x_{i,j} \geq 100, \forall_i \in N$$

Where $\boldsymbol{x_{i,j}}$ is the units of resource i obtained from the partner j.

EQUATION 7 shows that the total units accuired from all partners should not exceed the 100% of the total resources required. The second restriction shows that the number of the units obtained from the partner should not exceed the resources available to that partner.

EQUATION 8 – RESTRICTION 2

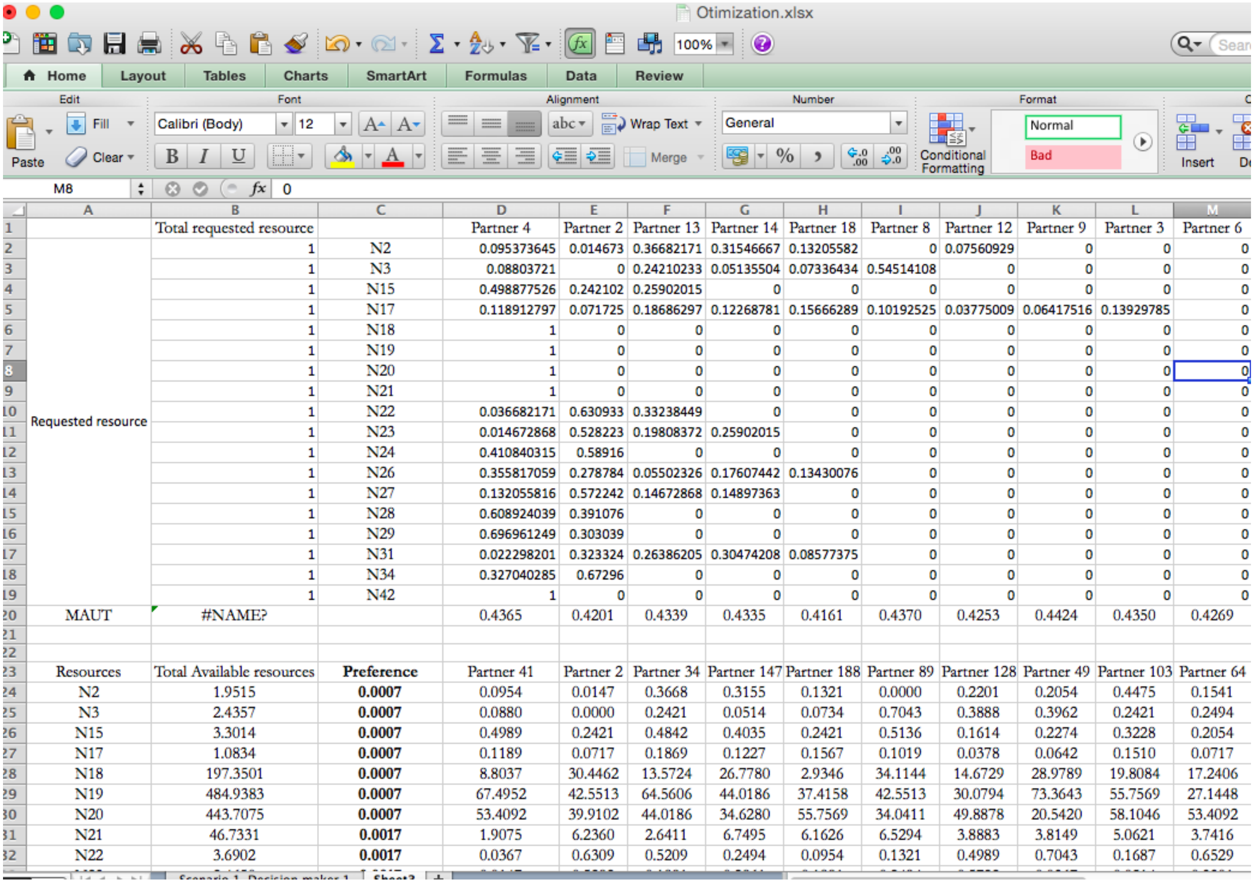
$$\boldsymbol{0 \leq xi, j \leq Rij}, \forall_{\boldsymbol{i}} \in \boldsymbol{M}, \boldsymbol{j} \in \boldsymbol{N}$$

Where $\boldsymbol{x_{i,j}}$ is the units of resource i obtained from the partner j.

And $\boldsymbol{R_{i,j}}$ is the number of the unit of resources i available to partner j.

A snapshot of the calculated result for one of the participants is shown below as an example :

FIGURE 6-13 A SNAPSHOT OF THE OPTIMISED EQUATION



	A	B	C	D	E	F	G	H	I	J	K	L	M
1		Total requested resource		Partner 4	Partner 2	Partner 13	Partner 14	Partner 18	Partner 8	Partner 12	Partner 9	Partner 3	Partner 6
2	Requested resource	1	N2	0.095373645	0.014673	0.36682171	0.31546667	0.13205582	0	0.07560929	0	0	0
3		1	N3	0.08803721	0	0.24210233	0.05135504	0.07336434	0.54514108	0	0	0	0
4		1	N15	0.498877526	0.242102	0.25902015	0	0	0	0	0	0	0
5		1	N17	0.118912797	0.071725	0.18686297	0.12268781	0.15666289	0.10192525	0.03775009	0.06417516	0.13929785	0
6		1	N18	1	0	0	0	0	0	0	0	0	0
7		1	N19	1	0	0	0	0	0	0	0	0	0
8		1	N20	1	0	0	0	0	0	0	0	0	0
9		1	N21	1	0	0	0	0	0	0	0	0	0
10		1	N22	0.036682171	0.630933	0.33238449	0	0	0	0	0	0	0
11		1	N23	0.014672868	0.528223	0.19808372	0.25902015	0	0	0	0	0	0
12		1	N24	0.410840315	0.58916	0	0	0	0	0	0	0	0
13		1	N26	0.355817059	0.278784	0.05502326	0.17607442	0.13430076	0	0	0	0	0
14		1	N27	0.132055816	0.572242	0.14672868	0.14897363	0	0	0	0	0	0
15		1	N28	0.608924039	0.391076	0	0	0	0	0	0	0	0
16		1	N29	0.696961249	0.303039	0	0	0	0	0	0	0	0
17		1	N31	0.022298201	0.323324	0.26386205	0.30474208	0.08577375	0	0	0	0	0
18		1	N34	0.327040285	0.67296	0	0	0	0	0	0	0	0
19		1	N42	1	0	0	0	0	0	0	0	0	0
20	MAUT	#NAME?		0.4365	0.4201	0.4339	0.4335	0.4161	0.4370	0.4253	0.4424	0.4350	0.4269
21													
22													
23	Resources	Total Available resources	**Preference**	Partner 41	Partner 2	Partner 34	Partner 147	Partner 188	Partner 89	Partner 128	Partner 49	Partner 103	Partner 64
24	N2	1.9515	**0.0007**	0.0954	0.0147	0.3668	0.3155	0.1321	0.0000	0.2201	0.2054	0.4475	0.1541
25	N3	2.4357	**0.0007**	0.0880	0.0000	0.2421	0.0514	0.0734	0.7043	0.3888	0.3962	0.2421	0.2494
26	N15	3.3014	**0.0007**	0.4989	0.2421	0.4842	0.4035	0.2421	0.5136	0.1614	0.2274	0.3228	0.2054
27	N17	1.0834	**0.0007**	0.1189	0.0717	0.1869	0.1227	0.1567	0.1019	0.0378	0.0642	0.1510	0.0717
28	N18	197.3501	**0.0007**	8.8037	30.4462	13.5724	26.7780	2.9346	34.1144	14.6729	28.9789	19.8084	17.2406
29	N19	484.9383	**0.0007**	67.4952	42.5513	64.5606	44.0186	37.4158	42.5513	30.0794	73.3643	55.7569	27.1448
30	N20	443.7075	**0.0007**	53.4092	39.9102	44.0186	34.6280	55.7569	34.0411	49.8878	20.5420	58.1046	53.4092
31	N21	46.7331	**0.0017**	1.9075	6.2360	2.6411	6.7495	6.1626	6.5294	3.8883	3.8149	5.0621	3.7416
32	N22	3.6902	**0.0017**	0.0367	0.6309	0.5209	0.2494	0.0954	0.1321	0.4989	0.7043	0.1687	0.6529

FIGURE 6-13 shows that in order to maximise the MAUT for the particular participant (decision maker), the following resources need to be selected. For example 9.5% of the resource N2 should be obtained from partner 4,whilst no units of N2 is obtained from partner 8, 9, 3, 6.

6.8.2 COMPARING THE RESULT OF THE FIRST QUESTIONNAIRE

To compare the result between the two groups, a variation of outranking method associated to Borda (Marchant, 1996) or Roy (Bouyssou, 2001) has been employed. The reason is that this is a classic MCDM problem, where a set of alternatives is selected based on preferences expressed by decision maker (Buoyssou, 2001). A common solution is to examine if for example, partner (a) is at least as good as for example, partner (b). The outranking techniques under this rule have been used to support decision-making in voting (Jurij, 2006), supplier selection (De Boer et al, 2008) or project assessment (Nurmi and Salonen, 2008) amongst others. If a selection consists of a set D of Decision makers (here 22 decision makers for each group), each having a preference order for a set of C candidates (here 20 partners), the Borda rule here is calculated where a partner receives *n* points each time they are selected as the most desirable, *n-1* points when they are selected second to most desirable, and no points every time they are selected as the least desirable (Russell, 2007). Here *n* is the number of candidates (here 20 partners) and 22 decision makers for each group of experts and non-experts. So using this technique, for experts, the Borda rule for partner i can be calculated as follows:

- Experts have never (0 frequency) selected partner 1 as their first choices (n=20), so the Borda count is (0 * 20)=0
- Experts have never (0 frequency) selected partner 1 as their second choices (n-1=19) so the Borda count is (0 * 19) =0
- …
- Experts have twice (2 frequency) selected partner 1 as their eighth choices (n-7=20-7) so the Borda count is (2 * 13)= 26

The total Borda count for partner 1 is the sum of above individual Borda counts for partner 1. These individual and total Borda counts are calculated in Appendix **16**. An example of these results for experts is exhibited in TABLE **6-16**.

