Kristin Heien Wilberg
Amund Leinaas Olafsen

BI Norwegian Business School

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Improving humanitarian response through an innovative pre-positioning concept: an investigation of how commercial vessels can be used to store and transport relief items

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Marianne Jahre

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Through collaboration with the research project "Contribute" we have had access to a seldom pool of resources consisting of researchers and practitioners in disaster relief and commercial logistics. This unique composition has provided a combination of both practical experience and theoretical knowledge which has made the process of developing this thesis highly interesting.

Amund Leinaas Olafsen and Kristin Heien Wilberg

Abstract

Both the number of natural disasters and the people affected by these disasters have increased substantially during the recent decades. Not only is the frequency higher, but the complexity, severity and magnitude of natural disasters has also increased. This trend, combined with the limited amount of funding provided by donors, has created a critical need for improved humanitarian response systems. Even though logistics has evolved from being seen as a necessary expense to become an important strategic factor in humanitarian interventions, there exists clear evidence that the current response systems does not always meet the needs of those people affected by disasters in an efficient and effective way.

The research presented in this thesis builds on the idea that the network of resources possessed by a commercial logistics service provider can be applied in an innovative way to improve the current humanitarian response systems. The aim of this research is to analyze whether the performance of humanitarian response can be increased by utilizing commercial vessels to pre-store and transport relief items. By applying operations research, a simulation model is developed in order to test various configurations of an alternative humanitarian response system. The outputs generated by the model is compared with data from previous disaster response in order to determine whether the alternative system is able to deliver relief items faster and to a lower cost than the current system.

Enhancing the performance of humanitarian relief operations through collaboration with a commercial logistics service provider can lead to a number of positive effects. Not only can more people receive vital assistance, a reduction in the portion spent on logistics will free up financial resources that can be used to improve internal processes and capacities, which supports a sustainable long-term development of humanitarian organizations. There exists a limited body of quantitative research within the field of humanitarian logistics and the research presented in this thesis seeks to address this limitation by utilizing an operations research technique to examine how the performance of disaster operations can be improved.

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1. Introduction, background and purpose

1.1. The reality faced by the humanitarian organizations

In November 1998 Honduras was hit by the most devastating hurricane in 200 years; the hurricane Mitch killed 10,000 people and left more than two million people homeless. The hurricane destroyed 400 bridges, washed out roads and left a three feet layer of mud on flooded airfields. When the storm had subsided Carlos Flores, the president of Honduras stated, "we lost in 72 hours what had taken us more than 50 years to build, bit by bit" (Samii et al. 2002, 1).

Although the hurricane Mitch was the worst that had hit the Gulf of Mexico in 200 years, the situation described above is unfortunately only one of many tragic stories. The reported number of natural disasters and the resulting number of people affected by these disasters has increased substantially during the recent decades. Climate change, unplanned-urbanization and poverty/ under-development are some aggravating factors that will result in increased severity of natural disasters in the future (IFRC 2012a). It has even been predicted that over the next 50 years natural disasters will increase five-fold (Thomas and Kopczak 2005). The combination of increased frequency, complexity and severity of natural disasters will widen the range of challenges humanitarian organizations are facing and their ability to design effective and efficient supply chains becomes a critical factor in order to assist the increasing number of people affected. When disasters occur, humanitarian organizations must deliver the needed items and services to victims rapidly, often under quite challenging circumstances. The physical infrastructure is often heavily damaged and there usually exists a high degree of uncertainty related to the number of people affected, as well as their immediate needs.

"During emergencies, the need to respond quickly and efficiently is paramount and an effective and well coordinated logistics operation becomes crucial in a humanitarian context – it means saving lives and diminishing the impact of communicable diseases" (IFRC 2012b). As a result, logistics in humanitarian organizations, which is defined as "the acquisition and delivery of requested supplies and services, at the places and times they are needed, whilst ensuring best value for money" (IFRC 2012b), plays a crucial role in the performance of humanitarian organizations. Despite this, the current growth in resources and capacity among the humanitarian actors does not keep up with the growth in need. According to Majewski et al. (2010) the percentage of people left unassisted is estimate to increase by 50 percent or more within the next decade. In addition, there has been a large increase in the number of humanitarian organizations that seek to contribute to reduce the perceived gap in coverage. Although this is a positive trend, there is a limited amount of funding available for the humanitarian sector and this raise in number of actors creates an even higher pressure on the humanitarian organizations to do more with less.

The increasing demand for humanitarian assistance, combined with a limited amount of funding and higher requirements from donors with respect to efficient disaster interventions, put pressure on the humanitarian organizations to "continue improving their capacities, whether in-house or outsourced, and adopt innovative and forward-looking strategies" (Majewski et al. 2010). One of the recommendations presented by Majewski et al. (2010, 16) is that humanitarian organizations should increase their cooperation with commercial logistics service providers "(…) in order to maximize strategic advantage and effectiveness" and together "(…) identify ways to expand the existing capacities of regional and sub regional logistics platforms in regions that face the highest vulnerability and risks". These recommendations highlight the importance of cooperation between commercial logistics service providers and humanitarian organizations in order to improve the performance of humanitarian supply chains. Keeping this in mind, and the fact that 80 percent of humanitarian operations costs are related to logistics activities (Van Wassenhove 2006), it is necessary to identify new and innovative ways to better utilize the resources applied in humanitarian relief operations.

The need for increased collaboration between the commercial and humanitarian sector has been identified and put on the agenda by the research project "Contribute", which is headed by BI Norwegian Business School. The research presented in this thesis is part of Contribute, which aims to improve the effectiveness and efficiency of disaster operations by identifying ways of developing and maintaining well functioning relationships and collaboration between commercial service providers and humanitarian organizations.

1.2. Contribute – The inspiration for this research

Contribute is a three year development and research initiative which consists of a unique composition of researchers and practitioners in disaster relief and commercial logistics. In addition to BI Norwegian Business School, the collaborating partners are Wilhelmsen Ship Service ASA (the world's leading commercial maritime service provider) and Everywhere - Humanitarian Response and Logistics Services (a firm that offers experts with specialist tools and techniques to actors involved in humanitarian response). The final goal of Contribute is to optimize help to beneficiaries and the research focuses on:

- Enhancing preparedness and planning activities of humanitarian organizations
- Increasing the alternatives for humanitarian organizations looking for suppliers of goods and services
- Encouraging relationships between humanitarian organizations and other actors involved in disaster logistics such as military and commercial
- Supporting measuring of disaster relief performance and continuous improvement
- Steering further in-depth studies for research and development on where the "industry" can be supported best

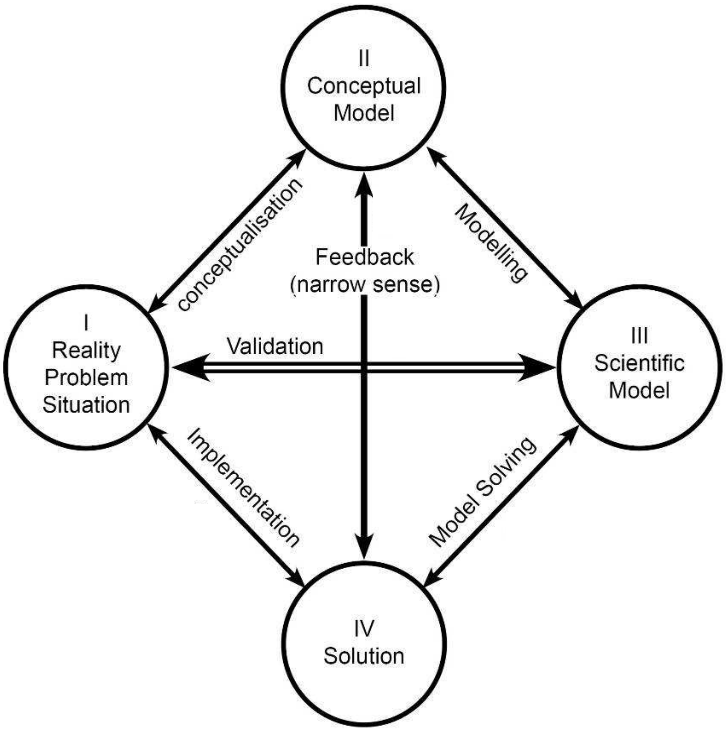
At present Contribute is divided into a number of subprojects. The first project had the purpose of creating a common platform and understanding of disaster relief by establishing a so-called "baseline". This constitutes the prototype of an updatable database tool that can be interrogated on a number of parameters to give an overview of the past, present and future humanitarian logistics market. By developing a process and collecting demand and response data for 63 specific disasters that occurred in the period 2005-2010, the basis for a future forecasting tool has been established. The finalized tool will be offered to actors who play a significant role in funding and operating humanitarian supply chains to provide (them with) better visibility of what is likely to happen. This makes it possible to support their achievements in improving logistics efficiency and effectiveness of their future disaster response through better planning, coordination and cooperation.

By combining the knowledge possessed by the partners of Contribute and the knowledge achieved through the baseline project, the purpose of this thesis is to contribute to the fulfilment of "the vessel project" which is another sub-project within Contribute. This project, and thus this study, aims to test and analyze whether Wilh. Wilhelmsen Holding ASA (WWH), which comprises of different subsidiaries, can improve the performance of the current humanitarian response system. Wallenius Wilhelmsen Logistics **(**WWL), as one of these subsidiaries, is heading the vessel project on behalf of WWH and hence, the study was conducted in cooperation with WWL. In order to test and analyse whether WWL can improve the performance of the current humanitarian response system a quantitative problem solving approach has been applied throughout the entire research process. The structure of this thesis and the different stages of the research process will be briefly described below.

1.3. The structure of the thesis

The structure of this thesis is based on the research process illustrated by Figure 1.1. The figure has served as a guideline throughout the entire research process, from the situational understanding was obtained to the conclusions were drawn.

Figure 1.1 The research process



Source: Mitroff et al. (1974)

The figure was initially created by Mitroff et al. (1974) and “represents a simple whole systems view of the activity of problem solving” (Mitroff et al. 1974, 47). The purpose of this study is to quantitatively test and analyse whether the performance of the current humanitarian response system can be improved and the problem solving approach visualized by the figure is well suited to structure such research. When aiming to improve the performance of real systems, the researcher usually goes through each of the phases described in the figure; the conceptualization phase, the modeling phase, the model solving phase and finally the implementation phase. A problem solving research process can start in any of the four circles. However, the starting point of this study was circle I, while circle II, III and IV represents the output from the subsequent phases. The figure will appear at the beginning of each chapter in order to guide the reader through the different phases, and before proceeding, a brief description of each of the following chapters will be provided.

Chapter 2: An innovative humanitarian response system

The problem solving process of this study seeks to improve the performance of the current humanitarian response system. In order to understand how the system is operating and whether any improvement potentials exists, the second chapter will provide an analysis of the current humanitarian response system and the challenges humanitarian organizations are facing related to this system. Based on this obtained situational understanding, the research question was formulated which required a thorough analysis of WWL’s network of logistical resources. The chapter is finalized with a presentation of an alternative humanitarian response system which seeks to utilize WWL’s resources in an innovative way.

Chapter 3: Conceptualizing the research

A tool was needed in order to quantitatively test, analyze and compare the performance of the proposed response system with the current system. The examination was conducted through quantitative modeling where the tool utilized was a simulation model developed in a computer program. In order to develop this simulation model information related to the system configuration, operating procedures and model parameters (input and output variables) were identified and collected. The conceptualization phase was finalized with the development of two conceptual models which describe the general characteristics of the system studied.

Chapter 4: The simulation model

The fourth chapter provides a walkthrough of the programmed simulation model, including the structure and how the model is to be used. This chapter also provides a description of how the simulation model was validated in order to check whether it represents the proposed response system in a proper way.

Chapter 5: Scenario results and analysis

When the simulation model was developed and validated, what-if analyses were conducted based on different simulation runs. Each of these runs can be seen as experiments where the capacity and the configuration of the proposed system are changed. Each combination of capacity and configuration creates a certain scenario and the outputs, in terms of performance measures, are presented and analyzed in order to determine whether the proposed response system is able to perform better than the current system.

Chapter 6: Discussion and interpretation of the results

Based on the analysis presented in chapter five, this chapter provides a discussion of which factors that has the largest effects on the performance of the proposed system and under which circumstances the proposed system outperforms the current. Further, the chapter elaborates on the potential advantages the humanitarian organization(s) can gain from a future cooperation with WWL and is finalized with an overall conclusion of the study.