TABLE 6-16 EXAMPLE OF THE BORDA COUNT FOR THE GROUP OF EXPERTS

		Partner 1		Partner 2		Partner 3		Partner 4	
Choice	N	Frequency	Borda	Frequency	Borda	Frequency	Borda	Frequency	Borda
1st	n	0	0	2	40	4	80	15	300
2nd	n-1	0	0	3	57	4	76	5	95
3rd	n-2	0	0	2	36	3	54	1	18
4th	n-3	0	0	9	153	2	34	0	0
5th	n-4	0	0	1	16	4	64	2	32
6th	n-5	0	0	2	30	0	0	0	0
7th	n-6	0	0	0	0	0	0	0	0
8th	n-7	2	26	0	0	1	13	0	0
9th	n-8	0	0	0	0	0	0	0	0
10th	n-9	0	0	1	11	0	0	0	0
11th	n-10	0	0	0	0	0	0	1	10
12th	n-11	3	27	0	0	0	0	1	9
13th	n-12	1	8	0	0	0	0	1	8
14th	n-13	0	0	1	7	0	0	0	0
15th	n-14	3	18	1	6	0	0	0	0
16th	n-15	13	65	0	0	0	0	0	0
17th	n-16	0	0	0	0	0	0	1	4
18th	n-17	0	0	0	0	0	0	0	0
19th	n-18	0	0	0	0	1	2	7	14
20th	n-19	0	0	0	0	3	3	10	10
Total Borda count			144		356		326		500

TABLE 6-16 shows that the total Borda count for partner 1,2,3,4 has been respectively calculated as 144, 456, 326, and 500. This means that in this set, partner 4 is the most desirable in the overall view of the experts. The final results of the Borda counts are calculated for all the 20 partners and are ranked in TABLE 6-17.

TABLE 6-17 EXPERT BORDA COUNT RANKING

Partner	Borda count	Type	Size	Expansion	Experience	Surge capacity
Partner 4	500	Military	Small	No	Low	Very high
Partner 5	427	Government	Small	Yes	Low	Low

Partner	Borda count	Type	Size	Expansion	Experience	Surge capacity
Partner 2	356	Military	Small	Yes	Low	Medium
Partner 16	344	Government	Medium	Yes	Low	Very high
Partner 3	326	Volunteer	Medium	Yes	High	High
Partner 7	294	Volunteer	Small	Yes	High	Medium
Partner 17	292	International	Very big	Yes	Very high	Medium
Partner 18	283	Government	Small	Yes	Low	Very high
Partner 8	271	Volunteer	Very big	Yes	Low	High
Partner 12	252	Government	Small	Yes	High	High
Partner 15	250	International	Big	Yes	Low	High
Partner 20	231	Government	Very big	Yes	Low	Low
Partner 19	203	Volunteer	Small	Yes	Very high	Medium
Partner 13	187	Volunteer	Small	Yes	Medium	Low
Partner 10	175	Volunteer	Small	Yes	High	Very high
Partner 14	151	Government	Small	No	Low	Low
Partner 1	144	Government	Big	Yes	Very high	Low
Partner 11	142	Government	Very big	Yes	Low	Medium
Partner 6	114	NGO	Small	No	Very high	Low
Partner 9	105	Government	Medium	No	High	Very high

TABLE 6-17 shows that based on the Borda count, for the group of experts, partner 4 who is a small military organisation with a high surge capacity, no international expansion, and low experience is the most desirable (with a 500 Borda count). Partner 9, who is a medium sized government organisation with no expansion, and a high degree of experience and surge capacity is the least desirable (with a 105 Borda count). The same process has been repeated for the non-expert group and the results are exhibited in TABLE 6-18.

TABLE 6-18 NON-EXPERT BORDA COUNT RANKING

Partner	Borda count	Type	Size	Expansion	Experience	Surge capacity
Partner 5	333	Government	Small	Yes	Low	Low
Partner 12	333	Government	Small	Yes	High	High
Partner 7	326	Volunteer	Small	Yes	High	Medium
Partner 2	318	Military	Small	Yes	Low	Medium
Partner 3	280	Volunteer	Medium	Yes	High	High
Partner 10	259	Volunteer	Small	Yes	High	Very high
Partner 18	259	Government	Small	Yes	Low	Very high
Partner 16	258	Government	Medium	Yes	Low	Very high
Partner 19	238	Volunteer	Small	Yes	Very high	Medium
Partner 4	233	Military	Small	No	Low	Very high
Partner 14	224	Government	Small	No	Low	Low
Partner 6	205	NGO	Small	No	Very high	Low
Partner 9	196	Government	Medium	No	High	Very high
Partner 13	195	Volunteer	Small	Yes	Medium	Low
Partner 15	186	International	Big	Yes	Low	High
Partner 8	177	Volunteer	Very big	Yes	Low	High
Partner 1	174	Government	Big	Yes	Very high	Low
Partner 11	155	Government	Very big	Yes	Low	Medium
Partner 17	136	International	Very big	Yes	Very high	Medium
Partner 20	135	Government	Very big	Yes	Low	Low

TABLE **6-18** shows that the non-experts preferred partner 5 and 12 equally (333 Borda count) mostly because they are both small governmental organisations, with international expansion. It seems that the non-experts care less about the surge capacity and experience. Their least favourite are partners 20 and 17 with (a 135 and 136 Borda count), who are very big organisations with international expansion, and low surge capacity and experience.

As far as the comparison of first and last choices of the experts and non-experts reveals, there is no evidence that by using the PREDIS model these two groups make the same choices. However, the NRMSE has been used to calculate a more precise percentage of error between the choices of the two groups. The NRMSE for difference between the two is calculated as 29% (Error between non-experts and experts) and 14% (Error between experts and non-experts). This means that at least 14% and at most 29% of the times, the non-experts' choices are different from the experts. This also means although the first and last choice of the majority of decision makers in the two groups are not the same, between 71% and 86% of the times experts and non-experts decide similarly using the PREDIS framework. The significance of this result is that the non-expert does so with no prior training or data other than the data that are freely available on the Internet through the UN related and World Bank related websites (including HDI, DRI, population, population density, and disaster type). Therefore, it is possible to conclude that although the result shows that the experts and non-experts may have various preferences, the model enables the non-experts to choose partners similarly to experts, if necessary.

6.8.3 THE RESULT OF SECOND QUESTIONAIRE (EXPERIENCE BASED FEEDBACK).

The second questionnaire was only given to the experts because as was mentioned before they needed to evaluate the PREDIS model with the existing models they had in place. This situation does not exist for non-expert so giving the second questionnaire to them would be meaningless. The result of the second questionnaire is presented in TABLE **6-19**.

TABLE 6-19 THE ACCUMULATED RESULT OF THE SECOND QUESTIONNAIRE

Participants information	Options	Number of responses	Percentage
The responder's age	a. Under 35	1	
	b. Between 35 to 50	12	
	c. Over 50	9	
The respondent's sector of experience:	a. Public humanitarian organisations (UN, Red Cross , MSF, etc.)	1	
	b. NGO	7	
	c. Non-military part of a government	6	
	d. Military	2	

Participants information	Options	Number of responses	Percentage
	e. Others (please explain)	5	
The respondent's experience in previous disasters:	a. One international disaster	2	
	b. Between one and five international disasters	2	
	c. More than five international disasters	9	
	d. Just national disasters	11	
1. Have you had a framework for partner selection in previous disaster situations?	a. Yes	15	68.18%
	b. No	7	31.82%
2. If yes, how long does it take to perform this framework in real situation?	a. Less than one hour	5	22.73%
	b. Less than five hours/ Not extremely detailed	10	45.45%
	c. Less than 12 hours	0	0.00%
	d. More than 12 hours	7	31.82%
3. How confident are you about the result of the decision from your existing framework?	a. Very confident	5	22.73%
	b. Confident enough to make a decision	17	77.27%
	c. Not so confident but is better than no framework.	0	0.00%
	d. It is against the nature of a disaster to be confident about any decision at the time of the disaster.	0	0.00%
4. How simple were to make you familiarise with the new model?	a. Relatively simple and time effective	13	59.09%
	b. Relatively simple but time consuming	3	13.64%
	c. Complicated but time effective	6	27.27%
	d. Complicated and time consuming	0	0.00%
5. Will you be able to perform this model at the real disaster situation?	a. Yes, if I have the detailed instruction	19	86.36%
	b. No, because I will not have time at the disaster situation.	1	4.55%
	c. No, because I will use my own framework.	0	0.00%
	d. No, for other reasons (please explain).	2	9.09%
6. How long does it take to perform the new model without the help of the facilitator?	a. Less than one hour	22	100.00%
	b. Less than five hours	0	0.00%
	c. Less than 12 hours	0	0.00%
	d. More than 12 hours	0	0.00%
7. Do you find this model helpful?	a. Yes	2	9.09%
	b. Yes, and I would recommend it to the colleagues.	15	68.18%
	c. No, and I would not recommend it to the colleagues.	0	0.00%
	d. No but I would recommend it to colleagues.	5	22.73%
8. If yes what are the reasons? (You can choose one or all the answers).	a. There is finally one guideline I can use.	0	0.00%
	b. It is quick to perform.	22	100.0%
	c. It uses available data.	5	22.73%
	d. It accommodates my preferences.	3	13.64%
	e. None of the above (Please explain)	3	13.64%

Participants information	Options	Number of responses	Percentage
9. If no (if you will not use it), what are the reasons?	a. It is vague.	0	0.00%
	b. I can't trust the procedure.	0	0.00%
	c. It is not realistic (not close to the real situation of disaster).	0	0.00%
	d. It is complicated to use.	0	0.00%
	e. None of the above (please explain)	3	13.64%
10. Would you lend us some time and identify the areas of improvement in the model?	Various comments	0	0.00%

The result of the TABLE **6-19** can be interpreted as follows.

The characteristics of the expert group - Experts age were mostly between 35 and 50 years old with the exception of one expert, under 35 and the remaining nine experts were over 50. They had experience in 2 public humanitarian organisations, 7 NGOs, 6 non-military parts of a government (in various countries), 2 military, and 5 others from private consultants and business continuity departments of private sector for-profit organisations. Eleven of them had experience of national disasters in their country, not exclusive to the experiences of working in international disasters. These characteristics give a wide range of expertise and perspectives to the simulation game.

Characteristics of existing frameworks- 68% of the experts (15 individuals) said that they already had frameworks in place for choosing partners, whereas 32% (7 individuals) did not have any framework. This is considering the fact that even the experts who have frameworks in place (two of them were described earlier) mostly rely on heuristics accounts of trust, previous experiences, self-declared resources, and capabilities. Another point is that the respected guidelines are mostly generic. For example, when choosing military partners they used guidelines such as the guideline European interagency security forum presents (eisf.eu, 2014). Despite the author's insistence, only two participants declared the framework they use for partner selection as was described earlier, none of which contained numerical and measurable guidelines. Therefore, the author concludes that in practice a specific numerical and measurable guideline, which can clearly compare various partners, is missing. Further investigation regarding the existing frameworks is required which can be the subject of another study. Another result is that within the existing frameworks (only two of them were disclosed to the author, and the existence of the rest is based on the participants declaration), 23% said they take less than one-hour to make decisions, 45% take between 1-6 hours to make decisions, and 32% take more than 12 hours to make a decision. Using these frameworks, 23% of the experts said they are very confident towards their decisions whilst 77% of the experts felt confident enough to make a decision. Predictably, there was no expert who lacked enough confidence to make a decision.

Characteristics of PREDIS model - 73% of the experts thought that the PREDIS model was simple to use, 59% of them thought it was time effective and 14% thought it was time consuming. The remaining experts (27%) believed that the PREDIS model was time effective however complicated to use. Considering these results, 86% of the experts will use PREDIS in a real situation if they have training beforehand and become fully familiarised with the process. One expert (4%) will not use it because of the lack of time at the time of the disaster. Furthermore, 9% of the experts, will not use it because they are not in the operation division anymore or because they are more interested in the prediction aspect of the model, and will follow their existing guidelines for the actual selection of the partners. All the experts (100%) believed that given prior training, a decision maker is able to use PREDIS model in the disaster situation without the aid of the facilitator, and make decisions within an hour. In fact, 77% of the experts found the PREDIS model helpful and 68% of them will recommend it to the colleagues. However, 23% of them will not use it because either they are retired or in non-operation divisions, though they will recommend it to colleagues. From those who found the model helpful, 53% did so because of its speed and 23% did so because it uses the available data. Another 14% did so because it accommodates their preferences. The remaining 14% found it helpful for other reasons including its predictive capabilities, due to its applicability to all countries, and because of its numerical values. It is noteworthy to mention these reasons are not exclusive and experts could choose more than one reason.

Possibility to expand PREDIS in practice - the experts provided various views. Some mentioned that the criteria that are more important to them, are water and sanitation, soap, transportation containers and menstrual hygiene. Therefore, they are not concerned with the secondary products like shampoo and toothpaste, and maybe it is possible to have these as bonus products that may only be added to the essential basket of requirements when the primary needs are met. Further research needs to be done to confirm the level of necessity of these products. In addition, they mentioned that a very important issue in the disaster situation are open wells, which can be easily contaminated with debris from the disaster and so forth, so this issue needs to be added to the requirements, in addition to the skills required for the decontamination of the water supplies.

They also suggested taking into account the relationship with host communities in order to get needs assessment. They suggested considering the lack of access to the communities in the estimations. They are concerned that even when the estimation is accurate, bringing the requirements to the communities is sometimes a difficult to impossible task. However, the issue of supplying the products is out of the scope of this research and can be the subject of further studies. They also suggested considering the core competencies as an agency, and another issue is to consider how difficult it is to move those supplies. This might be included in the PREDIS model later, by considering elements of delay or introducing a proportional value for the minimum requirements as the extra safety supplies as opposed to minimum requirements. Introducing some elements of risk to the model could cover this all. However, calculating the value for this risk for each product and each area considering the severity of the disaster, could be the subject of an extensive research in the future. In addition, the participants suggested considering some important assets apart from the type of partners, for example, some military assets are very important such as helicopters. This also could be introduced to the model by adding more weights to the essential supplies, which make the preferences lean more towards the partners with much valued equipment. The exact weight for this calculation however could be the subject of further studies.

Some provided an approach that is more theoretical, to the subject. For example, one suggestion was to consider the model on three levels: strategic level/macro level, global focus to a broader picture, and operational in detailed considerations. For example, they suggested sending the data to a strategic level to get a bigger view of what is needed to be done. Tactical/Micro perspective data, which needs to be timely, should be sent to the operation to set up the detail and support.

Another suggestion was to consider a pyramid structure and to define the three essential elements of analysis such as emergency response capability, measures of effectiveness such as people, equipment, training, and expertise in addition to measures of performance and quality assurance for audit purposes.

Another expert also suggested considering the capabilities of the individuals. While one suggestion was to consider mobilisation time, and differentiate between local partners and small partners when it comes to setting the preferences. Because the local partners have quicker access, which can be more effective for obtaining the limited resources they have, to the population in need, so they are more important than small foreign organisations that take some time to reach the affected population with their limited resources. This easily could be addressed by considering higher weights for local partners as opposed to small foreign partners. Another suggestion was to use the model in a thousand actual cases to measure its usefulness. Some stated that the model is unique compared to the existing incident management software.

One expert said that the model is not useful at the time of the disaster but good for scenario planning before a disaster. All the experts confirmed that having a range of predictions could help them plan better than if they have one solid number as prediction.

6.9 SUMMARY OF THE CHAPTER

The aim of this chapter was to test the suitability of the PREDIS model further for decision-making in the disaster situation. To that end, the following hypothesis are put forward. This hypothesis is Hb, ‘The PREDIS model assists the decision makers to make the same decisions faster’. The other hypothesis is Hc called: ‘The PREDIS model assists the non-experts to decide like an expert’.

These propositions were tested using a simulation game in a frame of a quasi-experiment. Using two series of expert and non-expert participants, a hypothetical scenario of disaster was re-played. The decisions the two groups made were registered and compared. The overall results were analysed in two parts. The numerical results of the decisions show that the PREDIS model has two major capabilities. It enables the experts and non-experts to predict the disaster results immediately and using the widely available data. It also enables the non-experts to decide almost the same as the experts; either in predicting the human impact of the disaster and estimating the needs or in selecting suitable partners. It is also the only framework of its type, which takes specific numerical values as input, and provides specific numerical values and clear decisions as outputs such as which partners to supply how many units of requirements.

Another part of analysis is associated with the question answered exclusively by experts. The conclusion drawn from this questionnaire is that although the experts already have their own heuristic frameworks, they are positive towards using the PREDIS model in real situations if they have prior training. This is because of the speed of PREDIS model, its relative simplicity, its use of available data, its predictive ability, and its clear decision outputs.

However, there are some limitations associated with the PREDIS model. First, it is purely theoretical at the moment and has yet to be tested in a real disaster situation. Second, the data used for estimating the needs have been accumulated from various sources and their applicability in the actual disaster scenario might differ for each organisation. The areas of improvement in the model are threefold. First, the PREDIS model can be adapted to each country's particular needs and capabilities. For example if the main nutrition for a culture is bread instead of rice, the requirements should be adapted accordingly. If a country is capable of providing enough doctors, this needs to be taken out of the requirements and so on. The reason is that at the moment the goal for the development of PREDIS model was to provide a holistic model, which can standardise the various disasters and make their effects comparable to each other. However, the author believes that using the same principles used in the development of PREDIS, it is possible to develop further a customised PREDIS for each individual country. For example, the same numbers of people, who have become homeless as a result of a disaster, need less aid in the US compared to Nigeria. Because based on the experts' experiences, the fewer homeless people in the US end up in shelters, and they mostly get help from the family or volunteer homes where they can stay. In addition, the PREDIS model has been based on the data from all countries. The author believes that customising one PREDIS model for each country will give a more accurate prediction. To that end, the preliminary discussion with various NGOs and other official humanitarian organisations should be conducted in order to use this model for individual countries and use the special needs in each country. Another area of improvement could be embedding the PREDIS model in software so all the complicated calculations are done on a computer. The decision makers can then just be concerned with inputting the disaster type and country, and entering their preferences for partner selection, and the software produces the predictions, need assessments, and suitable partners.

One important point, which is worthy to mention, is that the author initially aimed to assess the result of the simulation game using the Turing test (Turing, 1950). Specifically the variation described as the "subject matter expert Turing test", to see if the response of the machine (here the excel sheet embedded with the principals of the PREDIS model) is distinguishable from the expert's. The process was designed in a way that the pre-test asks for experts' specific decisions, then exposes them to the treatment (PREDIS model) and then uses the machine (computer) to generate the post-test result by incorporating the experts' preferences. This test is also known as a "Feigenbaum test" (Feigenbaum, 2003). However, the pilot study showed this test to be impossible to conduct, because experts would not give a clear set of decisions. For example, when asked "please rank and choose the partners you would use in the given disaster situation", in the pre-test experts would say "I would use the partners with whom I have had good relationships in the past", or "I would choose the partners based on the quality of previous experiences" or "I will call any local partner in the area to see if they can provide the resources". Therefore, comparing a list of chosen partners in the pre-test and post-test procedure was not possible. Consequently, the author ignored the use of Turing test and settled for the comparison of the result in the post-test between experts and non-experts. Therefore, the results of the pre-test in all cases were used just to show that at the moment an actual framework that provides clear comparable choices is non-existent.

CHAPTER 7
DISCUSSION

7 DISCUSSION

This study was conducted in the humanitarian sector. The main research question was how to reduce the problem of partner proliferation problem in disaster response networks. To deal with this question, an extensive literature review was conducted to identify the research direction. The review showed that the majority of the scholars suggest that optimising partners' configuration would influence the success of the collaboration. To that end, in the specific case of a disaster response, the previous experience shows that the majority of the practices have adopted supply chain design as the structure for disaster response. However, the failures in the previous large-scale disasters suggest that might not be the most suitable design. Therefore, recommendations, by another group of scholars, that consider the structure of the disaster response network as a temporary design such as VO to address the uncertainty of the disaster situation has been followed. The problem is the adoption of this structure as with any other collaborative structure is no guarantee for a successful collaborative act. Because the accumulation of the heterogeneous partners' interactions leads to the integrated performance of all participants. This collaboration will not be successful unless it is supported by the efficient operation of a suitable collection of partners. The issue is that due to the uncertainty of the disaster situation and the temporary nature of the collaboration in a disaster response phase, the literature on this area is limited to a few studies. In fact, even those few studies are limited to the scheduling and allocation techniques and no study specifically addresses the partner selection in a disaster response network. This gap signaled the future direction of the research.

CHAPTER 7
DISCUSSION

7.1 QUESTIONS AND HYPOTHESIS

Reviewing the existing decision techniques and determinants for partner selection in the areas beside the disaster response (where the research is limited) provides a list of available determinants and decision techniques for partner selection. Based on the principles of Decision theory and the Resource-based theory, the research outlines the best suitable techniques and determinants and outlines a design for the research. The main research question is to investigate "How to reduce the partner proliferation problem". Two solutions are suggested which are to run concurrently including re-structuring the DRN into a VO by selecting fewer partners out of a pool of potential partners or VBE. This is based on existing literature, which suggests the existing long-term structures are not suitable for all phases of a disaster life cycle and suggest short-term structures for the response phase. The principals of the Resource-based view outlines that if the collaboration is to be successful it needs to focus on the resources, also based on the principles of the Resource-dependency theory the companies collaborate in order to acquire critical resources and reduce uncertainty (Barringer and Harrison, 2000) which is the case in the disaster situation. In order to select partners, the research suggests the resource-based criteria including physical and human resources, whose data are available at the time of the disaster. It is possible to optimise the allocation of these resources to the disaster's needs if the prediction of the needs is available. The idea is to find a way to predict the human impact of the disaster (including the number of fatalities, homeless and injured), and by using the historic data about how many units of resources are required in similar situations, estimate the approximate needs. The rest would be an optimisation problem using the mathematical programming based on the principles of the utility theory. This insight outlines the design of the research to investigate three main studies in addition to one hypothesis and two propositions.

- First hypothesis (Ha)- If and how is it possible to predict the human impact of the disaster at the time of the disaster strike? The answer to this hypothesis is the essence of the first study, which uses statistical and mathematical techniques with a soft system approach to provide a predictive model for a disaster's human impacts. This is designed based on the hypothesis that there is a relationship between the human impact of the disaster and the severity of the disaster.