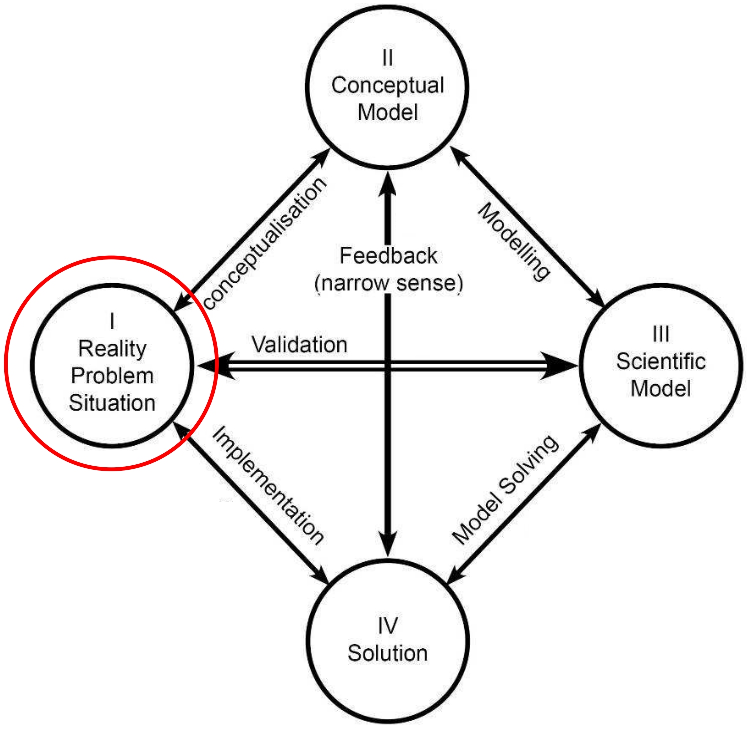
Chapter 7: Recommendations for future implementation

Implementation of the proposed response system is beyond the scope of this study. However, this last chapter provides some considerations and recommendations which should be taken into account if the proposed response system is to be implemented as a pilot project in the future.

2. An innovative humanitarian response system

The starting point of this study, which is illustrated by the red circle in Figure 2.1, was to obtain a comprehensive understanding of the current humanitarian response system, the measures they have undertaken in order to improve the performance of their response and some of the challenges that still remains. The situational understanding obtained from this analysis created the basis for the research question which will be presented in this chapter. In order to reach the purpose of this study, which is to contribute to the fulfillment of the vessel project, a thorough analysis of WWL's network of logistical resources was conducted. Based on both the analysis of the current humanitarian response system and WWL's network of logistical resources, an innovative humanitarian response system is presented at the end of this chapter.

Figure 2.1 The research process



Source: Mitroff et al. (1974)

2.1. The current humanitarian supply chain

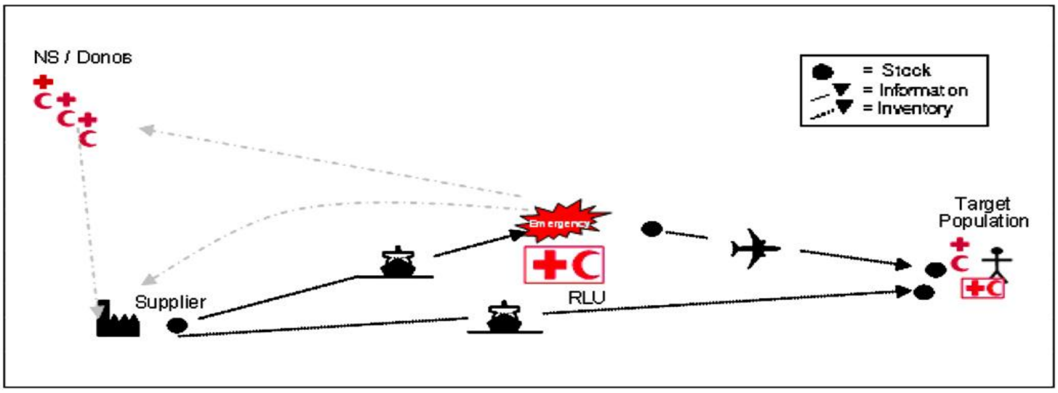
The combination of not knowing exactly where the next disaster will occur, the short lead time needed in order to assist the people affected and the limited amount of founding, forces the humanitarian organizations to emphasis the important trade-off between effectiveness and efficiency. "Effectiveness is defined as the extent to which customer requirements are met, while the efficiency is the measure of how economically the resources are utilized when providing a given level of effectiveness" (Beamon and Balcik 2008, 13). In order to reach a high level of effectiveness the assessed demand must be fulfilled as soon as the needs arise, which requires a short lead time in order to reduce the amount of human suffering created by disasters. A short lead time would either require an extensive use of airfreight or a significant number of storage facilities located in any possible vulnerable area in order to facilitate the availability of relief items. On the other hand, such a high degree of effectiveness is not in line with an efficient utilization of the humanitarian organizations scarce resources.

Humanitarian agencies have over the recent decade become increasingly aware of the significance of logistics in disaster response, (Majewski et al. 2010) and thus the important trade-off between effectiveness and efficiency has been addressed in order to improve their supply chains. As a result, some of the major humanitarian organizations, such as the World Vision International (WVI), the World Food Program (WFP) and the International Federation of Red Cross and Red Crescent Societies (IFRC) have all established storage facilities in strategic locations around the world which has reduced the lead time while the operational cost is kept at a sustainable level (Gatignon et al. 2010). This change has led to a decentralization of the humanitarian supply chains, and combined with an increasing focus on preparedness ahead of disasters made the agencies able to respond faster and more accurate than before (Jahre and Heigh 2008; Gatignon et al. 2010).

Using the IFRC as an example, this section will describe how their current decentralized supply chain is designed and operated. The choice of using the IFRC to exemplify how a current humanitarian supply chain operates was based on four different reasons. First, it is the world's largest humanitarian organization that provides assistance without discrimination (Jahre and Heigh 2008) to people in all parts of the world. Second, the IFRC provides logistical services to other humanitarian organizations that do not possess the required resources (IFRC 2012c). This indicates that the IFRC is not only an important organization for the people affected by disasters, it is also an important logistical actor within the humanitarian sector. Third, the IFRC is the organization that has received most attention from researchers, and thus much information about the organizations is available (e.g. Samii et al. 2002; Jahre and Heigh 2008; Jahre et al. 2009; Schulz and Heigh 2009; Gatignon et al. 2010; Charles 2010; Charles et al. 2011). Finally, the IFRC's supply chain has been designated as the best-in-class for the non-profit sector (Gatignon et al. 2010). Thus, if WWL is able to reduce the challenges faced by the humanitarian organization that is perceived as the best-in-class, it is likely believe that WWL will also manage to reduce the challenges other humanitarian organizations are facing.

Figure 2.2 visualizes the IFRC's current decentralized supply chain which was developed in order to respond more efficient and effective when disasters occur. The supply chain is based on a pre-position structure where three regional logistics units (RLUs) are strategically positioned in Dubai, Kuala Lumpur and Panama (Jahre and Heigh 2008). According to Jahre et al. (2009, 1016) the idea of the decentralized structure was to "reduce negative consequences of lack of local knowledge and long distances to affected areas (...)" and hence, "improve customer service by getting nearer to the field (...)" (Charles 2010, 16). The RLUs are responsible for "sourcing, procurement, warehousing, and transport of relief goods and equipment to meet the specified and required needs at least cost" (Jahre and Heigh 2008, 46) within their respective geographical region.

Figure 2.2 The IFRC's decentralized supply chain

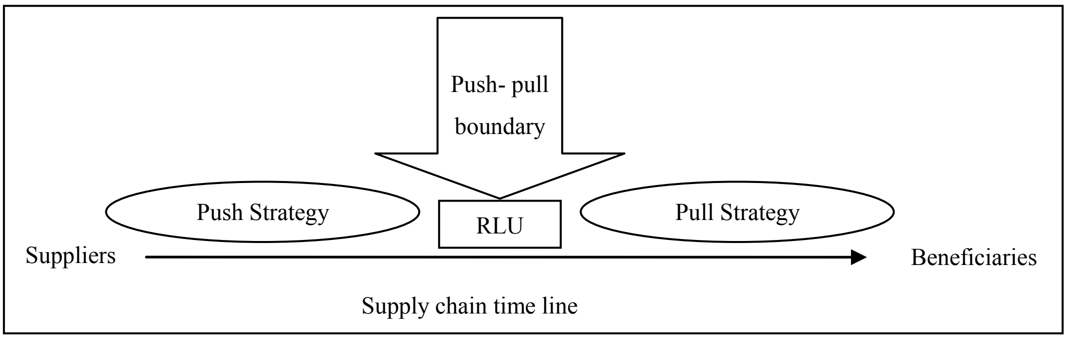


Source: IFRC (2005) in Jahre and Heigh (2008)

In the decentralized supply chain relief items are shipped from suppliers to the RLU in the preparatory phase by efficient modes of transportation, such as vessels. In the event of a disaster, the needed items are flown in from the RLU by cargo planes in order to cover the immediate needs. In the meantime, an appeal is launched by the humanitarian organization and the follow-up replenishments can be shipped from the suppliers' inventory to the disaster area by slower but more cost efficient vessels (Gatignon at al. 2010).

The establishment of pre-positioned relief items in a decentralized structure changed the supply chain strategy from a pull to a push-pull strategy. A pure pull strategy implies that both the production and transportation of products are postponed until the actual demand is known, while a push strategy implies that both production and transportation is based on speculation and conducted prior to the demand is assessed (Pagh and Cooper 1998). Both the pull and the push strategy have their pros and cons. However, a combination of the two, where it is possible to utilized the advantages from both, has emerged as a supply chain strategy that outperform those that solely relies on either push or pull (Simchi-Levi et al. 2004). By combining the two strategies, the initial stage is typically based on a push approach utilizing long term forecasts and economies of scale, while the later stages are based on actual customer demand, focusing on responsiveness and maximization of service level (Wanke and Zinn 2004; Simchi-Levi et al. 2004).

Figure 2.3 The push-pull boundary in the decentralized supply chain



Source: adopted from Simchi-Levi et al. (2004)

As illustrated in Figure 2.3, the RLUs represent the push-pull boundary in the decentralized supply chain, where a push strategy is applied in the preparedness phase while a fast and responsive pull strategy is utilized during the initial response phase. The first part of the decentralized supply chain is utilizing a full speculation strategy where "all manufacturing tasks are performed prior to the product being differentiated by location (…)" (Listou 2008, 61). The push strategy relies on forecasts and takes advantage of the rule of forecasting; implying that aggregated forecasts (all RLUs combined) is more accurate compared to a forecast for a single unit (Simchi-Levi et al. 2004). The improvements in forecasts, due to the utilization of information technology (IT) and institutional learning, combined with standardization of products, makes it possible for the IFRC to push relief items down the supply chain with an acceptable level of uncertainty. This stage is conducted during the preparedness phase which allows the IFRC to use slow but highly efficient modes of transportation (e.g. vessels). Due to a high level of demand uncertainty within the regional level (where, when and how much), the last part of the decentralized supply chain applies a pull strategy based on logistics postponement. The relief items are pre-stored at the RLUs and the last part of the transportation is postponed until the actual demand is known utilizing effective mode of transportation (e.g. airplanes and helicopters).

Any organization has to consider the trade-off between costs and responsiveness in order to choose their desired customer service level (CSL). According to Chopra and Meindl (2010) the optimal level of product availability is determined by the cost of understocking one unit relative to the cost of overstocking the same unit. Any humanitarian organization strives to achieve a high degree of product availability due to the potential cost of understocking relief items which implies a risk of lost lives. Responsiveness in humanitarian interventions is crucial and the combined push-pull strategy contributes to a higher level of product availability in the event of a disaster. Several case studies have revealed that the decentralized supply chain has made the IFRC's humanitarian interventions faster, better and cheaper (e.g. Jahre and Heigh 2008; Gatignon et al. 2010; Charles et al. 2011). This implies that the decentralized supply chain enables the IFRC not only to deliver the relief items/ services faster and to a lower cost, they are also able to deliver a higher amount of the requested items. The IFRC was recognized for their improvements and received the prestigious European Supply Chain Excellence Award in 2006. The jury emphasized that "for scale, responsiveness and performance, (the IFRC) are outstanding: all the more so when you realize that they exist to operate in precisely the places where normal supply chains have broken down (…)" (Charles et al. 2011, 1).

2.1.1. The challenges that still remain

Even though the decentralized supply chain has improved both the efficiency and effectiveness of the IFRC's operations, they are still faced with the same challenge as any other humanitarian organization; it is impossible to estimate the exact demand of relief items and the geographical location of the next disaster. Thus, every time a disaster occurs, the humanitarian organizations must set up a temporary supply chain in order to assist the affected area. As a result, the last part of any humanitarian supply chain (which is exemplified by the arrow from the RLU to the target population in Figure 2.2) can be categorized as a project based supply chain that is set up when a disaster occurs and terminated when the operation is finished. In addition to the use of expensive airfreight, the drawback with this project based supply chain is the large amount of time that is usually needed to mobilize both physical and organizational resources in order to set up an efficient and effective flow of goods and information. Further, local prices of transportation, storage and other logistical services are likely to increase when a disaster occurs due to the need of urgent supply, high demand and capacity constraints (Jahre and Heigh 2008). As a result, the humanitarian organizations, which are working towards the same goal of reducing the amount of human suffering, need to compete with each other for the local resources, leading the prices to increase (Maon et al. 2009; Pettit and Beresford 2009; Balcik et al. 2010). The high uncertainty related to both the amount of time and money needed to set up a project based supply chain indicates that there still remain challenges in order to utilize the scarce resources in the most efficient way.