- First proposition - If and how is it possible to estimate the needs of the affected population at the time of the disaster strike? The answer to this proposition is the essence of the second study, which uses archival data to provide evidence-based estimation for, needs in each disaster situation. This is based on the hypothesis that there is a relationship between the disaster's human impact and the needs of the affected population.

- Second proposition- If and how is it possible to select partners based on the data at the time of the disaster strike. The answer to this proposition is the essence of the third study, which uses an optimisation technique for selecting hypothetical partners.

Moving on from this a series of separate yet interrelated studies were conducted including prediction, estimation, and optimisation, which were planned so that the results of each study were fed into the next study and this produced the PREDIS model as the overall result of the research. The PREDIS decision technique was then evaluated from the experts' perspectives using a quasi-experimental design, which employed a simulation game as its treatment phase.

In order to match and optimise the available resources of a set of partners (supply) to the needs of the affected area (demand), the human and material loss of the disaster needs to be calculated. A review shows that the existing research in this area is limited to specific geographical areas or disaster type. Moreover, the data used for the prediction will only be available days after the disaster .The first available official data about impact and requirements is released 72 hours after the disaster in the MIRA report. Most of the decisions need to be made before this time to prevent fatalities and the spread of disease, etc. To close this gap, this research utilised a variety of techniques to investigate the possibility of developing a decision-making tool for partner selection in a disaster response network in the first 72 hours after the disaster strike. To that end, the author built upon the principals of Resource-dependency theory and Decision theory under uncertainty to develop a decision technique in the explained situation. The logic behind this attempt is that, if a predictive technique could be developed to estimate approximately the human impact, and needs of the affected population quickly after the disaster strike, it is possible to combine the decision makers' expertise and experiences with the data about the available resources to the partners to decide which partner should provide which requirements.

7.2 DEVELOPMENT OF DISASTER/COLLABORATION LIFE CYCLE CONFORMITY MODEL

The disaster/collaboration life cycle conformity model is an attempt to answer the main question. This in combination with development of the PREDIS model outlines the contribution of the research. The process of developing the conformity model includes providing a literature based argument on the necessity and suggestions put forward for restructuring the disaster response network. This is based on the assumption that the collaborative act is a necessity for disaster response, and therefore the activities related to this phase of disaster management need to operate in a network structure. However, building on the suggestion provided by Noran (2011), a suitable structure for response phase is VO. This is of significance on various levels.

- The VO structure for a disaster response implies that the selection of the partners in the configuration phase is required to be made from a pre-qualified pool of partners or VBE. This connects the subject strongly to the collaboration literature, where scholars provide numerous tools for partner selection. However, the further investigation of these tools and criteria renders them unsuitable for partner selection in a disaster response due to the lack of information, time pressure, and uncertainty inherent in the disaster response situation. The criteria that can be used in this situation is the partners' resources because in general when the partners express their interest in being a part of disaster response network, they have a clear idea about the units of physical and human resources they have at their disposal at any given time. Other information about trust, their previous performance, and alignment and so on may not be that clear or quick to obtain. For that reason, resource has been selected for building the rest of the model. In fact, the premise of the PREDIS model is built upon this assumption that by knowing the number of affected people in the population, is it possible to estimate their needs and the resources required for them and therefore select the partners accordingly. The truth is the PREDIS model is valid so far as this assumption holds and in cases where the partners do not have a clear understanding of the resources they hold or can mobilise in real-time measures, the output of the PREDIS model is untrustworthy. However, one might argue that if any partner at any given time has insufficient information about their resources, they should be prevented from entering the disaster area and providing help in the first place. However, this condition cannot be satisfied for the partners who like volunteers attend the scene immediately, and therefore the PREDIS model cannot be used for these types of volunteers anyway. Further research could be conducted in order to find new criteria other than resources that might be used for partner configuration in a disaster response. Furthermore, more research could be conducted to assess the dynamics and the potential requirements for the volunteers who attend the scene in the early hours. To summarise, the premise of using resources as the criteria for partner selection (in combination with other partner characteristics, and decision maker preferences is explained in the OPTIMISATION study and informs the basis for the ESTIMATION study.

- The VO structure for disaster response renders it compulsory to have a permanent VBE for a disaster response network. Despite the author's search to find an exemplary VBE in a real disaster case, the data about the available partners and the resources they possessed at any given real disaster was not found. In fact, the establishment and regular update of a database for a permanent VBE of humanitarian partners is one of the suggestions of this research for future considerations of the humanitarian society. To that end, a hypothetical pool of partners (Appendix 10 and Appendix 11) was created and used for the OPTIMISATION and SIMULATION studies. If in the future a database as such becomes available, the model needs to be re-examined and refitted if necessary based on the data obtained from the real partners.

- The conformity model presented here is complementary to Drabeck's (1986) disaster life cycle and Noran (2011). It borrows the different phases of the disaster life cycle and combines them with the disaster event mapping provided by Noran. The aim is to address the conformity of the disaster response within the disaster life cycle in respect to their positioning within the operational structures. The significance of this model is that even though various scholars have suggested using the VO for the disaster response (Noran, 2011; Grabowski and Roberts, 2011; Javaid et al., 2013), the similarities of the two, which leads to their conclusion, were not justified. To that end, this research drawing from the literature, points out twenty areas where the VO and Disaster Response Network (DRN) overlap. The conformity model also combines the concept of a collaborative life cycle from Thoben and Jagdev (2001) and Sitek et al. (2010) and provides an understanding of how the two life cycles (Disaster life cycle and collaborative life cycle) conform together. A potential area for further research would be to investigate the dynamics in which the network structure transforms through various disaster life cycles. For example, what happens when a long-term network such as supply chain during the preparation or mitigation suddenly transforms into a VO for disaster response, and again how it dissolves into the supply chain again during the recovery.

CHAPTER 7
DISCUSSION

7.3 DEVELOPMENT OF THE PREDIS DECISION SUPPORT TOOL

The process of developing PREDIS includes accumulating, evaluating, and analysing the existing data in order to recognise the predictable patterns and detect the relation between the results. The disasters, which were the source of data in this phases, were natural onset disasters and registered between 1980 and 2013 including 11,000 records found and cross-examined from various humanitarian sources (including Emdat.be, 2014; Munichre.com, 2014; ReliefWeb, 2014, Gdacs.org, 2014). The geographical dispersion of the disasters includes every country where the data were available. The records were then filtered into 4252 records of the disasters where the five predictive variables (Disaster type, HDI, DRI, Population and population density) were clearly stated. The procedure was designed based on combination of pattern recognition techniques and rule-based clustering for prediction and discrimination analysis to validate the results further. The result was that there is a relationship between the disaster human impact (fatality, homeless, injured) and the criteria, including disaster type and socio-economic characteristics of the affected country such as population, population density, HDI and DRI, became the basis of the prediction in this research. The result was finding a pattern between disaster severity and the five mentioned criteria. Using regression analysis and the MA rule, a framework was put forward to estimate the disaster's human impact (fatality, casualty, homeless) based on their severity rank in early hours of disaster strike. The predictions in this model were outlined in two worst and best-case scenarios, which respectively inform the lower range and higher range of the prediction. Which range limit the decision makers choose to proceed with, depends on their personal preferences. The study of why they choose the way they choose, however, is out of scope of this research, but it could be an interesting approach to further research for an operational behaviourist. In this research, the focus is on the result of their decision, and not the causality of the choice itself.

7.3.1 PREDICTION

The PREDICTION study answers the first proposition- if and how possible is it to predict the human impact of the disaster at the time of the disaster strike? The answer to this question is yes. It is possible to predict the human impact in the disaster within a range. In the existing PREDIS model, the fatalities could be predicted with a 3.10% error (1.7% for the lower limit and 4.5% for the higher limit). In addition, the accumulated number of homeless and injured is calculated with a 2.4% error for both lower and higher limit. The findings in the process of developing the predictive framework can be articulated as follows.

- There is a relationship between the fatalities in disaster and disaster type. In fact the fatal power of the disaster types can be ranked from lowest to highest as Storm/Flood/Volcano/Cyclone/Flashflood, Tsunami/Earthquake This has been previously pointed out by the Sphere project (2011) in linguistic measures and this research to some extent confirms it in numerical values using an analysis of the fatality ratio. There is also a relationship between fatality and HDI and DRI of the country as well as a relationship between the fatality and population and population density of the country. Previously Rodriguez et al. (2011) showed that the severity of a disaster is related to the HDI, DRI, population, and population density. They used fuzzy logic to quantify the linguistic measures characterised by NGO decision makers. This research further shows that fatalities as well as severity is related to the above criteria.

- A sceptical reader might point out that a range for prediction might be counted as a weakness for the model. The author argues that a prediction of a range has previously been conducted in the literature. For example, in a flood due to the dam break in Netherlands, eight methods for dam and dyke breaks were used to predict the impact within the range from 23 fatalities to 5236 fatalities (Jonkman et al, 2002). The importance of having a range instead of a solid number is also confirmed by 100% of the experts who participated in the simulation game. This is discussed further in the findings of the simulation game.
- Another argument is that the author believes that the PREDIS model presented here exceeds the existing frameworks in a variety of criteria. First of all the existing methods such as Hazard US or HAZUS (Schneider and Schafer, 2006) require a high degree of precise data provided by highly funded and equipped entities such as NASA with extremely well trained staff and they are less applicable in developing countries. The PREDIS model can work with the simple freely available data on variables such as population, HDI, DRI, and disaster type and it can be quickly employed in any country regardless of their level of socio-economic development. PREDIS can also be complimentary to the method developed by Aleskerov et al. (2005), which although is designed to be used in the countries with less developed infrastructures, it focuses on mitigation and preparedness phases. To that end, PREDIS in this case can be used to inform the decisions further in the response phase after the planning for

mitigation has been implemented and before the planning for recovery is launched. PREDIS is also different from the decision support tools for severity assessment (Rodriguez et al. 2011) which aims to assist the NGOs in the prioritisation of their tasks after the disaster strike. Although their method is robust and sophisticated, it requires a great deal of mathematical and analytical expertise. The step-by-step guide of PREDIS model with a platform of embedded formulas requires almost no technical expertise and any decision maker with a minimum level of literacy could benefit from that. PREDIS is also different from the methods such as EMPROV which are designed to support improvised decision-making (Mendoza, 2007) because they assume the data are available and do not provide frameworks for predicting the unavailable data such as fatalities during the disaster response.

- The study also shows that this prediction could be further strengthened if the data about population within 100 km and the magnitude of the disaster becomes available for the all records in the database.
- The method of pattern finding in this study is to some extent similar to rule-based clustering used for prediction in various studies (Deboer, 1998; Mendoca, 2007; Rodriguez, 2011). However, it is unique in a sense that it uses the available data to predict the impact in early hours of disaster strike with no real-time data drawn from the area. All of the other frameworks discussed above use some level of data drawn from the disaster area days after the disaster strike. They also do not specifically address every disaster type and country.