2.2. The research question

The challenges presented in the previous section applies not only to the IFRC, it applies to any other project based humanitarian response system. If WWL should (be able to) improve the performance of the current humanitarian response system, it must be able to reduce the challenges related to the project based supply chain. As previously mentioned, Majewski et al. (2010, 16) highlights the need for humanitarian organizations to "continue improving their capacities, whether in-house or outsourced, and adopt innovative and forward-looking strategies". In order to identify these innovative strategies, the authors recommend that humanitarian organizations should increase their cooperation with commercial logistics service providers. The research question of this study is in line with this recommendation and is based on the objective of the vessel project in Contribute:

> *"Is it possible to utilize WWL's network of logistical resources in order to improve the performance of the current humanitarian response system?"*

There exist different metrics that can be used to measure the performance of a humanitarian response system, where some examples are: appeal coverage, donation-to delivery time, financial efficiency and assessment accuracy (Davidson 2006). The performance metrics used in this study are based on the three-part performance measurement framework presented by Beamon (1999). This framework consists of resource-, output- and flexibility metrics which are all critical to the success of any humanitarian intervention. Table 2.1 presents the metrics that will be applied in order to measure whether WWL is able to improve the performance of the current response system.

Table 2.1 Performance metrics applied in the study

Performance metric type:	*Goal:*	*How this is measured in the study:*
Resources	High level of efficiency	Is WWL able to deliver relief items to a lower cost compared to the current system?
Output	High level of effectiveness	Is WWL able to deliver the relief items with a shorter lead time compared to the current system?
Flexibility	Ability to respond to a changing environment	Is WWL able to increase the delivery flexibility compared to the current system?

Source: adapted from Beamon (1999)

Level of efficiency and effectiveness are both measured in quantitative terms and compared to the previous response while the ability to respond to a changing environment (level of agility) is presented in qualitative terms and compared in relative terms to the previous response. The efficiency is measured as price per pallet delivered while the effectiveness is measured as the level of customer service level (to what extent customer requirements are met) in terms of average demand fulfilled and the time it takes from the needs arise until the relief items are delivered (lead time). In order to make sure that scarce resources are used in the most optimal way it is highly important for any humanitarian organization to consider the trade-off between efficiency and effectiveness (determining the optimal level of product availability). This issue has been discussed and considered throughout the study where the aim has been to reveal whether an alternative response system can yield a higher level of product availability to a lower cost than the current response systems are able to do.

It is necessary to obtain a thorough understanding of WWL's network of logistical resources in order to reveal whether they can improve the performance of the current system. The next section will present an analysis of the logistical services WWL is offering and the resources they have access to both through direct ownership and through business relationships. In addition, a discussion of whether their resources are well suited to support a humanitarian operation is presented.

2.3. WWL's network of logistical resources

WWL was founded in 1999 after the merger between Wallenius Lines of Sweden and Wilh. Wilhelmsen Lines of Norway and is currently operating one of the world largest RoRo[1] fleets. The company delivers global shipping and logistics solutions where the main customer segments are manufacturers of cars, rolling equipments (e.g. agricultural, mining and construction equipment) and break bulk cargo (e.g. power generation equipment, boats and railcars). WWL has a specialized "factory-to-dealer" concept, which requires a supply chain that integrates ocean transportation, terminal handling, technical services and inland distribution in an effective and efficient manner. This concept enables a "one-stop logistics solution", where customers only need to inform what, when and where and WWL will coordinate an optimal flow of goods and information in their customers' outbound supply chains.

WWL offers a comprehensive portfolio of logistics services which can be divided into five main business segments: (1) ocean transportation, (2) terminal services, (3) technical services, (4) inland distribution and (5) supply chain management (SCM). The ocean transportation service is a port-to-port service which is

[1] RoRo vessels are designed to carry wheeled cargo which is rolled on and off the vessel by the use of a ramp

primarily focused on deep-sea shipping (long distance deliveries) however, transshipment services are also provided when short-sea shipments are required. WWL's terminal services include e.g. customs clearance, storage and preparation of cargo for further transportation. Due to an increased focus on product postponement in the car industry, the demand for technical services has increased tremendously. This service mainly involves preparation of rolling equipment (e.g. accessory fittings) in accordance with quality standards for the marketplace. The inland distribution services include both domestic and international transportation of cargo, either directly from manufacturer to dealer or from manufacturer to port and then to dealer. The final service provided by WWL is SCM, where the aim is to bring speed, accuracy, improved visibility and cost-efficiency to their customers' outbound supply chains. Through process management, visibility, reporting and supplier management, WWL is capable of planning, coordinating and monitoring the flow of goods and information in an optimal way.

In order to deliver these services, WWL is dependent on a large pool of resources which they either control directly or have access to through their extensive network of suppliers and partners. According to Håkansson and Snehota (1995) a company consists of a resource collection comprising the vast amount of resources the firm has access to or controls. This implies that in order to understand a company's resource collection, it is not sufficient to only examine the resources they directly control as if they were an isolated island, one must also consider the resources it has access to through relationships and interactions with other companies. “Relationships are a company's most important assets, because without them it cannot gain access to the resources of others, acquire the supplies it needs, or solve its customers' problems and thus generate revenue. (…) Relationships are in many ways the asset that bind together all of the other assets of a company and convert them into something of economic value” (Ford et al. 2003, 49).

The framework of Håkansson and Waluszewski (2002) was applied in order to understand WWL's comprehensive network of resources, both those they directly controls and those they have access to through business relationships. In this framework the authors distinguish between physical resources (facilities and products) and organizational resources (business relationships and business units).

These categories have been applied in other studies of logistics resources (e.g. Gadde et al. 2002; Jahre et al. 2006) where the objective has been to explore and analyze logistics from a resource perspective. In the following subsections WWL's physical and organizational resources will be presented. The first three subsections will focus on the resources they directly control through ownership, and the last section will examine the additional resources they have access to through different business relationships.

2.3.1. Facilities

"The physical infrastructure for transportation and communication represents significant logistics resources. The elements of this infrastructure that provide time, place and form utility are identified as facilities" (Gadde et al. 2002, 87). These facilities can further be divided into "fixed facilities" and "transportation facilities", where the latter forms a transportation network that connects the fixed facilities together (Heskett et al. 1964, 43).

WWL's extensive fleet of vessels and trucks represents the transportation facilities of the company that connects the different fixed facilities. Their fleet of vessels consists of 61 modern RoRo carriers, which are designed to carry huge cargo loads, and the largest vessels have the capacity to transport up to 7,500 car equivalent units. The vessels at WWL's disposal are unique in that they can be loaded/ unloaded at ports without special infrastructure, (e.g. cranes) that for example containerships require. These vessels are serving 18 trade routes in six continents (Africa, Asia, Europe, North America, South America and Oceania) and connect more than 70 ports worldwide. The extensive network of vessels and routes makes WWL able to reach a strategic port within a maximum of seven days after notification. WWL's dedicated fleet of trucks consists of approximately 1,000 units which connects the different fixed facilities in three different ways: (1) manufacturer and dealer, (2) manufacturer and port or (3) port and dealer. These trucks are designed to transport cars, rolling equipment and break-bulk cargo, and in 2011 the fleet transported more than 2.5 million units. The fixed facilities directly controlled by WWL consist of 11 terminals which together are handling more than 3.5 million units annually. These fixed facilities are used to store cargo as well as prepare the cargo for road, rail or ocean transportation.

In order to handle the physical flow of products between the fixed and transportation-related facilities, software resources, which enable information exchanges between the facilities, are critical for an optimal execution (Shapiro 2007). WWL has advanced software resources for planning and an information exchange which enables a customized IT solution including Advanced Track and Trace (ATT) and Electronic Data Interchange (EDI) programs. The ATT software provides customers with full visibility of their cargo and the EDI software transfers electronic data or documents between the different facilities. These systems enable an interchange of data and documents without human intervention which reduces the possibility of errors. Both systems are crucial in order to achieve an optimal flow of goods and information between the facilities.

2.3.2. Products

According to Gadde et al. (2002) the nature of products is an important determinant of logistics networks. When analyzing WWL, it is clear that their logistical network is specialized to handle three specific segments; cars, other rolling equipments and break bulk cargo. The whole network is therefore designed to manage an effective and efficient flow of these products where standardization is an important factor to create economies of scale related to product handling, transportation and warehousing. Cars represent a higher degree of standardization compared to break bulk cargo, which can vary from windmills to yachts. In order to cope with cargo that is not standardized, WWL has developed a set of standardized rolling equipments (bolster- and mafi-trailers). When placing the break bulk cargo on these equipments it is possible to standardize the cargo which enables a better utilization of both fixed and transport-related resources.

2.3.3. Business units

According to Gadde et al. (2002) a business unit can be a firm or part of a company that operates as a problem-solving actor which combines human-, financial- and technology resources in appropriate ways. This combination of resources is according to Stock and Lambert (2001) the main issue in logistics because they complement one another. As a result, the business unit possesses specific capabilities through human resources which designs and manages the pool of physical resources.

WWL's business units create a unique combination of human resources. With offices throughout North America, South America, Asia, Europe, Africa and Oceania it is possible for WWL to have a global reach and mindset, combined with local knowledge. These offices optimize the movement of cargo through the port to its final destination, where local knowledge about laws and regulations related to customs clearance and road transportation are strictly necessary. In addition, the extensive presence enables WWL to gain from local knowledge related to business language, culture and practice in the different regions where they operate. "Knowledge is our most powerful engine of production" (Marshall 1965, 115) and according to Håkansson and Waluszewski (2007, 140) it is the "knowledge of resources that constitute capabilities, or more exactly the knowledge about the services, applications, that resources render when combined". WWL's business units are possessing specific capabilities through profound knowledge, which makes them able to design and manage an optimal flow of goods and information for its customers through a unique combination of different resources.

2.3.4. Business relationships

As previously mentioned, business relationships are perhaps a firm's most important resource. Through different relationships "resource elements within a business unit are connected to resource elements in other business units" (Gadde et al. 2002, 89) and these interactions effect how resources are combined and recombined over time (Jahre et al 2006). According to Gadde et al. (2002) a significant part of a firm's total resource base is located beyond the ownership boundaries, which is an argument that matches well when we examine WWL's total pool of resources.

WWL has established a diverse supplier base of third party logistics providers (3PLs) which either operates in local markets or globally. Some of these 3PLs are permanently connected to WWL's daily operations, while others are bonded through a more "dormant relationship" and only called upon for specific projects. These 3PLs are providing truck, rail, terminal and warehouse services as well as short shipment and barge services. In addition to these 3PLs, WWL has a close relationship with Wilhelmsen Ships Service (WSS), which is the world's leading maritime service provider. WSS has a comprehensive network of resources throughout the world and operates offices in 125 countries. In addition to these offices, WSS has access to a large number of terminals and storage facilities. Through all these different relationships, WWL has access to an impressive pool of local knowledge and physical resources throughout the world. This, combined with their SCM service, makes WWL capable of delivering a "single point of contact" solution to their customers that combines resources of their own and others in an optimal way, which further reduces costs, provides greater reliability and increased control throughout their customers' supply chains.

2.3.5. Are WWL's resources suited to support a humanitarian response operation?

WWL's comprehensive network of resources, which enables them to deliver logistics solutions that integrate ocean transportation, terminal handling and inland distribution, is currently not intended for humanitarian operations. However, if the relief items can be standardized through the use of rolling equipment (bolster-/ mafi-trailers) it will not differ from any other break bulk cargo that the WWL system is designed to handle. The relief items that are delivered by the suppliers/ producers to the humanitarian organizations' pre-storing facilities are normally placed on pallets (or other standardized units) before they are shipped. This implies that the palletized relief items could be placed directly on a trailer (or in a container and then on a trailer) and be handled in the same way as other types of break bulk cargo.

If the relief items are placed on trailers, the facility related resources that WWL possess, or have access to through business relationships (vessels, terminals, ports, warehouses and trucks), can be well suited to handle (transport and store) basic relief items (e.g. shelters, kitchen sets, tents and jerry cans). The RoRo vessels can be loaded/ unloaded without special infrastructure (e.g. cranes), which make them well suited to operate in a disaster affected area where the infrastructure of ports might be damaged. The cargo transported by these vessels are, in contrast to containerships, placed below the deck, which implies that relief items can be stored without being exposed to debilitating factors (e.g. seawater and dust). This reduces the risk of damaging the relief items during storage and transportation. WWL's large fleet of RoRo vessels operates 18 routes which serve more than 70 ports globally and many of these ports are located in disaster prone areas (e.g.

Jakarta, Chennai and Laem Chabang). WWL's business units, which are located at these ports, possess an extensive base of local knowledge of e.g. law, regulations and business practice/ culture, which is a required resource in order to efficiently transport relief items from the ports/ terminals to the disaster areas. In addition, their ATT program can provide the humanitarian organizations with full visibility regarding the location, type and amount of relief items at any point in time. This indicates that even though WWL's resources are not designed to handle relief items, the features of the resources matches well with the humanitarian organizations' needs.

2.4. An innovative humanitarian response system

As described in section 2.1.1, the main challenge of the last part of any humanitarian supply chain is the uncertainty related to the demand of relief items and the location of the next disaster. Thus, every time a disaster strikes the humanitarian organizations must spend time to mobilize both physical and organizational resources that are required in order to support the affected area. In addition, local prices of logistical services will often increase due to the need of urgent supply, high demand and capacity constraints (Jahre and Heigh 2008; Maon et al. 2009; Pettit and Beresford 2009; Balcik et al. 2010).

In contrast to the humanitarian organizations, WWL is operating mostly permanent supply chains, serving regular sailing routes, where organizational and physical resources are mobilized to create an efficient and effective flow of goods and information. Combining the permanent supply chains with their SCM service, enables WWL to manage their customers' outbound logistics (from factory to dealer) through a "single point of contact" solution. Even though WWL is not currently providing this solution to the humanitarian sector, the previous section indicates that the features of WWL's extensive network of logistical resources seem to match well with the requirements of the humanitarian organizations. WWL possess the required resources needed to manage the humanitarian project based supply chain, and by forming a partnership with WWL the same "single point of contact" solution could be provided to the humanitarian sector. Although the idea of establishing a partnership between humanitarian organizations and commercial logistics service providers is not a new idea, this study seeks to utilize WWL's resources in a way that, as far as we know, has not yet been done.

The idea is to reorganize the structure of the current project based supply chain and create a new supply chain that consist of two different phases which both utilize WWL's resources in a new way. In the first phase, the project based supply chain will be a part of WWL's permanent supply chain (as a "dormant" supply chain) by pre-storing relief items on board vessels and terminals. This implies that relief items are permanently pre-stored at different terminals and onboard WWL's vessels that operate regular sailing routes. As a result, the use of aircrafts in the current project based response system, which is illustrated by Figure 2.4, will be replaced with WWL's vessels as illustrated by Figure 2.5.

Figure 2.4 The current system

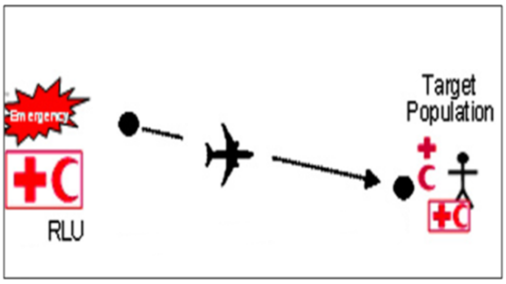
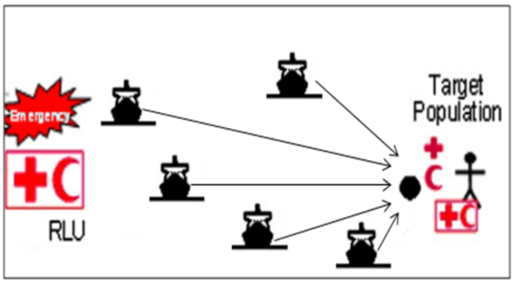


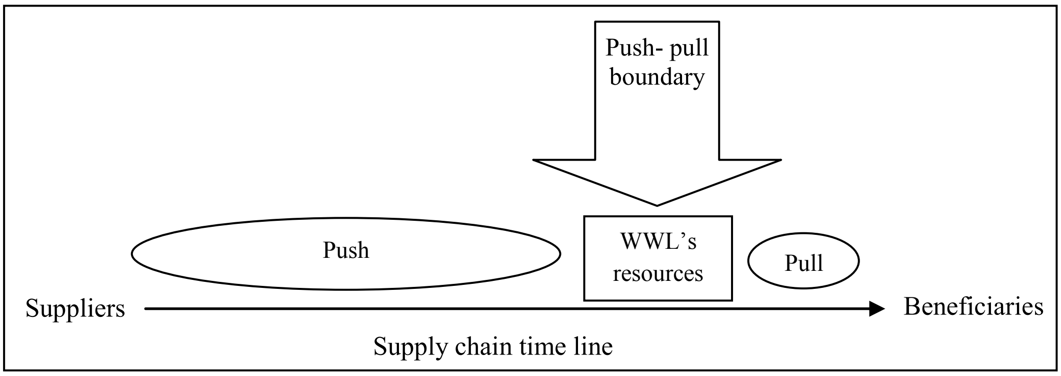
Figure 2.5 The proposed system



Source: adopted from IFRC (2005) in Jahre and Heigh (2008)

In the event of a disaster, the second phase will be initiated and the humanitarian organization will provide WWL with information regarding disaster location and specify the demand of relief items that need to be delivered. WWL will then activate the "dormant" supply chain and the relief items that are pre-stored onboard the vessels will be unloaded at the WWL port that is located closest to the disaster area. In the meantime, WWL will mobilize both physical and organizational resources and set up the inland transportation from the port/ terminal to the disaster area. This innovative response system would imply a shift in the current push-pull boundary towards the beneficiaries as illustrated by Figure 2.6 on the next page. Through an increased push phase, a higher degree of speculation will be applied and the new push-pull boundary will be established in the shift between the two phases; where the "dormant" supply chain becomes activated.

Figure 2.6 The push-pull boundary in the proposed response system



Source: adopted from Simchi-Levi et al. (2004)

"When disaster strikes and the needs peak, it is already too late to develop solutions that are not in place before" (Tomasini and Van Wassenhove 2009, 554). By creating a permanent partnership with WWL and utilizing their resources as described above, it is possible to reduce the uncertainty related to the amount of time and money that is spent on mobilizing resources when disasters occur. In addition, replacing aircrafts with less expensive vessels will most likely reduce the costs related to humanitarian response. Further, by establishing floating warehouses within a permanent supply chain, supported by a network of fixed facilities (terminals), would increase the number of storage facilities and with a high probability of moving them closer to the location of future demand as depicted in Figure 2.6 above. This would imply a reduction in distances from the storage facilities (the push-pull boundary) to the affected areas, which might keep the lead time at the same level or even lower compared to the use of airfreight.

According to Lee (2004) the best supply chains are not only highly responsive and efficient, they are also agile. Supply chain agility is defined as the ability to "respond to short-term changes in demand or supply", and according to Charles et al. (2010) there are different capabilities that an organization needs to possess in order to achieve a high level of agility. One of these capabilities is delivery flexibility, which is defined as "(…) the ability to change planned or assumed delivery dates" (Slack 2005, 1193). Uncertainty is omnipresent in the humanitarian world and quick changes in demand of relief items (when, where, what and how much) have forced humanitarian organizations to continuously improve their level of agility in order to respond quickly when a disaster occurs. The suggested solution implies a combination of fixed and floating storage facilities which enables a quick mobilization of the required resources. This increases the humanitarian organizations' level of agility, by improving their delivery flexibility e.g. where one facility (vessels or terminals) can easily be supported by (other) floating storage facilities (vessels). In addition, increased delivery flexibility would make humanitarian organizations able to respond faster to the continuously increasing short-term changes of demand that is related to natural disasters.

This innovative idea could improve the performance of humanitarian response and increase the number of beneficiaries that receive vital assistance and hence, "(…) mitigates the urgent needs of a population with a sustainable reduction of their vulnerability in the shortest amount of time and with the least amount of resources" (Tomasini and van Wassenhove 2004, 1).

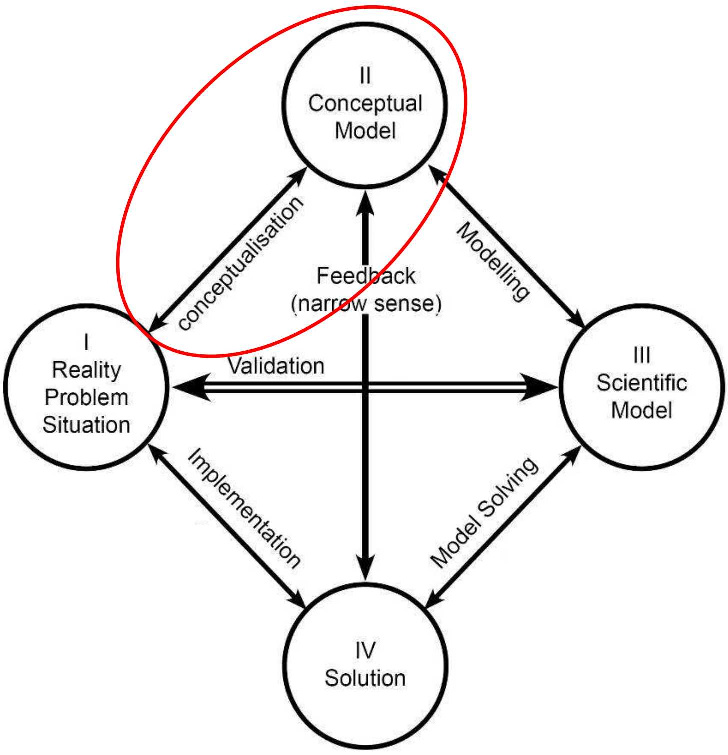
2.5. The research objective

The proposed response system presented in the previous section requires a new project based humanitarian supply chain to be set up within WWL's permanent network of resources. Before this system can be tested in reality and implemented as a permanent solution, it is necessary to examine how it performs compared to the current response system. The objective of this study is to provide the management of WWL and their potential humanitarian counterpart with a tool that can test and analyze if the proposed response system is able to increase the effectiveness and efficiency of humanitarian response and if so, how this system should be designed. As a result, the tool can support decision-makers within WWL and humanitarian organizations when discussing potential future collaborations. The next chapter will present the selected research method and technique utilized when the decision support tool was designed and developed.

3. Conceptualizing the research

The previous chapter provided an analysis of the IFRC's supply chain which is considered to be one of the best response systems that is currently operating within the humanitarian sector. Further, the challenges related to the last part of any humanitarian supply chain was discussed. Based on these findings and the analysis of WWL's network of logistical resources, an innovative humanitarian response system was presented. This chapter will describe the conceptualization of this study, which is illustrated by the red circle in Figure 3.1. The first section will present the selected research method and technique, as well as the appropriate quality criteria for this research. Further, the chapter describes the data that was collected in order to develop the decision support tool and finalizes with a presentation of two conceptual models which visualize the configurations of the proposed humanitarian response system.

Figure 3.1 The research process



Source: Mitroff et al. (1974)

3.1. Research methodology

The objective of this study is to develop a decision support tool that can be used to examine whether the proposed response system can perform better than the current system. Such an examination, which involves testing and analyzing a proposed system, can be categorized as operations research (OR). This field of study is defined as a "scientific approach to decision making, which seeks to determine how best to design and operate a system, usually under conditions requiring the allocation of scarce resources" (Altay and Green 2006, 476). The techniques applied within this field of research utilize formal methods such as mathematics, statistics and computer science in order to solve complex decision-making problems.

OR as a field of study developed during the First World War where the Allied forces created groups of scientists from different disciplines, and by combining their interdisciplinary knowledge they were able to create efficient solutions to complex military problems. Back in the civilian life, the researchers started to apply the methodology in universities and businesses in order to solve real-life problems in operations management (OM) e.g. solving large-scale production and distribution problems within the oil and gas industry (Ravindran, 2008). Gradually, the complexity of the problem formulation was increased, "making use of progress made in mathematics, statistics and computer science, leading to the development of OR as a branch of applied mathematics and computer science" (Bertrand and Fransoo 2002, 244). The research stream has focused on solving practical problems and less attention has been "paid to the scientific modeling of operational processes, that is, describing the statistics and dynamics of the processes that are the object of study in OM" (Bertrand and Fransoo 2002, 244). Despite this limited focus on the scientific aspects, the research stream has contributed with valuable insight. Methods and techniques developed by OR have made a tremendous impact on the design and control of operational processes, like mathematical optimization techniques (linear programming, network analysis and queuing theory) and simulation (Bertrand and Fransoo 2002; Ravindran, 2008).

Quantitative modeling has usually been the basis for research within the field of OR. "Quantitative model based research can be classified as a rational knowledge generation approach" and is "based on the assumption that we can build objective models that explain (part of) the behavior of real-life operational processes (…)" (Bertrand and Fransoo 2002, 249). Models in OR could be defined as "an external and explicit representation of part of reality as seen by the people who want to use that model to understand, to change, to manage and to control that part of reality in some way or other (Pidd 1999, 120). There is a causal relationship between control variables and performance variables which enable the researcher to build a model that can predict future state of the process modeled, rather than be restricted to only explain the unique observations made. Hence, all claims are therefore unambiguous and verifiable (Bertrand and Fransoo 2002). OR models are based on mathematical and logical reasoning, and possessing the "external and explicit" representation makes it possible to challenge and examine the model itself and the results it produces. This also means that it can be represented by a logical language e.g. a computer program, enabling researchers to utilize powerful tools to investigate and find solutions to highly complex problems.