- The initial understanding of the author is that the quality of prediction could be improved if a PREDIS model is re-fitted for each country separately. For example, here the fatalities for each country has been used for pattern finding, but if we use the record of fatalities for each state in a country, then the predictions could possibly be improved and the prediction range would narrow. However, this requires the availability of a database for each state of each country for decades. This could be another area for the future research if that becomes available.

7.3.2 ESTIMATION

The ESTIMATION study answers second proposition- If and how is it possible to estimate the needs of the affected population at the time of the disaster strike? Using various resources (FEMA, 2007, 2014; UNDRO, 1982, 1992; Sphere project, 2011; IASC, 2012; IFRC, 2000, 2009, 2012; WHO, 2011), the minimum standard requirements for a disaster response in four humanitarian clusters (WASH, Nutrition, Health and Shelter) was defined, and combination of the loss prediction and needs estimation provides the basis for estimating the demand of the affected population in disasters.

- This exceeds the use of minimum standard requirements provided by the Sphere project because it draws upon various sources to provide the data about the required units of medical help (IASC, 2012; IFRC, 2000, 2009, 2012; WHO, 2011) and nutrition (IFRC, 2000, 2009, 2012), which are left open to the judgment calls of the humanitarian organisations in the Sphere project. This framework could also further be developed to provide data about fatality management, evacuation, and required well contamination teams. This could also be an area for further research.

- This also complements the existing literature (described above) because it draws upon various studies to provide the priority of the disaster type, and tasks during each disaster type. Even though some linguistic priorities are practiced in the literature (Sphere project, 2011), the numerical priorities that can contribute to the quantification of the needs were missing. The priorities suggested in this research are required to be investigated further with the fuzzy logic analysis of the experts' opinions regarding the priorities of each, task/need for each disaster type/country. However, this is another extensive research in its own merit and is out of scope of this research. Nevertheless, this research provides the preliminary basis for the further development of such framework.

7.3.3 OPTIMISATION

The OPTIMISATION study answers the third proposition- if and how is it possible to select partners based on the data at the time of the disaster strike. To find out the supply capacity of the partners and selecting them accordingly in order to configure the final VO, an optimisation technique was used. The model is based on two major assumptions. The first assumption is that the VBE for humanitarian partners already exists. However, creating and maintaining such a VBE requires the cooperation of international humanitarian bodies. The model cannot be fully tested before the creation of a standardised accredited VBE database containing the data about humanitarian partners, their selection criteria, and regular updates of the database. Second the model is built upon the secondary data from various sources

(Emdat.be, 2014; Munichre.com, 2014; ReliefWeb, 2014; Gdacs.org, 2014), amongst others in which the data varies from case to case. Therefore, the model is as accurate as its data feed. In the absence of this VBE, a sample of 300 partners was randomly generated based on a series of criteria (including type, size, surge capacity, experience and resources at their disposal), which is discussed in the questionnaire. The model needs to be refitted if the data about an actual VBE becomes available. The process in this part is similar to a variety of partner selections based on MCDM (Fiedrich et al., 2000; Nourjou et al., 2014a, 2014, b) where the partners are the candidates. The variable which needs to be maximised is the utility of the partners in the eye of the agent (here the decision maker). However, the constraints in this model are just the resources, because the focus of the research was on reducing the partner proliferation by restructuring and partner configuration, and not the optimisation. The author believes that this is a more realistic measure for disaster, because the methods that use qualitative measures such as reputation (Javaid et al, 2013), are less likely to be able to obtain the data they require about the partners within the early hours after the disaster strike. However, the optimisation could be improved if other constraints such as time and cost could be considered. This could also be improved if the tasks can be separately defined in detail, and then the task allocation and resources related to the allocated task of each partner could be optimised. To that end the PREDIS can be complementary to the abundance of existing methods for task allocation and scheduling techniques (Felder and Brinkmann, 2002; Ozdamar, 2004; Zheng et al., 2007; Yi and Kumar, 2007; Zografos and Androutsopoulos, 2008; Zhao and Han, 2010; Su et al., 2011) in disaster management, as a quicker data feed.

7.4 EVALUATION OF PREDIS MODEL

In order to further investigate the suitability of PREDIS model, the model is evaluated and assessed in the eyes of real human decision makers. The second phase includes the design of a simulation game using various expert and non-expert participants. 44 individuals (22 experts and 22 non-experts) participated in the process of a quasi-experimental design, where the post-test and pre-test were separated by a simulation game as treatment. This is an attempt to answer the following proposition: Is the decision support tool developed in the previous steps (PREDIS model) effective in disaster situations? Three hypotheses are considered in this research:

Hypothesis (Hb): The PREDIS model assists the decision makers to make the same decisions faster. The simulation game confirms this hypothesis as all the experts (100%) agreed that given prior training, a decision maker is able to use PREDIS model in the disaster situation without the aid of a facilitator and make decisions within an hour. Comparing it to the existing frameworks, 23% of the experts take less than 1 hour to make decision, 45% take between 1-6 hours to make decisions and 32% take more than 12 hours to make a decision. This means 77% of the experts currently take more than an hour to make the decisions with almost no available of data and purely based on their experience. However, PREDIS enables them all to decide in less than an hour and based on the data,

Hypothesis (Hc) : The PREDIS model assists the non-experts to decide like an expert decision maker. Although the first and last choices of the experts and non-experts are not the same, in 71%-86% of the times, experts and non-experts decide similarly using the PREDIS framework. The significance of this result is that the non-expert does so with no prior training or data other than the data, which are freely, available on the Internet through the UN related and World Bank related websites (including HDI, DRI, population, population density and disaster type).

There are a few points that are worth mentioning first, the quality of the decisions, which were made, were not assessable. However 86% of the experts favoured the PREDIS to their existing frameworks due to its simplicity (73%), time efficiency (59%), use of available data (23%) and accommodating their preferences (14%).

A sceptical reader might criticise the design because the MIRA report presented in the simulation game might defeat the purpose (prediction and decision-making within 72 hours). The author however defends the design of the simulation game for the following reasons. The initial plan was to provide the MIRA report in the pre-test to get the decision maker to decide based on the information available 72 hours after the disaster strike. Then in the post-test give them the PREDIS framework which needs no information about the disaster in real-time because it works with data about population, population density, HDI and DRI and the type of disaster. Finally, compare the result of both phases and see to what extent the selected partners are similar and therefore draw the conclusion that whether PREDIS makes decision makers to make the same decisions faster. However this could not happen because in the pre-test no participant selected actual comparable partners. The decision process in this phase was vague and was rarely based on the non-numerical guidelines. To that end, comparing the set of partners in pre-test and post-test rendered it impossible. However the author still argues that the fact that most of the participants said they could use PREDIS within one hour to decide whilst their current decision-making process takes five hours on average, is an indication that the PREDIS model helps the decision maker to decide faster and therefore bridges the gap between the time the decision is required and the time that the data becomes available.

Furthermore, the research shows that comparing to the existing decision models in humanitarian sector the PREDIS could prevails the existing guideline which either are vaguely based on flow charts of qualitative judgment calls from the decision maker's part (IESF) or are based predominantly on highly specialised data (HAZUS). In a sense, PREDIS gives numerical predictions and estimations, and clearly expressed choices of partners whilst it is using simple available data usable for people with the least technical background.

In addition, based on the expert's opinion and the initial research, the PREDIS compared to the existing decision models in the commercial sector (incident management and business continuity software) has a better predictive capability. A preliminary search retrieved 28 business continuity software packages (CIRmagazine.com, 2014) launched in 2013-2014 alone. There are numerous incident management software packages as well eleven of which are mentioned here in NIJ (n.d). The significance of PREDIS over these software packages is that unlike the above software it does not require the real-data feed, which is difficult or impossible to obtain in a disaster situation, especially in less developed countries with a lower level of communicative infrastructures. However the PREDIS could well be combined with some of above software in order to give rise to the planning and actions after decision-making. The investigation and comparison through existing software suitable for this purpose could be another subject for an extensive research.

7.5 SUMMARY

This chapter describes the results of the present study concerning two complementary solutions for the partner proliferation problem. It provides a conceptual framework for restructuring the disaster response into a VO and then provides a predictive decision support tool to assist in selecting the suitable partners for this restructuring. To that end, drawing upon the existing literature, archival data, and studies, the research investigates five different hypotheses to answer one main question. In the process, the research employs various qualitative and quantitative techniques including panel data analysis, regression analysis, MA rule, rule-based analysis, archival data analysis, linear programing optimisation, quasi-experiment, simulation game, and Borda count. The research encompasses the interdisciplinary fields of decision-making under uncertainty, disaster management, and collaborative networks. The result is a decision support tool called PREDIS that is capable of the prediction, estimation, and optimisation of partners based on the principles of Decision theory and Utility theory. The experts and non-experts confirm the suitability of the PREDIS model in addressing the gap between decisions required in the early hours after the disaster strike and the information, which becomes available later. In addition, this model can be combined with the existing planning.

CHAPTER 8
CONCLUSION

8 CONCLUSION

This study has attempted to create a sound theoretical and practical foundation for explaining the complexity of the partner proliferation problem in disaster response networks and its relationship with decision-making under uncertainty.

The main research question asked whether the partner proliferation problem in disaster response networks could be reduced. The answer to this question was twofold. First, it was presented that this problem is in part associated with the long-term structure of the disaster response network adopted in practice and this could be addressed by re-structuring the disaster network in a short-term collaboration called the VO. Second, the success of the VO operation could be improved by the careful selection of the relief partners. This defines the problem as a sub-category of decision-making under uncertainty, and it is explained through the principles of the Decision theory and Resource-dependency theory.

The results of the present study indeed show that the uncertainty of the disaster situation could be reduced by providing a temporary approach to the structure of the relief network in addition to providing data for decision-making through prediction and estimation. The PREDIS model as the main product of this research explains the relationship between the human loss of the disaster and the preliminary data available at the time of the disaster. These preliminary variables are population, population density, type of the disaster and socio-economic characteristics of the disaster including HDI and DRI. This provides a solid platform for the prediction of the human impact of the disaster within the first 72 hours after the disaster strike. Combining these predictions with the estimation of the needs for the affected population, would give rise to the optimisation of the supply/demand by maximising the utility of the selected partners from the perspective of the decision makers.

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This is linked to a variety of research in the field of operations research and decision sciences through resource allocation, optimisation, prediction, and estimation techniques and also the collaboration field of studies related to the structure and systems thinking, as well as the disaster management and emergency response. The present thesis provides an explanation that may be the assumption that "the high level of uncertainty during the disaster situation renders the prediction and estimation obsolete", can be revisited. The study suggests the possibility of finding a pattern between the impact of the disaster and the existing data by reviewing the historic data. The PREDIS model shows that there is a good chance that the impact of the disaster could be predicted to some extent and the existing methods of decision-making based on reactionary response could be improved as a result of the knowledge gained from this process.

Although a number of studies have been conducted to predict the impact of disasters, this research is a unique study of its kind as it provides a holistic approach to partner configuration. It covers all the geographical regions, disaster types (within the natural onset category), and is based on a range of data on disaster impacts in all the countries where the data has been available since 1980.