Models are representations of certain aspects and parts of reality (a system) and they enable researchers to get an understanding of the causes and effects on a system if changes were to be implemented, e.g. revealing the consequences of a change in the routing system for air control without affecting the actual control system. Hence, by creating a model it is possible get a comprehension of the consequences of a change without exposing the real environment for adverse effects from trial and error. However, no model in OR will be a complete representation of reality, if it was so, it would be "as complicated, expensive and as disastrous when things go wrong as the reality itself" (Pidd 1999, 120). Models seek to represent parts of reality and this partiality is governed by the researchers' intended use of the model, where the aim is to make sure that the model fit for some specific purpose.

3.1.1. Simulation as an operations research technique

A simulation model is applicable when the performance of large and complex system needs to be evaluated but where it is difficult to "capture the system dynamics in straightforward equations that could be used in an optimal technique" (Harmonsky 2008, chap. 12 p. 22). Compared to an optimization model, which seeks to find an optimal solution to a certain problem, simulation models are heuristic- meaning that the model provides outputs from different scenarios where the researcher compares the results without necessarily finding the optimal solution. The best scenario(s) could be further examined by the use of sensitivity analysis in order to test whether the selected scenario(s) could yield an even better result and under what circumstances a scenario performs better than others. Further, simulation as a modeling technique has over the years developed to be one of the most widely used tools to observe the behavior of supply chains and analyze the effectiveness and efficiency of logistical systems where it is too costly or impossible to obtain real world observations (Manuj 2009; Bottani and Montanari 2010; Law and McComas 2001).

Simulation adds a temporal aspect to a model, which by definition is a static representation of a system, by "depicting how the system being modeled changes over time" (Sokolowski and Banks 2009, 17). Simulation can be defined in several ways, however all definitions capture the aspect of predicting the behavior or performance of a specific system over time while input variables are changed (Sokolowski and Banks 2009). An alternative humanitarian response system, as proposed in this study, does not currently exist, and hence it is not possible to get an understanding of the system's performance unless it is set up in reality or modeled by the use of computer technology. Establishing such a system in reality, only to test whether it would be beneficial to utilize WWL's existing resources when storing and transporting relief items, would be way too costly (both in terms of money and the amount of human suffering if the proposed system fails to deliver). As a result, it was decided to develop a simulation model in order to examine the performance of the proposed system. Simulation is an appropriate OR technique to use in order to understand how the performance of a proposed humanitarian response system changes when the configuration of the system is changed. By changing the input variables (e.g. capacity of the resources), the simulation model will be able to predict the effects on the performance variables (e.g. cost of transportation and lead time) without disturbing the real system. This methodology refers to what Pidd (1999) terms "reflection before action" where the model represents a convenient world "in which one can attempt things without the possible dire consequences of action in the real world" (Pidd 1999, 119).

Simulation models are descriptive and can either be deterministic or stochastic. A stochastic simulation model has a random component which is not controlled by the researcher, while a deterministic simulation model describes a system's performance assuming there are no random effects. The humanitarian response system, as it is simulated in this study, does not have any random effects assigned to it and hence, it is a deterministic simulation model. A deterministic simulation model involves state variables (e.g. capacity of vessels, speed and loading/ unloading time) describing the state of a system at a given discrete point in time and equations or other relationships describing how the state variables change over time as functions of decisions and external event (Shapiro 2007; Harmonsky 2008). The researcher controls the input variables and due to the lack of randomness there is no uncertainty related to the changes in the state of the system. Depending on the system studied, the events are characterized as discrete or continuous. Most applications of simulation in practice are discrete-event simulation, including the simulation of the proposed response system in this study, where the event is related to changes in the state of the system modeled. "Discrete event simulation is a computer-based methodology that allows modeling an existing or proposed system, capturing key characteristics and parameters of that system, such that the model emulates the behavior and the performance of the system as events takes place over time" (Harmonsky 2008, chap. 12 p. 1). Analyzing the different scenarios generated by the simulation model provides an understanding of the behavior of the proposed humanitarian response system and how the performance varies as changes in the input variables are made.

3.1.1.1 What-if simulation; an experimental research design

Simulation as a method is a widely used tool to observe the behavior of supply chains in order to understand their level of efficiency and effectiveness and to "… assess the impact of changed input parameters on the resulting performance, without examining real case examples" (Bottani and Montanari 2010, 2860). As a result, it "enables companies to perform powerful what-if analysis leading them to better planning decisions" (Chang and Makatsoris 2001, 26). What-if analyses are used to evaluate changes in an existing system or to support a decision on how a proposed system should be designed. Such an analysis is often preferred when a limited number of alternatives are to be considered, and it serves as a useful tool in order to understand effects of change to a single or a limited number of variables. Further, what-if analyses are well suited to test and analyze various aspect of a certain supply chain such as network configuration, facility location, inventory policies and transportation routes and modes (Rosenfield 1985).

In order to understand how the proposed humanitarian response system should best be designed to perform better than the current response systems, it is necessary to run the simulation model with different system configurations. By changing the state variables it is possible to evaluate the performance of the system through a what-if analysis e.g. how a reduction in capacity onboard vessels will affect the total lead time. The simulation model will be run every time a new "what-if change" is made to the system, creating a specific scenario. Each of the scenarios that are tested in the model can further be seen as a unique experiment. Thus, it is appropriate to categorize the research design of this study as experimental. Experimental design is the way to decide the configuration of input variables before the simulation model is run in a systematic way and examines the changes in the performance variables. "Real life" controlled experimentation of logistics and supply chain systems is difficult to conduct, which makes experimental designs using computer simulation models an attractive alternative for understanding system behavior within the field of logistics (Chang and Makatsoris, 2001).

3.1.2. Previous operations research conducted on humanitarian response systems

According to Kovács and Spens (2011), most of the recent publications within the area of humanitarian logistics are case-studies and conceptual reviews, and the authors emphasize the lack of empirical or analytical studies that can really make a substantial contribution to the challenge of humanitarian logistics. This statement might hold for most of the existing research on humanitarian logistics, however, some researchers have provided an analytical approach to assist decision-makers in designing more efficient and effective response systems. These publications have focused on how humanitarian organizations can increase the efficiency and effectiveness of their response operations by applying quantitative tools. The majority of these studies have utilized OR techniques by focusing on facility location problems (maximal covering location problem) or transportation planning/ vehicle routing problems (optimizing the flow of relief items through existing distribution networks).

Haghani and Oh (1996) and Oh and Haghani (1997) developed detailed routing and scheduling plans and analyzed how personnel and relief items (such as food, clothing, medicine and machinery) could be transported in the most efficient manner in order to minimize the loss of life and maximize the efficiency of the relief operation. Due to the high uncertainty regarding the condition of the infrastructure in a disaster area and the problems this might cause for transportation, Barbarosoğlu et al. (2002) analyzed how the use of helicopters could decrease the lead time for aid delivery. Further, Ozdamar et al. (2004) analyzed how to transport different relief items from a number of supply centers to distribution centers located close to the affected area. These studies, which are focusing on transportation planning/ vehicle routing problem, have the same objective of minimizing the amount of unsatisfied demand by utilizing the proper routs and transportation modes.

With regards to facility location problems, the objective is also to minimize the amount of unsatisfied demand, which in this context means saving life. However, the analytical starting point is different. In these studies the researchers are not primarily focusing on the mode of transportation that should be used from the different distribution centers to the affected area; they are concerned with determining the optimal geographical location for the different facilities/ distribution centers. In the commercial sector, facility location decisions are concerned with maximizing profits and the trade-off between efficiency and effectiveness is therefore a main challenge (Balcik and Beamon 2008). Studies conducted on facility location in humanitarian relief utilize the same factors to determine the optimal locations, but the aim of maximizing profit is replaced by minimizing human suffering. Maximal covering location problems (MCLP) have the objective of "maximizing the total number of people served within a maximal service distance, given a fixed number of facilities or budgeted limitations" (Balcik and Beamon 2008, 105). Hale and Moberg (2005) presented a general approach on how to establish a secure site location process in order to balance the operational effectiveness and efficiency by identifying the minimum number and possible locations of storage facilities. The same approach was applied by Balcik and Beamon (2008) which developed a model to determine the number and location of facilities within the relief network.

Tatham and Kovács (2007) presented an alternative approach on how relief items can be transported and stored compared to the research presented above. The purpose of this case study was to compare the costs and lead time of an alternative response system with the system that actually responded to the 2005 Pakistan earthquake. This alternative system utilizes a suitably sized vessel as a floating warehouse located near a risk area, containing sufficient relief items to meet the need of the affected people. When a disaster strikes, the vessel will immediately sail towards the port located closest to the disaster area and unload the relief items. The proposed system, which is referred to as sea-basing, is a widely used concept within the Armed Forces (Tatham and Kovács 2007). In the study, three different configurations/ scenarios of the proposed response system was tested and analyzed; (1) purchase of a suitable vessel (new or second hand), (2) hire of capacity on an existing vessel when a disaster occurs and (3) charter of a vessel on a long-term basis. The purpose of the study was to compare the costs and lead time of these scenarios with the actual response which utilized airfreight. The authors conclude that the alternative strategy is not only less expensive compared to the use of airfreight, it also increased the effectiveness by lowering the lead time. The OR technique applied in this study could be defined as a manual what-if simulation, where a given set of input variables are changed in order to investigate the effect on the performance of the system (e.g. "what" happens to the performance of the system when the number of containers stored onboard the vessel is changed).

The proposed response system presented in this thesis utilizes WWL's terminals and vessels to pre-store and transport relief items. These vessels are serving regular routes, and when a disaster occurs, the items will be unloaded at the port located closest to the disaster area. Research conducted on such a response system has not yet been identified. However, the study conducted by Tatham and Kovács (2007) shares some of the same conceptual ideas underlying this study, and the authors highlight the need for further research within this area in order to investigate the use of the sea-basing concept within the humanitarian sector. Although most of the studies presented above have not applied "what if" simulation, they have all served as guidelines when the relevant input variables were identified and collected in this study. In addition, they present formal techniques used when approaching complex decision-making problems within the field of relief logistics such as computer software and mathematical and statistical methods. As a result, the studies contribute with concrete ideas on how efficiency and effectiveness can be increased and how a proposed system can be modeled and tested by the use of computer software.

3.1.3. Quality criteria of the research

The most prominent criteria used to evaluate a quantitative research are according to Bryman and Bell (2007) validity and reliability, where the latter refers to the degree to which a measure of a concept is stable over time. With regards to the simulation model, a test of reliability would imply that the model is run at different times where the outputs generated are compared. If the correlation between the different outputs is high, the measures would be categorized as reliable. If no changes are made to the simulation model there is no doubt that the outputs generated by the model today will be consistent with the outputs generated by the model in the future and thus, the measures would be reliable at any time. On the other hand, if the simulation model needs to be changed in the future (either the value of the input variables or the relationship between them) in order to represent the system in an accurate way, the outputs generated by the model would no longer be consistent with the previous outputs. This implies that the conclusions drawn in this thesis, which are based on the outputs from the simulation model, are only reliable if the value of the input variables and/or the relationship between them is not changed.

According to Bryman and Bell (2007) the quality measure of validity is concerned with whether a measure of a concept really measures that concept. With regard to this study, "validation is the process of determining whether a simulation model is an accurate representation of the system, for the particular objectives of the study" (Law and McComas 2001, 22). As a result, a simulation model is valid if the system simulated is a good representation of the real system (if a system exists) or how the system would operate if it was implemented in reality (if the system does not currently exists). On the other hand, if the simulation model is not valid, the conclusions drawn by the researcher, which are based on the outputs generated by the model, would have no/ low value (Sadoun 2000). This implies that the quality measure of validity is not only appropriate, it is also highly important with regards to the selected research technique in this study.

As models are supposed to be abstractions and simplifications of reality, it is not possible to obtain absolute model validity (Law and McComas 2001). However, the entire research process of this study has to a large extent focused on ensuring that the system simulated is a good representation of how the system would have operated if it was implemented in reality and thus develop a model with high validity. Even though the research process presented by Mitroff et al. (1974) indicates that the process of validation should start when that simulation model has been developed, subject-matter experts (SMEs) have been involved throughout the entire research process. Partners of Contribute with experience in humanitarian response and employees of WWL with in-depth knowledge of the company's resources and systems have not only provided essential feedback during the process, they have also actively participated in some of the steps. When the research process started it was essential to understand the reality faced by the humanitarian organizations and the challenges they have to cope with in order to indentify the improvement potential that exists within the current humanitarian response system. This situational understanding was not only obtained through secondary sources (e.g. books, articles, documents or web pages) but also through conversations with partners of Contribute with experience in this field. With regards to WWL and how their resources can potentially be utilized to support a humanitarian intervention, a close collaboration with different employees of the company was highly necessary throughout the research process.

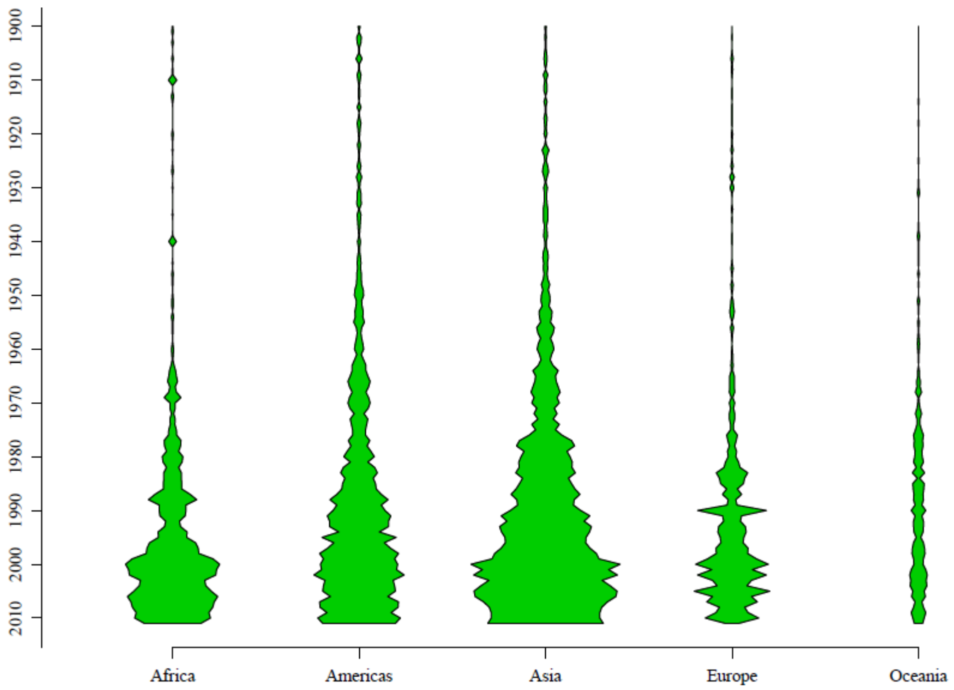
In order to create a valid simulation model the SMEs were not only included when the objective of the study was decided they were also included when input variables were identified, collected and verified, the conceptual model was made, and when the simulation model was programmed and validated for the last time. As a result, the issue of quality is discussed in the different parts of this thesis were these steps are presented.

3.2. Identification and collection of input variables

The objective of the simulation model is to compare the performance of different configurations of the proposed response system with the system that responded to the disasters. Responsiveness and cost are the performance variables of the simulation model and hence, all variables (independent) that would affect the value of these two performance measures needed to be identified and collected before the model could be developed. The process of identifying the input variables was done in cooperation with different partners of Contribute and the value of each input variable was collected either as primary or secondary data.

During "the baseline project" Contribute collected detailed information about 63 disasters that have occurred throughout the world. However, due to the limited time frame of a master thesis is was decided to only focus on the disasters that had occurred in one specific region. The geographical scope of this study was set through a discussion with partners of Contribute with extended experience and knowledge in humanitarian response. The region of Asia was selected, which is one of the most vulnerable and exposed regions to natural disasters. This is supported by Figure 3.2, showing the number of disasters that was reported in different regions (continents) between 1900 and 2010.

Figure 3.2 Number of natural disasters reported between 1900 and 2010



Source: EM-DAT (2012a)

The choice of Asia as the region of focus also matches well with WWL's ability to respond to disasters in this region. Asia is one of the areas where the company has its most extensive network of logistical resources in terms of routes, vessels, terminals, offices/ agencies and trucks.

Activities undertaken in disaster relief operations can be divided into different phases; preparedness, response and reconstruction (Kovàcs and Spens 2007). When data was collected by Contribute the focus was only on the response phase (which starts immediately after the disaster occurs and last for a year) and this phase was further divided into three sub-phases; (1) the first 12 weeks, (2) week 13 to 26 and (3) week 27 to 52. The collected data was categorized according to these phases, and this study has only focused on the first sub-phase (first 12 weeks) which is defined as the “immediate response phase”.

The process of identifying and collecting input variables was divided into two steps, the first focused on the previous response while the second focused on the response of the proposed system.

3.2.1. Input variables related to the current response system

With regards to the system that responded to the 16 disasters the following five input variables were identified:

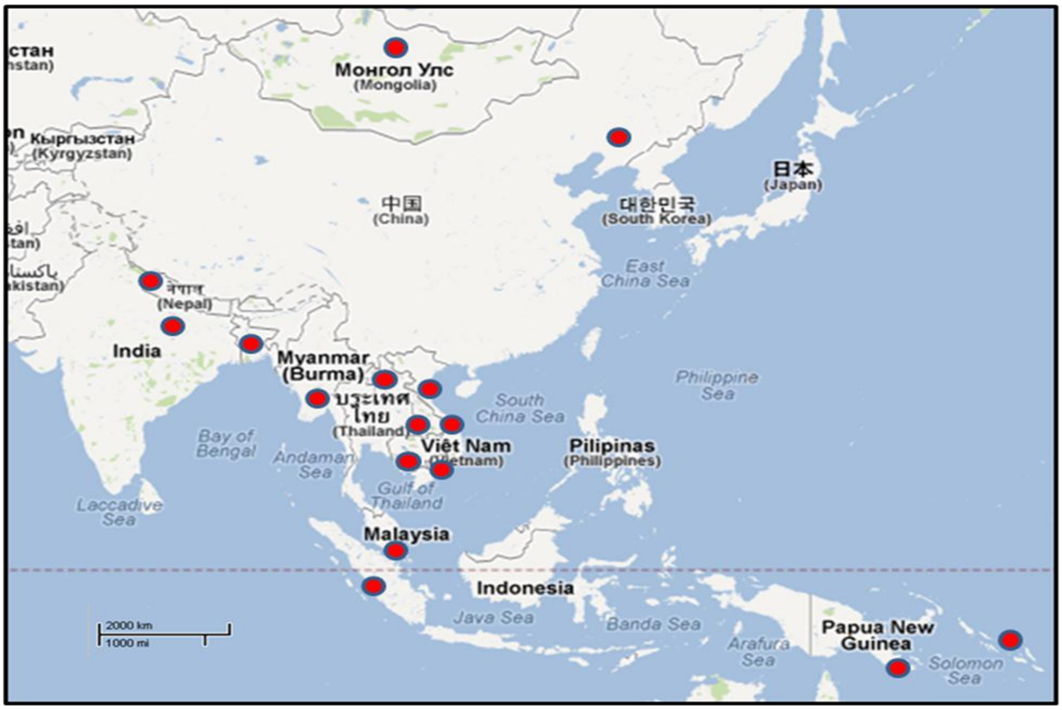
1. The geographical location of each disaster
2. The humanitarian organizations that responded to each disaster
3. The type and amount of relief items that was delivered to each disaster
4. The total lead time of the previous response to each disaster
5. The cost of the previous response to each disaster

The data collected by Contribute contained all the information needed in order to determine the value of each input variable and as a result, the values of these input variables were collected as secondary data. The process of identifying and collecting the values of these five input variables will be explained in the following subsections.

3.2.1.1 The geographical location of each disaster

Out of the 63 disasters included in the “baseline” project, 16 had occurred in the region of Asia, and the geographical locations of these disasters are depicted in Figure 3.3 on the next page. Even though the disasters are scattered throughout the region, the majority of these disasters are located in South-Eastern Asia.

Figure 3.3 Geographical locations of the 16 disasters



3.2.1.2 The humanitarian organizations that responded to each disaster

This input variable was included in order to get an overview of the different organizations that frequently respond to disasters in the selected geographical area. In addition, it was important for WWL to obtain this information in order to know which humanitarian organization(s) they potentially could cooperate with in the future if a pilot project were to be undertaken. In total, 24 different humanitarian organizations responded to the previous 16 disasters.

3.2.1.3 The type and amount of relief items that was delivered to each disaster area

Contribute also collected data related to both type (e.g. shelter, blanket or food) and amount (in terms of kg and m3) of relief items that were delivered to each disaster. As this study is focusing on the immediate response phase, only the items that were delivered during the first twelve weeks were included.

3.2.1.4 The lead time of the previous response to each disaster

In the simulation model the lead time (effectiveness) of different scenarios of the proposed system is compared to the lead time of the previous response to the 16 disasters. The data collected by Contribute did not provide information regarding when the items in the immediate response phase were delivered. Hence, the lead time was set to twelve weeks with an equal number of deliveries assigned to each week (e.g. if the total amount of items that was delivered during the first phase was 120,000 kg the simulation model calculates that 10,000 kg (120,000 / 12 weeks) was delivered in each of the twelve weeks).

This methodology was discussed with partners of Contribute, and it was concluded that only a small amount of items are normally delivered during the first weeks due to the time it takes to set up a project based response system. However, when the response system is established, it is possible to speed up both the batch size and the delivery intervals. The time it takes to set up a response system varies to a great extent, from one disaster to another, and combined with the lack of documentation regarding the lead time of the previous response system, it was decided that the method described above was appropriate.

3.2.1.5 The cost of the previous response to each disaster

The "baseline" project identified nine different logistical activities that all generated a certain cost with regards to each disaster. These nine logistical activities are:

1. International warehousing (INWH)
2. International transport air (INTA)
3. International transport sea (INTS)
4. International transport land (ITTL)
5. Customs clearance (CSCL)
6. Local warehousing (LCWH)
7. Local transport air (LCAR)
8. Local transport sea (LCTS)
9. Local transport land (LCLD)

In order to find the total cost of the previous response to each of the 16 disasters the cost of these activities were added together.

3.2.1.6 Summary of the input variables related to the previous response system

For each of the 16 disasters an excel sheet (exemplified by Table 3.1 below) was mad, which contains all the input variables described above. Each disaster has a unique disaster number (e.g. 2007-0557) as shown in the first column in Table 3.1, while the second column provides information about the geographical location of the disaster. The third column shows which humanitarian actors that responded to the disaster and column four provides data on the type of relief items that was delivered by these organizations. Column five, six and seven provides information about the number of units shipped as well as the total kg and m3 that these units constitute. In the next nine columns the cost of each logistical activity are shown and in this example, the activities that generated a cost when responding to this disaster were: international transportation sea (INTS), customs clearance (CSCL), local warehousing (LCWH), local transportation air (LCAR), local transportation sea (LCTS) and local transportation land (LCLD). The total cost of the previous response to this disaster is obtained by adding up the numbers in the last column which corresponds to $24,015.

Table 3.1 Summary of the input variable related to previous response

Disaster response							Cost of logistical activities									Cost of response
Disaster	Location	Actor	Item	Number of units shipped	Total kg	Total M3	INWH	INTA	INTS	INTL	CSCL	LCWH	LCAR	LCTS	LCLD	
2007-0557	Papua N. G.	IFRC	Cereals	5 352	5 352	10	$0	$0	$642	$0	$24	$27	$10 597	$268	$749	$12 591
2007-0557	Papua N. G.	IFRC	Hygiene kits	242	1 331	7	$0	$0	$160	$0	$17	$19	$2 635	$67	$186	$3 597
2007-0557	Papua N. G.	Caritas Int.	Shelter	190	11 400	40	$0	$0	$0	$0	$0	$106	$0	$0	$1 596	$3 526
2007-0557	Papua N. G.	World Vision Int.	Cereals	22 000	22 000	42	$0	$0	$0	$0	$0	$112	$0	$0	$3 080	$3 852
2007-0557	Papua N. G.	World Vision Int.	Oils	2 200	1 980	3	$0	$0	$0	$0	$0	$9	$0	$0	$308	$449

3.2.2. Input variables related to the proposed response system

The input variables related to the proposed response system were mainly collected as primary data. The process of identifying and collecting the value of each input variable was done in close cooperation with WWL through several interviews, meetings and email correspondences. WWL has never provided this type of logistical service before, and thus the process was demanding and lasted for over a year. Most common classifications of interviews are based on how they are structured, and can be classified as highly structured, semi-structured and unstructured (Easterby-Smith 2008). With regard to this study, semi-structured interviews/ meetings were carried out where both parts (WWL and us) prepared a specific list of topics and questions (agenda) that would be covered. This type of structure was chosen in order to open up for different ideas and opinions, where the agenda created a framework for the interviews/ meetings.

The next section will explain how the input variables related to the proposed response system were identified and collected. In order to structure this section each of the variables has been placed in one of the following groups:

1. Routes and vessels
2. Ports and terminals
3. Inland transportation
4. Prices

3.2.2.1 Routes and vessels

WWL has a total of four inbound and outbound routes that sail to/ from Asia, as well as two routes that only operate within the region of Asia. All of these routes could potentially be included in the model in order to maximize the number of port calls. However, the outbound/ inbound routes have a limited number of port calls in Asia, and due to the length of the routes (e.g. sailing Asia-Europe-Asia) the frequency of the port calls in Asia is low. If these routes where to be included, the total amount of relief items stored in the response system would increase significantly and hence reduce the efficiency, without necessarily increasing the effectiveness (e.g. long response time if the vessel is located in Europe when the disaster occurs). As a result, only the two routes that operate within Asia were included (Intra Asia NE – SE and SE Asia Express). With regards to the vessels, only those that serve the routes regularly were included in the study. One vessel serves the Intra Asia NE – SE route, while four vessels serve the SE Asia Express route.

Further, the following input variables were determined:

- Average speed of vessels was set to 18 knots/ hour.
- It takes the vessels one month to complete the routes.
- Average time spent in port (unloading and loading the vessel) was set to 12 hours.
- Average time to conduct customs clearance was set to 24 hours.