8.1 CHARACTERISTICS OF PREDIS MODEL

The objective of the current research is to provide a solution to reduce the problem of partner proliferation in disaster-affected areas. The main research question is concerned with how to reduce the partner proliferation problem. In response to the specific case of disaster response this can be more clearly defind as how to configure response networks quickly in the early hours after the disaster strike in order to avoid the rush of inexperienced and unsuitable partners into the area.

The preliminary suggestion is to re-structure the DRN into a VO. Although this research conceptually shows that this is possible and helpful, there is one limitation. The VO requires a VBE as a long-term pool of partners with pre-evaluated humanitarian actors. Although this is very important, it is out of scope of this research. It requires the commitment and funding of the international humanitarian community to develop and maintain a holistic database with the constant update of the individual partners.

Another complementary suggestion, which involves the selection of fewer beneficiaries, was considered. This is basically a decision-making problem. To that end the design of the research was set as the process of development of a decision technique for ranking and/or selecting the suitable partners in the disaster situation based on priorities of the needs and the preferences of the decision makers. This suggestion is the subject of the research and leads to the creation of the PREDIS model. The PREDIS model is basically a decision support technique customised to configure a short-term collaboration of humanitarian partners in the frame of a Virtual Organisation that has the capability of forming within the early hours of a disaster strike when the actual human impact and the aid requirements are unknown. It is capable of predicting the human impact, estimating the needs, and selecting the partners.

8.2 CONTRIBUTIONS

The present research is designed to provide a technique for partner ranking/selection in disaster response virtual organisations. Drawing upon the data of 4,252 disasters between 1980 and 2013, the present research put forward a technique for needs estimation, and partner selection by creating five interrelated frameworks including DSA, PREDICTION, ESTIMATION, OPTIMISATION, and SIMULATION. In addition, the research employs various qualitative techniques including analysing the archival data, questionnaire and quantitative and decision support tools including regression analysis, MA rule, Borda rule, Linear programing optimisation, MCDM (Multi-criteria decision-making), Analytical Hierarchy processing (AHP), Linear Programming (LP), Multi-attribute utility theory (MAUT) to develop a number of decision techniques based on secondary data as follows.

The first contribution is the Disaster Severity Assessment tool (DSA), which is a decision framework, developed to diagnose the severity of disasters drawing upon the records of 4252 previous natural onset disasters.

The second contribution is the human impact prediction tool, which uses regression analysis and the comparison of the averages on the above data, to put forward a framework for estimating the disaster's human impact (fatality, casualty, homeless). This prediction is based on their severity rank in the early hours of a disaster strike. Which scenario the decision makers choose to proceed with, depends on their financial means and their risk aversion qualities. The significance of the first and second contributions is the fact that they use data, which are available at the time of the disaster.

The third contribution is the needs estimation tool. This framework uses various resources to articulate the minimum standard requirements for disaster response in four humanitarian charter clusters (WASH, Nutrition, Health, and Shelter). The combination of this tool with the first two frameworks can provide the basis for the estimation of needs in disasters.

The fourth contribution is a framework for partner configuration using the principles of Utility theory. In this step, the partners are ranked based on their importance for hypothetical decision makers. Using the AHP technique, a matrix of hypothetical decision makers' preferences is built and used to find the value of each partner in the eye of the decision maker. This step can be defined as a resource allocation problem with the target of optimising the utility of the response partners' set for each decision maker.

The contributions of the research then were consolidated in a decision platform called the PREDIS decision support tool. This platform is evaluated by a simulation game, which was conducted as a quasi-experiment using expert and non-expert participants. The results show that the PREDIS model's significance is threefold. First, it is the first decision framework of its type that enables the decision maker to predict and estimate the needs and select the partners using the data that are readily available for each country at the time of the disaster. It also enables non-experts to make decisions almost as well as experts in a disaster situation. Moreover, it enables experts and non-experts to make decisions within one hour after the disaster strike using the limited data available before and immediately after the disaster strike.

8.2.1 CONTRIBUTIONS TO THEORY

This research provides a unique insight into the growing body of research that examines the proliferation problem in a disaster response network. It can be categorised as a part of decision-making under uncertainty where it is attempted to reduce the uncertainty by "gaining accumulated access" to other firms' resources meaning that every member has access to the resources of all the other members. This is based on the principles of Resource-dependency theory and through collaboration. Because the collaboration act in practice is no guarantee of a successful disaster response due to the interaction of contributors, the most suitable group of partners to accumulate and share their resources are selected based on the optimisation technique using the principles of the Utility theory.

In this process, the research provides two original contributions to the field. First of all, the conceptual conformity model, which asserts the overlaps of certain disaster management phases with certain structures. The significance of this model is that it takes the temporary nature of the disaster response into account by considering a temporary structure like VO and drawing suitable partners for each operation as soon as the demand (here the disaster induced need of the population) arises. At the same time, this model accommodates the longer-term operations in other phases of disaster management (preparedness, recovery, and mitigation) by providing a long-term structure such as a supply chain.

The second contribution is the PREDIS model, which predicts the human impact of a disaster, estimates the needs, and optimises the partners for a quick structuring of the response network within the early hours after the disaster strike. The significance of the model is in its ability to use the pre-existing data in order to predict the impact of the data before the release of the first official data within the first 72 hours. In fact, based on the experts' opinion it is possible to run and complete the whole model including the decision makers' preferences within one to five hours after the disaster strike.

Several theoretical contributions emerge from this research. First, to the knowledge of the author, this research is the first work to investigate the partner proliferation problem in detail within the concept of disaster response network. It is also the only research of its kind, which combines the VO structure within the concept of proliferation in a disaster response network. Moreover, it is the first framework, which predicts the impact of a disaster without limiting it to one disaster, one geographical area or one year unlike the similar predictive frameworks. The research also is one of the pioneers in using a simulation game design for incorporating the human agents' opinions into the model. In that aspect, it integrates the hard and soft decision techniques within the concept of Systems thinking theory. Although the use of a combination of Resource-dependency theory and Decision theory is common practice in the literature, the combination of the above theories, in order to improve the collaborative success in short-term disaster operations is rare. Furthermore, despite the fact, the simulation game design applied in the last phase of this research has been extensively used in the medical and psychological field of decision-making, it is seldom applied in the field of disaster management. Although by using simulation game design the research enters the area of operational behaviour to some extent, due to the recent development of this discipline, further research is required to confirm the conformity of this model within this discipline. The complementarities of the above capabilities of the research may reinforce earlier studies and provide a valuable contribution to the understanding of the complex mechanisms of relationships between the determinants of the disaster impact, the way the expert and non-expert decision makers think and decide, and the effect of re-structuring the disaster response network in VOs. To that end, this research provides a number of theoretical implications:

- VO can structure the response network in a disaster life cycle, whilst the rest of the life cycle can be structured by long-term collaborative structures.
- There is a relationship between the disaster human impact (fatalities, homeless, injured) and the criteria including disaster type and socio-economic characteristics of the affected country including population, population density, HDI and DRI. These criteria are the basis for the prediction in this research.
- There is a stronger relationship between the above criteria if we add the magnitude and population within 100 km of the centre of the impact. These data are

not available for all the disasters so they are not used for the predictions in this research. However, the author asserts that adding them to the model in the future, if they become available, would probably provide a better prediction.

- It is possible to optimise the partner selection, in a disaster situation, and reduce the proliferation of partners using the PREDIS model.
- It is possible to enable non-expert and expert decision makers to predict, estimate, and optimise the partner selection in a disaster situation within one hour after the disaster strike using the PREDIS model.
- The PREDIS model; assists decision makers to make decisions more quickly.
- The PREDIS model assists the non-experts to decide almost as well as experts.

8.2.2 METHODOLOGICAL CONTRIBUTION

The contribution of this study in terms of methodology is that this research is one of only a few studies to combine decision criteria and decision techniques from a variety of heuristic and mathematical decision techniques into the concept of decision-making in disaster management. It also uses a multi-layer approach to choose the appropriate predictive technique for the first study (PREDICTION). It embarks with regression analysis and continues with the MA rule in order to isolate the most appropriate method for prediction. Then it compares the NRMSE of the predicted result by each method to choose the best prediction.

Another significance is that it uses two phases for validation of the PREDIS model. First, it uses the hypothetical scenarios to show the mechanism of the model and it identifies whether the model works in its own right, then provides a simulation game design to simulate the decision-making under uncertainty in the disaster situation by taking into account the opinion of human agents. This is as well as differentiating between two groups of human agents: Experts and non-experts. By putting forward the results of the resulting decisions from both groups, the research enables the researcher to identify how the decision-making could be different using different agents from different backgrounds. It also uses mathematical optimisation in addition to the opinion of human agents, which is in accordance with the background of the research, which integrates the heuristic and mathematical approaches of decision-making. Overall, the research fills the gap in the fledgling field of disaster management, especially by enriching the predictive power of the decision maker.

8.2.3 PRACTICAL CONTRIBUTION

By bridging the gap in the field, especially by enriching the predictive power of operations, the result of this research may hugely improve the performance of humanitarian operations. In addition, this is the first time a holistic framework has been utilised, its practical significance is twofold. First, it relies on the available data at the time of the disaster, which are freely available to the public. This would reduce the cost of the data gathering, and the time required for collecting and analysing this data. Consequently, it speeds up the response time of the operation to the disaster by almost 72 hours, which is vital at the time of the disaster. In addition, it is the only existing framework not limited to a certain type of disaster (although it just considers the five type of disasters) or geographical or chronological order. These unique characteristics make it possible for decision makers to compare the effects of the different types of disasters happening in different areas at different times.

Another contribution is that the model has the capability of accommodating the socio-economic characteristics of the affected population, which hugely influences the required aid in humanitarian response practices. The PREDIS model also has the capability of facilitating the predictions of damages as required by the insurance industry. Another practical contribution is that by providing a range of predictions (minimum, maximum and best case scenario, worst-case scenario) it enables the decision maker to decide based on their budget limitations and personal preferences. It also gives different organisations the chance to customise the model using their own database if required. However, the author believes that this model in long-term could facilitate establishing a centralised database for humanitarian response which is long overdue. This also could help in the long run to provide a basis for introducing universal performance measures, and a framework for humanitarian operation because the universal data feed renders the organisations and their performance comparable to each other. Moreover, the PREDIS model enables the experts and non-experts to customise their decision-making process by entering their personal preferences into the process regardless of their experience, knowledge and budget.

8.3 LIMITATIONS AND FUTURE RESEARCH DIRECTION

The PREDIS model is based on two major assumptions. The first assumption is that the VBE for humanitarian partners already exists. However, creating and maintaining such a VBE requires the cooperation of the international humanitarian bodies. The model cannot be fully tested before the creation of a standardised accredited VBE database containing data on humanitarian partners, their selection criteria, and regular updates of the database. This project can be further discussed with international humanitarian entities with regards to the applicability of launching a universal initiative for gathering data and building a universal humanitarian database.