3.2.2.2 Ports and terminals

When the two trade routes were identified, data regarding the different ports that are served by these routes were collected. The vessel that operates the Intra Asia NE – SE route serves 10 ports, while the vessels that operate the SE Asia Express route serves 14 ports. However, some of these ports are served by both routes and in total the five vessels are serving 16 different ports within the region of Asia. The ports that are served only by the Intra Asia NE – SE route, have one port call per month. The ports that are served only by the SE Asia Express, have four port calls per month, while the ports that are served by both routes have five port calls per month. Figure 3.4 and 3.5 provides an overview of the different ports that are served by the two routes.

Figure 3.4 Intra Asia NE – SE trade route

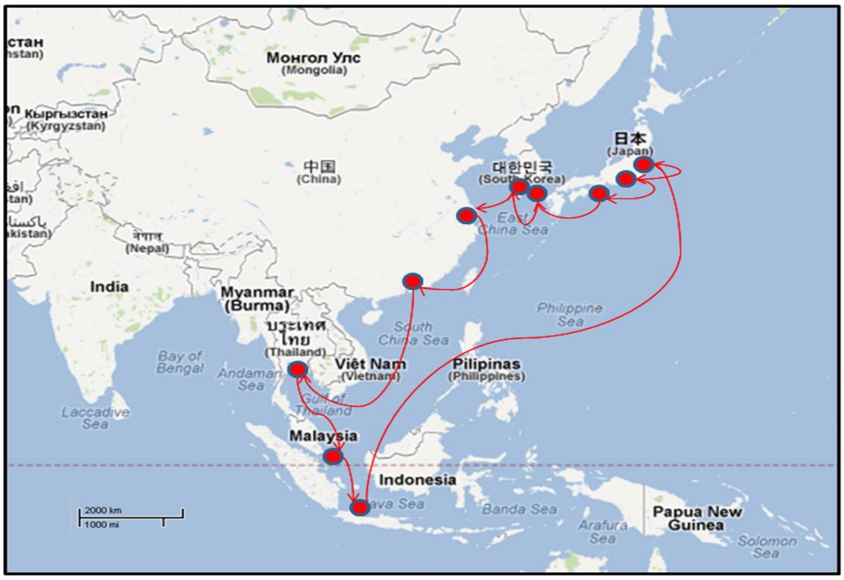
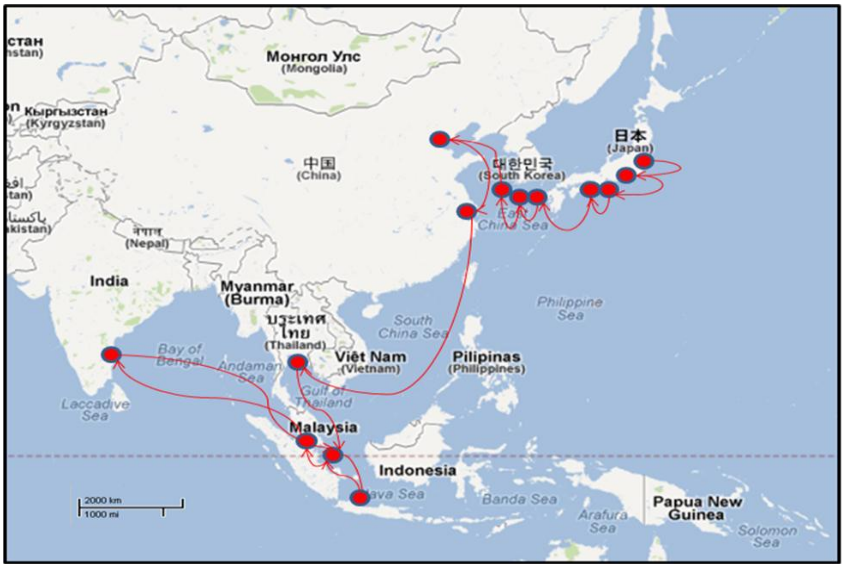


Figure 3.5 SE – Asia Express trade route



WWL has access to a large number of terminals throughout Asia that can be used to pre-store relief items, and hence it was necessary to decide which of these that should be included in the simulation model. The terminals were selected based on the geographical locations of the 16 disasters (see Figure 3.3) in order to best support the affected areas. The selected terminals were; Tianjin (China), Shanghai (China), Laem Chabang (Thailand), Singapore (Singapore), Jakarta (Indonesia) and Chennai (India). Figure 3.6 provides an overview of the geographical location of the six terminals, which are located at (or very close to) the ports that are depicted in Figure 3.4 and 3.5.

Figure 3.6 The geographical location of the 6 terminals

The purple spot in Figure 3.6 represents a distribution center (DC) located in Singapore serving as a transshipment terminal used to reload the vessels.

3.2.2.3 Inland transportation

The proposed response system do also includes the last part of the transportation from the selected port/ terminal to the disaster area. WWL has a comprehensive network of logistical resources related to inland transportation in Asia, both in terms of facilities (e.g. trucks and warehouses) and business units and relationships (e.g. offices and agencies). The first input variable collected was the distances from the previously identified ports (see Figure 3.4 and 3.5) to the disaster areas. The distances from the ports/ terminals to the 16 disaster areas were collected as secondary data from Google maps (Google 2012). The average speed of trucks was set to 40 km/ h and the value was decided based on a discussion with partners in Contribute, with experience in humanitarian response operations, and employees of WWL, with local knowledge from the region. The value takes into account the uncertainty regarding the infrastructure of a disaster area (e.g. damaged roads). Finally, the average time spent on loading and unloading a truck was set to four hours.

3.2.2.4 Prices

With regards to prices the following yields:

- The relief items are stored and transported on pallets containing a maximum of 1.2 m3 or 750 kg.
- The prices require a batch size of 75 pallets (the minimum number of pallets to be pre-stored at any facility). This requirement is set in order to be able to utilize a standardized transport unit (bolster- or mafi-trailer) with a capacity of 75 pallets.
- In the simulation model, the 16 previous disasters represent the number of responses per year. In order to be able to respond to these disasters at any time, pallets will be pre-stored onboard vessels/ terminals 365 days a year.

The price for pre-storing relief items onboard vessels

When a disaster occurs, the relief items that are pre-stored onboard the vessels are unloaded at the WWL port located closest to the disaster area. At some point in time the vessels will be reloaded with the same number of pallets that was released during the response. In practice, depending on how the response system is set up, this reloading could be done at any port the vessels are calling. However, in the simulation model, the DC in Singapore (see Figure 3.6) serves as a hub and all replenishments from suppliers and reloading of vessels will take place at this location. Due to the nature of disasters it is impossible to know in advance when they will occur and hence, it is also impossible to know in advance where the vessels will be located when the disaster strikes. As a result, it is difficult to know for how long the relief items will be stored onboard the vessels, and how much time it takes before the vessels are reloaded at the DC after a certain response. Based on these considerations, it is assumed in the simulation model that relief items stored onboard vessels are continuously replaced, meaning that there is always the same number of pallets pre-stored onboard the vessels at any time. This assumption is important with regards to the price; the selected number of pallets will incur a fixed storage cost per day (24 hours) it is pre-stored onboard a vessel, and due to the assumption of continuously replacement, this cost will incur 365 days a year.

WWL has never provided this type of service to any company before which made the process of identifying a realistic price quite challenging. However, the simulations are run with prices that are sensible from a commercial perspective, which implies that the prices can be set to a lower level in the future if corporate social responsibility is taken into account. In order to set a price per pallet per day, WWL needed to know how many pallets they potentially should deliver to the 16 disasters (the annual demand). An increase in the total number of pallets delivered during a year would lower the price and vice versa, implying the declining price structure shown in Table 3.2. As an example, if WWL delivers a total of 15,000 pallets to the 16 disasters, the price per pallet per day is $2.75 while an increase in the total number of pallets to 25,000 reduces the price per pallet per day to $2.50. The price per pallet includes; (1) storing the pallet onboard the vessel, (2) loading and unloading the pallet and (3) customs clearance.

Table 3.2 Price structure for pre-storing relief items onboard vessels

Total number of pallets delivered per year	Daily price per pallet
0 – 10,000	$3.00
10,001 – 20,000	$2.75
20,001 – 30,000	$2.50
30,001 < ∞	$2.25

The price for inland transportation

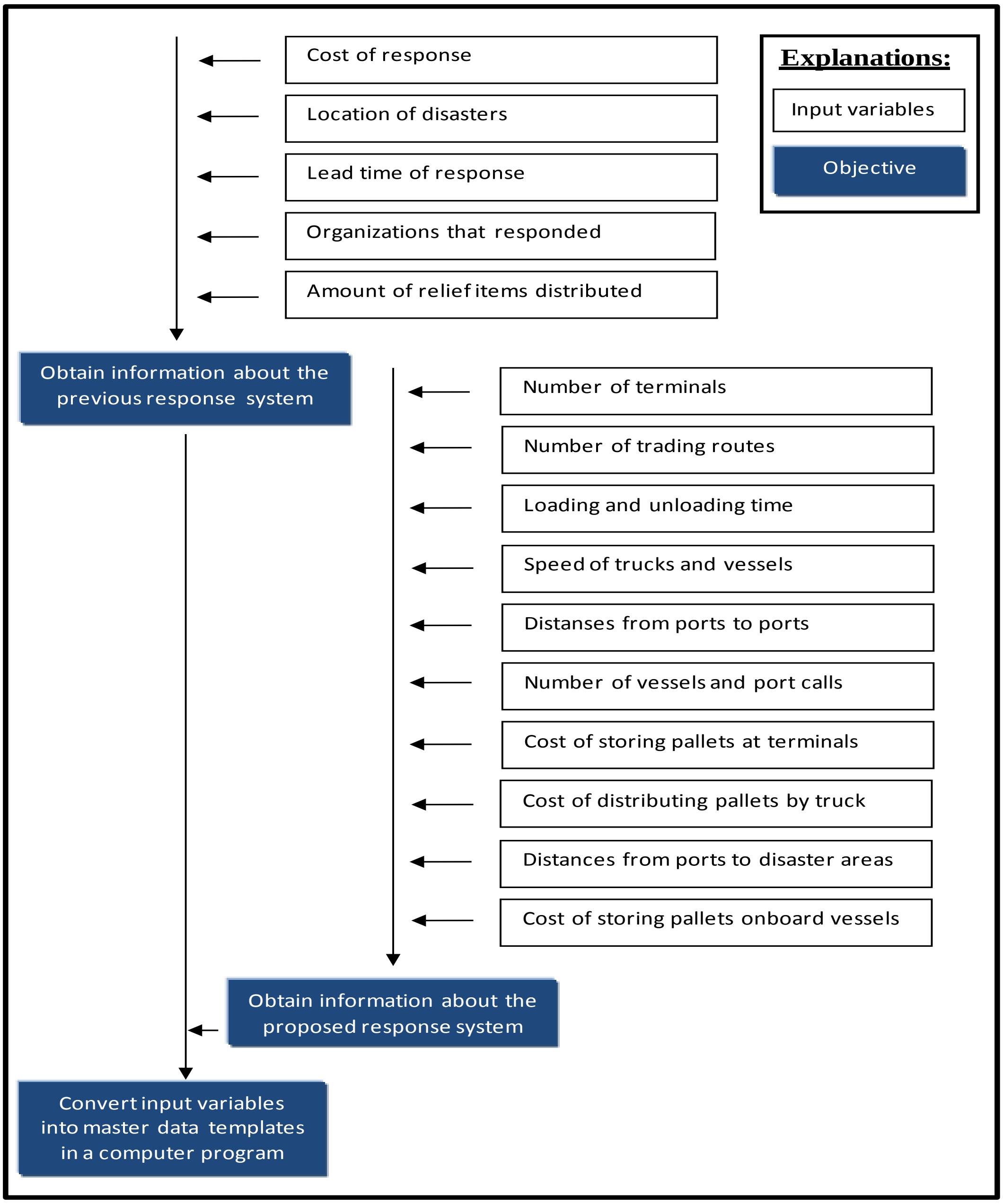
The price for inland transportation is to some extent country/ sub-region specific. However, an average price of 0.1 $/pallet/km was set based on the cost of WWL's current operations in the region which includes all the costs associated with this activity (e.g. depreciation of truck, fuel and salary to driver).

The price for storing relief items at terminals/ DC in Singapore

The price of this activity, which was set to 0.4 $/pallet/day, also reflects an average of different country/ sub-regional prices and includes; (1) storing the pallet at the terminal/ DC in Singapore and (2) transporting the pallet from the terminal to the port.

Figure 3.7 below summarizes the input variables identified and collected, both with regards to the previous response as well as the response of the proposed system. When these figures were verified by the partners of Contribute, the data created the basis for the master data templates in a computer program.

Figure 3.7 Identified and collected input variables



3.2.3. Quality of input variables

All of the input variables collected both with regards to the current and the proposed response system will serve as master data for the simulation model. This implies that the outputs generated by the simulation model are based on the values of these variables and the relationships between them. If the quality of these input variables is low the simulation model will not be valid and thus, the conclusions that are drawn will provide little or no value. This section will provide a discussion about the quality of the input variables, where the aim is to underline that even though the process of identifying and collecting input variables lasted for over a year, there still exists uncertainty related to some of the values.