Second, the model is built upon secondary data from various sources (Emdat.be, 2014, Munichre.com, 2014; ReliefWeb, 2013a; Gdacs.org, 2014), amongst others in which the data varies from case to case. Therefore, the model is only as accurate as its data feed.

Third, the prediction of the injured and the homeless population is based on the available aggregated data, in the absence of separate data sets. Despite the author's attempts, data individually reporting the injured and homeless were not found for any of the 4252 cases. However, if they become available in the future the author believes that repeating the process of prediction may greatly improve the quality of the predictions.

The author is aware of the limitations of the research, however because this attempt is the first attempt of this type, she is very optimistic that this framework could be further used and developed or totally transformed into a fully functioning framework for planning a disaster response. Although the contribution of the current study is its model, further empirical research is required to develop an extensive database for the potential humanitarian partners at the industry level.

The future research direction could follow different paths. For example, the PREDIS model is based on the resources-based optimisation, it takes into account the decision makers' preference and characteristics in various other criteria such as experience, type, and size of the organisation, its surge capacity, and international expansion. Further research is required to identify the actual non-resource based determinants of partner selection in collaborative networks with the focus on disaster response. Another suggestion is to provide a holistic research study involving all humanitarian actors in order to further identify and standardise the minimum requirements in a disaster response by considering the actual disaster type, and the geographical location and culture of each potential affected county. Another path could be the application of the PREDIS model to various case studies and analyse the result and the areas of improvement. In addition, the PREDIS model could be more accurately customised if it could analyse the data for each individual country, where it is possible to define exact scenarios for each disaster type, and the needs and partners required. This also may greatly improve the quality of the predictions and estimations.

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Appendix 1 - HDI

The file is the official UNDP report, which shows the Human Development index for each country and its components for the year 2012. For example Norway and Austrialia have the highest and second highest value respectively equal to 0.955 and 0.938. These values have been used as a part of DSA rank.

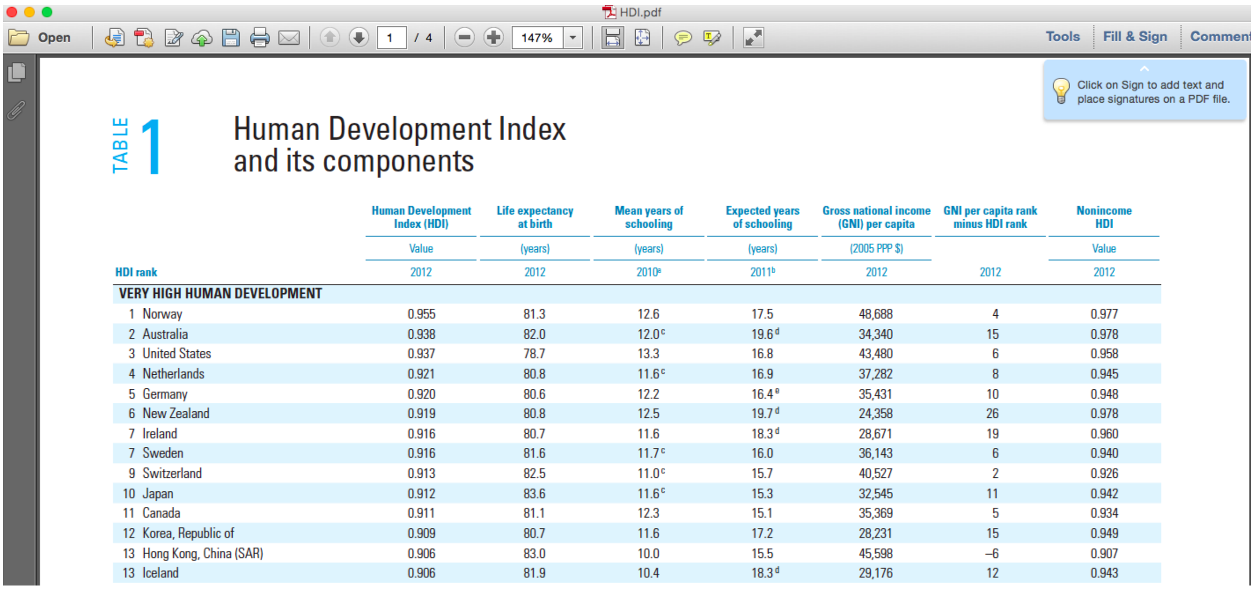


TABLE 1 Human Development Index and its components

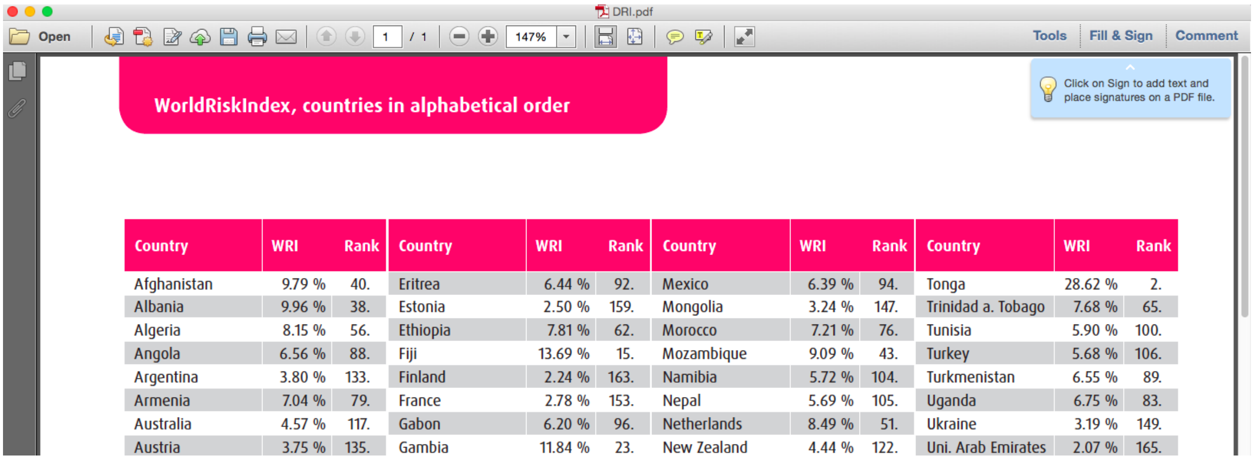
HDI rank		Human Development Index (HDI)	Life expectancy at birth	Mean years of schooling	Expected years of schooling	Gross national income (GNI) per capita	GNI per capita rank minus HDI rank	Nonincome HDI
		Value	(years)	(years)	(years)	(2005 PPP $)		Value
		2012	2012	2010[a]	2011[b]	2012	2012	2012
VERY HIGH HUMAN DEVELOPMENT								
1	Norway	0.955	81.3	12.6	17.5	48,688	4	0.977
2	Australia	0.938	82.0	12.0[c]	19.6[d]	34,340	15	0.978
3	United States	0.937	78.7	13.3	16.8	43,480	6	0.958
4	Netherlands	0.921	80.8	11.6[c]	16.9	37,282	8	0.945
5	Germany	0.920	80.6	12.2	16.4[e]	35,431	10	0.948
6	New Zealand	0.919	80.8	12.5	19.7[d]	24,358	26	0.978
7	Ireland	0.916	80.7	11.6	18.3[d]	28,671	19	0.960
7	Sweden	0.916	81.6	11.7[c]	16.0	36,143	6	0.940
9	Switzerland	0.913	82.5	11.0[c]	15.7	40,527	2	0.926
10	Japan	0.912	83.6	11.6[c]	15.3	32,545	11	0.942
11	Canada	0.911	81.1	12.3	15.1	35,369	5	0.934
12	Korea, Republic of	0.909	80.7	11.6	17.2	28,231	15	0.949
13	Hong Kong, China (SAR)	0.906	83.0	10.0	15.5	45,598	–6	0.907
13	Iceland	0.906	81.9	10.4	18.3[d]	29,176	12	0.943

Although this data is available from the UNDP website, for the readers' convenience an example of it is also available from this address:

https://www.dropbox.com/home/PhD%20thesis%20appendix?preview=HDI.pdf

Appendix 2- DRI

The file is an official world risk report which shows the disaster risk in every country and its rank. For example in the first row Afghanistan world risk index is 9.79% which is higher than Eritera with 6.44 %. This means than the risk of a disaster devastating Afghanistan is higher thatn Eritera.



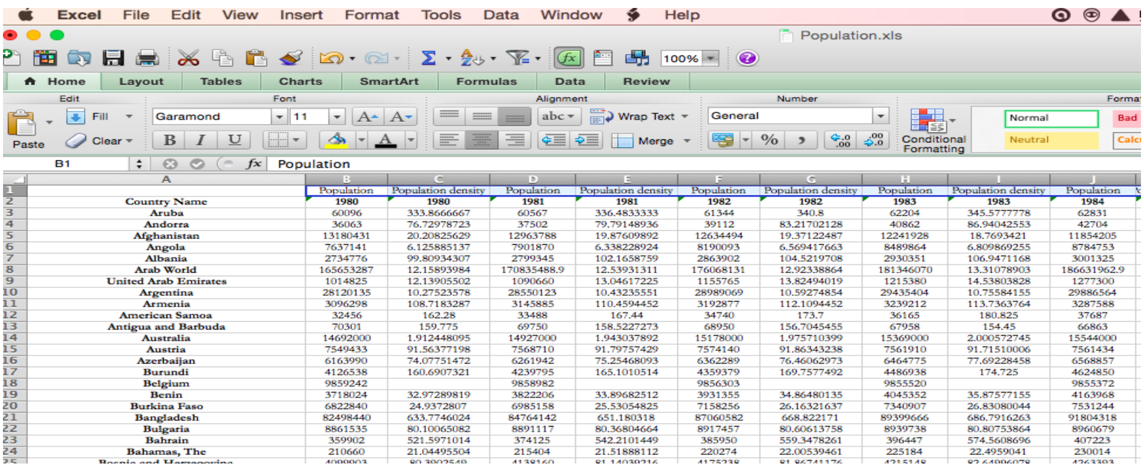
WorldRiskIndex, countries in alphabetical order

Country	WRI	Rank	Country	WRI	Rank	Country	WRI	Rank	Country	WRI	Rank
Afghanistan	9.79 %	40.	Eritrea	6.44 %	92.	Mexico	6.39 %	94.	Tonga	28.62 %	2.
Albania	9.96 %	38.	Estonia	2.50 %	159.	Mongolia	3.24 %	147.	Trinidad a. Tobago	7.68 %	65.
Algeria	8.15 %	56.	Ethiopia	7.81 %	62.	Morocco	7.21 %	76.	Tunisia	5.90 %	100.
Angola	6.56 %	88.	Fiji	13.69 %	15.	Mozambique	9.09 %	43.	Turkey	5.68 %	106.
Argentina	3.80 %	133.	Finland	2.24 %	163.	Namibia	5.72 %	104.	Turkmenistan	6.55 %	89.
Armenia	7.04 %	79.	France	2.78 %	153.	Nepal	5.69 %	105.	Uganda	6.75 %	83.
Australia	4.57 %	117.	Gabon	6.20 %	96.	Netherlands	8.49 %	51.	Ukraine	3.19 %	149.

Although this data is available from the world-risk reports, for the readers' convenience an example of it is also available from this address: https://www.dropbox.com/home/PhD%20thesis%20appendix?preview=DRI.pdf

Appendix 3- Population and population density

The file is the accumulated data obtained from world bank website for the years 1980-2013 for all the countries. The first row in each year represents the population of the country in that year and the second row is the population density. For example in the first row the population of Aruba in 1980 has been 60,096 and its population density has been 333.86.



	A	B	C	D	E	F	G	H	I	J
1		Population	Population density	Population	Population density	Population	Population density	Population	Population density	Population
2	Country Name	1980	1980	1981	1981	1982	1982	1983	1983	1984
3	Aruba	60096	333.8666667	60567	336.4833333	61344	340.8	62204	345.5777778	62831
4	Andorra	36063	76.72978723	37502	79.79148936	39112	83.21702128	40862	86.94042553	42704
5	Afghanistan	13180431	20.20825629	12963788	19.87609892	12634494	19.37122487	12241928	18.7693421	11854205
6	Angola	7637141	6.125885137	7901870	6.338228924	8190093	6.569417663	8489864	6.809869255	8784753
7	Albania	2734776	99.80934307	2799345	102.1658759	2863902	104.5219708	2930351	106.9471168	3001325
8	Arab World	165653287	12.15893984	170835488.9	12.53931311	176068131	12.92338864	181346070	13.31078903	186631962.9
9	United Arab Emirates	1014825	12.13905502	1090660	13.04617225	1155765	13.82494019	1215380	14.53803828	1277300
10	Argentina	28120135	10.27523578	28550123	10.43235551	28989069	10.59274854	29435404	10.75584155	29886564
11	Armenia	3096298	108.7183287	3145885	110.4594452	3192877	112.1094452	3239212	113.7363764	3287588
12	American Samoa	32456	162.28	33488	167.44	34740	173.7	36165	180.825	37687
13	Antigua and Barbuda	70301	159.775	69750	158.5227273	68950	156.7045455	67958	154.45	66863
14	Australia	14692000	1.912448095	14927000	1.943037892	15178000	1.975710399	15369000	2.000572745	15544000
15	Austria	7549433	91.56377198	7568710	91.79757429	7574140	91.86343238	7561910	91.71510006	7561434
16	Azerbaijan	6163990	74.07751472	6261942	75.25468093	6362289	76.46062973	6464775	77.69228458	6568857
17	Burundi	4126538	160.6907321	4239795	165.1010514	4359379	169.7577492	4486938	174.725	4624850
18	Belgium	9859242		9858982		9856303		9855520		9855372
19	Benin	3718024	32.97289819	3822206	33.89682512	3931355	34.86480135	4045352	35.87577155	4163968
20	Burkina Faso	6822840	24.9372807	6985158	25.53054825	7158256	26.16321637	7340907	26.83080044	7531244
21	Bangladesh	82498440	633.7746024	84764142	651.180318	87060582	668.822171	89399666	686.7916263	91804318
22	Bulgaria	8861535	80.10065082	8891117	80.36804664	8917457	80.60613758	8939738	80.80753864	8960679
23	Bahrain	359902	521.5971014	374125	542.2101449	385950	559.3478261	396447	574.5608696	407223
24	Bahamas, The	210660	21.04495504	215404	21.51888112	220274	22.00539461	225184	22.4959041	230014

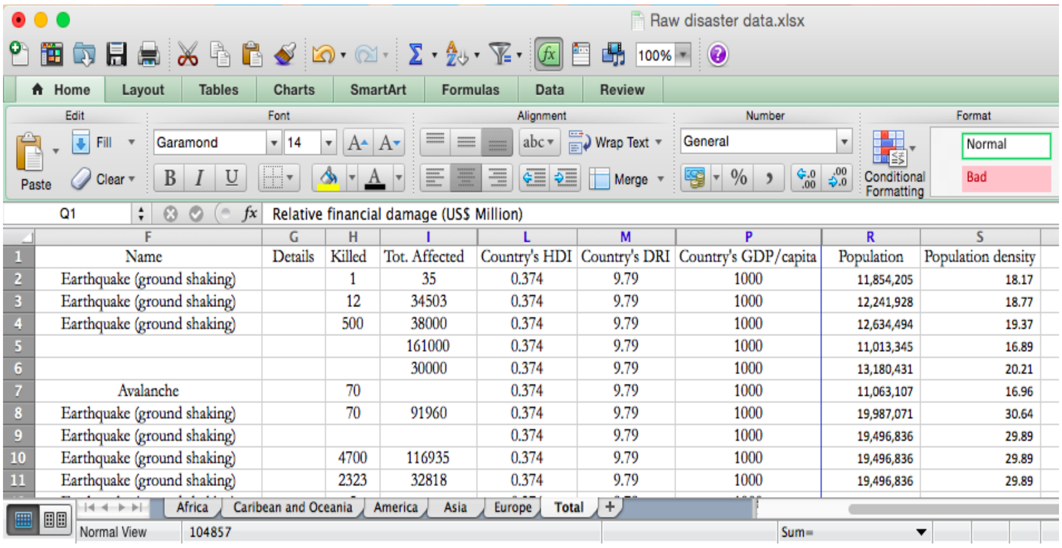
Although this data is available from the World Bank website, for the readers' convenience an example of it is also available from this address: https://www.dropbox.com/s/rkqhmet75m1gn2c/Population.xls?dl=0

Appendix 4- Magnitude, alert level and estimated affected population

Although this data is available from the GDACS website, for the readers' convenience the accumulated data it is also available from this address:

https://www.dropbox.com/s/0a4gzgt7ywdicf9/GDACS.xlsx?dl=0

Appendix 5- The raw data



	F	G	H	I	L	M	P	R	S
1	Name	Details	Killed	Tot. Affected	Country's HDI	Country's DRI	Country's GDP/capita	Population	Population density
2	Earthquake (ground shaking)		1	35	0.374	9.79	1000	11,854,205	18.17
3	Earthquake (ground shaking)		12	34503	0.374	9.79	1000	12,241,928	18.77
4	Earthquake (ground shaking)		500	38000	0.374	9.79	1000	12,634,494	19.37
5				161000	0.374	9.79	1000	11,013,345	16.89
6				30000	0.374	9.79	1000	13,180,431	20.21
7	Avalanche		70		0.374	9.79	1000	11,063,107	16.96
8	Earthquake (ground shaking)		70	91960	0.374	9.79	1000	19,987,071	30.64
9	Earthquake (ground shaking)				0.374	9.79	1000	19,496,836	29.89
10	Earthquake (ground shaking)		4700	116935	0.374	9.79	1000	19,496,836	29.89
11	Earthquake (ground shaking)		2323	32818	0.374	9.79	1000	19,496,836	29.89

Worksheet with the name "Raw data" containing the accumulated database used in this research for building the PREDIS model in the first study. Due to the big size of the excel sheet, the file is uploaded into the following address: https://www.dropbox.com/home/PhD%20thesis%20appendix?preview=Raw+disaster+data.xlsx

Appendix 6- Prediction calculation form

Worksheet with the name "Prediction calculation form" containing the result of DSA ranking and prediction used in this research for building the PREDIS model in the first study. Due to the big size of the excel sheet, the file is uploaded into the following address:

https://www.dropbox.com/s/pz38dz1wl9zn175/Predictions%20calculation%20form.xlsx?dl=0

Appendix 7- Neural network analysis

Worksheet with the name "Neural network" containing the result of the predictions using the neural network analysis. This model is built upon 3000 records and predicting the 1252 remaining data. Due to the big size of the excel sheet, the file is uploaded into the following address: https://www.dropbox.com/s/20cisllnbpe9ffw/Neural%20Network.xlsx?dl=0

Appendix 8- Injured/homeless ratio

Worksheet with the name "Injured homeless ratio" containing the data based on the formulas presented in the research and providing the result of homeless, injured ratios for each country. Due to the big size of the excel sheet, the file is uploaded into the following address: https://www.dropbox.com/s/k5yjb2mia3p0y7o/Injured%20homeless%20ratio.xlsx?dl=0

Appendix 9- Health cluster minimum standard

Worksheet with the name "appendix 9" containing the data and calculation for health cluster requirements. Due to the big size of the excel sheet, the file is uploaded into the following address:

https://www.dropbox.com/home/Public?preview=Appendix+9.xlsx

Appendix 10-List of 300 hypothetical partners

Worksheet with the name "List of 300 partner" containing the data randomly generated for creating a list of hypothetical partners. This list is used as the basis for optimisation result in the third study. Due to the big size of the excel sheet, the file is uploaded into the following address:

https://www.dropbox.com/s/9ju8vprHczczbon/List%20of%20300%20partners.xlsx?dl=0

Appendix 11- List of 20 hypothetical partners

Worksheet with the name “List of 20 partner” containing the data randomly generated for creating a list of hypothetical partners. This list is used as the basis for simulation game partner selection. Due to the big size of the excel sheet, the file is uploaded into the following address:

https://www.dropbox.com/s/9ju8vprHczczbon/List%20of%20300%20partners.xlsx?dl=0

Appendix 12- The PREDIS model platform

Worksheet with the name “The PREDIS model platform” containing the all embedded macros based on the formulas and frameworks presented in this research. Due to the big size of the excel sheet, the file is uploaded into the following address:

https://www.dropbox.com/s/svwt504xsx43eeh/PREDIS%20model%20platform.xlsx?dl=0

Appendix 13- Booklet for simulation game

Worksheet with the name “booklet” containing the all embedded macros based on the formulas and frameworks presented in this research. Due to the big size of the excel sheet, the file is uploaded into the following address:

https://www.dropbox.com/s/3awpgmpxfh7p3sc/Booklet.docx?dl=0

Appendix 14- Exemplary PREDIS platform filled with data from and expert participant

Worksheet with the name “Exemplary PREDIS platform filled with data from and expert participant” containing the data obtained from an expert participants for calculating the result of the PREDIS model. Due to the big size of the excel sheet, the file is uploaded into the following address:

https://www.dropbox.com/s/spkl39hi0s4ixnh/Examplary%20PREDIS%20platform%20filled%20with%20data%20from%20and%20expert%20participant.xlsx?dl=0

Appendix 15 Presentation

A power point file with the name "Presentation" contains the presentation of the simulation game before the process starts. Due to the big size of the file,it is uploaded into the following address:

https://www.dropbox.com/

Appendix 16 – The accumulated result of the selections

An excell file with the name "The accumulated result of the selections" contains the full list of selected partners for each participants in both groups. Due to the big size of the file,it is uploaded into the following address:

https://www.dropbox.com/