With regards to the proposed response system, some of the values of the variables are fixed, which means that there exists no uncertainty related to the measures (e.g. the location of terminals and ports, number of routes and port calls and distances between the ports). Even though all the variables related to the proposed response system (except distances) are gathered as primary data where employees of WWL have used internal resources (knowledge and software programs) to identify and calculate the right values, there still exists some uncertainty related to the measures. WWL has never provided this type of logistical service before, and thus their software is not designed to calculate the price of this service. As a result, the prices of pre-storing pallets onboard vessels/ at terminals are estimated based on different calculations. There is no doubt that the intention has been to identify the correct price of these services however, the process has been quite challenging and due to the lack of existing prices related to these services, a conservative approach was applied. This implies that WWL guarantees to not charge a higher price than the prices used in the simulation model if the system were to be implemented in the future.

There is also uncertainty related to the input variables for inland transportation. When a natural disaster occurs, the infrastructure (e.g. roads and bridges) can be damaged and the shortest way from a given port to a disaster area may not be operative and hence, the estimated distance applied in the model might be too low. Even though the average speed of trucks (40 km/ h) seeks to take this into account it is impossible to entirely eliminate this uncertainty. The same uncertainty applies to the price of inland transportation and the conservative approach used to determine the price of pre-storing pallets on vessels/ terminals was also applied when this price was set.

All of the variables related to the current response system are collected as secondary data. According to Bryman and Bell (2007) there are some limitations/ uncertainties related to the use of secondary sources which the researcher should take into account. The lack of familiarity with the data is probably the most important limitation when it comes to the use of secondary sources due to the difficulty of assessing the quality. In order to cope with this limitation, the partners of Contribute that actually collected the data have openly discussed the question regarding the quality. The sources used to collect this data were official reports, statistics and other available information regarding demand and response of relief items, logistical services, and funding. Even though the partners of Contribute spent a great amount of time to identify the different sources, there is a large variation in the level of detailed information provided by the humanitarian organizations related to their previous response operations. In addition, statistics and official reports used to identify the demand and response to the 16 disasters can also contain measurement errors. As a result, there also exists uncertainty related to the input variables of the current response system.

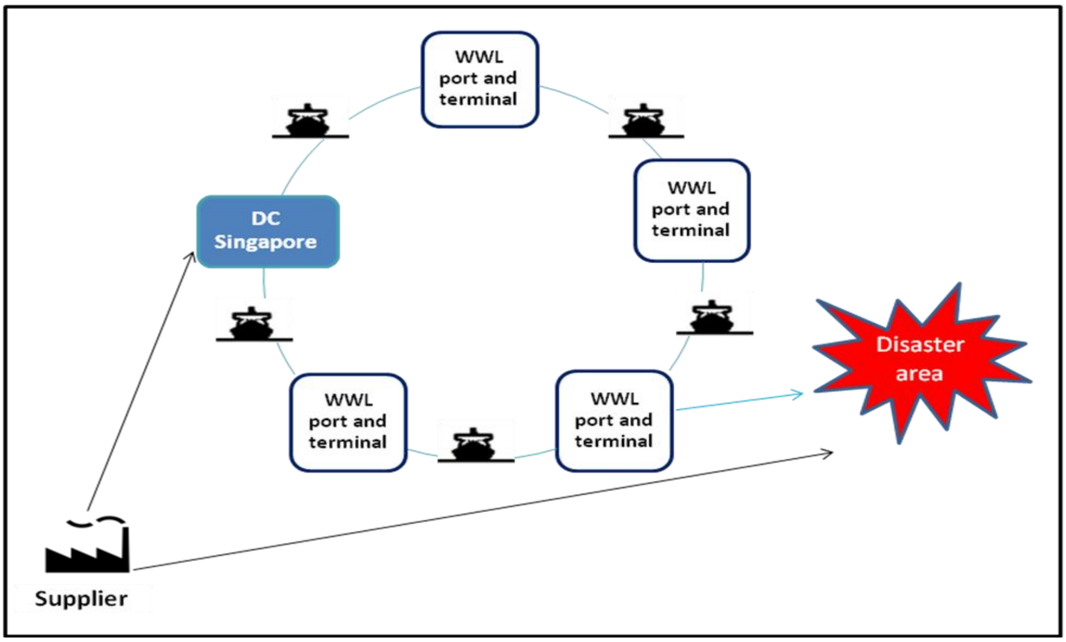
3.3. The conceptual model

This last section finalizes the conceptualization of the study by presenting the conceptual model of the proposed response system. The conceptual model was created for two reasons. First, it served as a tool for communication and discussion, making sure that all the partners involved in Contribute had a common understanding of how the simulation model was designed and hence, the conceptual model was used in order to validate the system that should be simulated. Secondly, the conceptual model served as a guideline throughout the modeling phase where the simulation model was developed in a computer program.

Figure 3.8 visualizes the conceptual model of the proposed response system as it was presented to Contribute. In this configuration, relief items are pre-stored onboard each of the five vessels and when a disaster occurs the items will be unloaded at the WWL port located closest to the disaster area. No matter where in

Asia the disaster occurs the vessels will never deviate from its planned route, which means that the port used to unload items must be part of the route the vessel serves. When the pallets are unloaded at the port, the vessel will continue its voyage and reload pallets when it reaches the DC in Singapore. Once the vessel has reloaded additional pallets with relief items it can continue to deliver to the same or a new disaster.

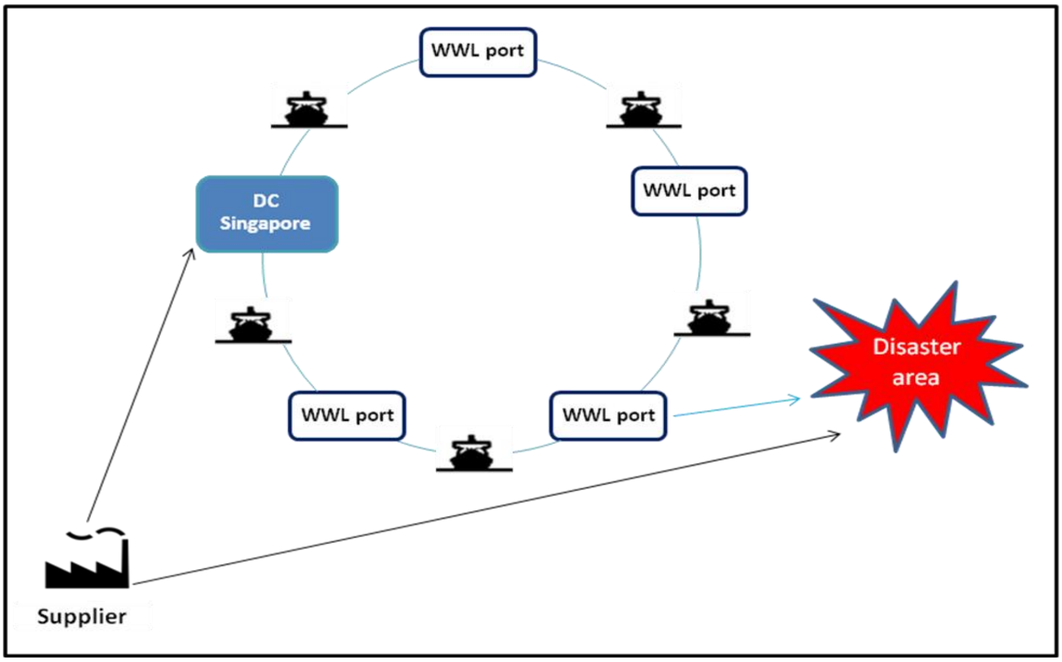
Figure 3.8 The conceptual model for the first configuration



The logic behind the DC in Singapore is the following; a limited number of pallets are permanently pre-stored at the DC (this number equals the number of pallets that are pre-stored on each vessel and will vary depending on the selected capacity in the simulation model). When a disaster occurs, the suppliers of relief items will start to fill up the DC with the required batch sizes at suitable intervals. As a result, the additional pallets that are available from the DC are delivered during the immediate response phase and the DC will not be further supplied when this phase is finalized. The number of pallets that are available from the DC during the immediate response phase is exactly three times the number of pallets that are pre-stored onboard each vessel. This number is set because the vessels only have time to be reloaded twice during the immediate response phase (each trade route takes one month to complete). Further, when a disaster occurs, the relief items that are pre-stored on the closest terminal will immediately be transported directly to the disaster area by trucks. These terminals are not intended to be used to reload the vessels, they will only serve as additional storage facilities supporting the disasters that occurs within their geographical area.

When the conceptual model was validated by the partners of Contribute it, was decided that the simulation model should also be able to simulate an alternative configuration of the proposed response system which relies solely on vessels without the support from the terminals. Hence, a slightly different conceptual model was developed which is illustrated by Figure 3.9.

Figure 3.9 The conceptual model for the second configuration

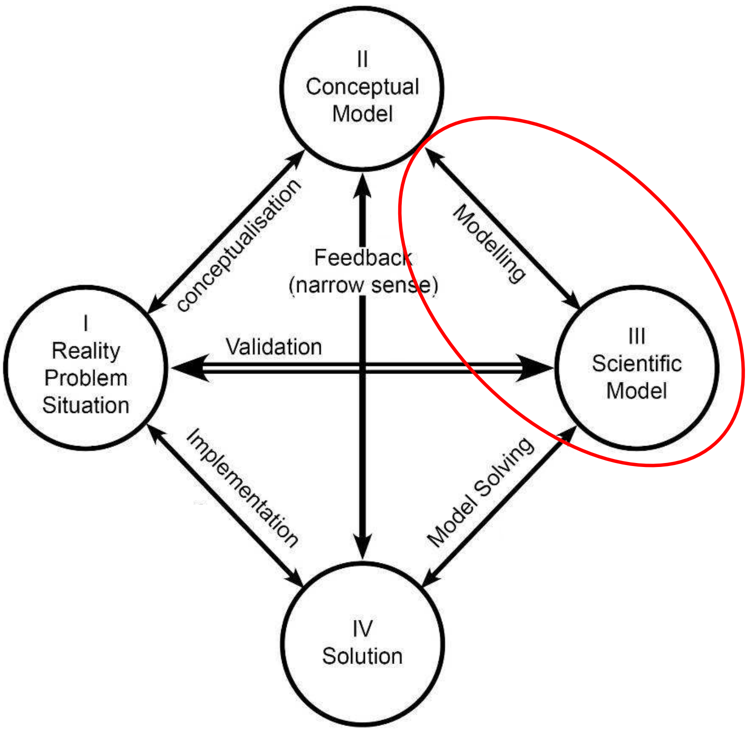


As illustrated by the figure, the second conceptual model is exactly the same as the first only without the terminals. This implies that pallets with relief items will be pre-stored at fewer facilities compared to the first configuration. The input variables summarized in Figure 3.7 and these conceptual models, were the main outputs from the conceptualization phase and created the basis for the modeling phase where the simulation model was developed.

4. The simulation model

As described in the previous chapter, what-if simulations will be conducted in order to test whether the proposed response system performs better than the current system. Further, the collected data regarding both the current- and the proposed- response system were presented and the chapter was finalized with two conceptual models illustrating different configurations of the proposed response system. Both the input variables and the conceptual models were used to guide the development of the simulation model. This chapter will present the output of the modeling phase as visualized by the red circle in Figure 4.1, where the objective is to provide a walkthrough of the programmed simulation model and how it was validated in order to make sure that the model represents the system studied in an appropriate way.

Figure 4.1 The research process



Source: Mitroff et al. (1974)

4.1. The selected software

When studying the behavior of a proposed system through a simulation model, it is necessary to use a computer program to logically express the relationships between the different variables. In order to select the proper software the researcher must consider the complexity of the system studied, which increases with both the number of variables and the relationships between them. There exists a wide variety of ready-made simulation programs such as Arena, iGrafx and ProModel which are all suited when conducting a discrete event simulation study with random variables (stochastic models). The model created in this thesis is deterministic, which means that there is no randomness in the variables and the numbers of configurations are limited. These characteristics indicate that the features of advanced simulation software are superfluous when conducting "what-if" analysis on the proposed response system. As a result, the system was modeled in Microsoft Excel (MS Excel) and Visual Basic for Application (VBA) was utilized to run the simulation model. MS Excel was chosen for four reasons:

1. It is a software we are familiar with and hence it was not necessary to spend time to understand an advanced simulation program.
2. There exists an extensive amount of easily accessible information about the software and the possibilities and features it possesses.
3. The software is well suited when performing "what-if" analysis; by modeling the system in the right way it is easy to observe the changes in the performance variables when input variables are changed.
4. If the model where to be used or further developed by others it is important that the selected software is well known and does not require any special competence/ knowledge. MS Excel is a widely used software and applied in most commercial and nonprofit organizations.

In the next section the simulation model developed in MS Excel will be presented. The development process has been iterative, where the final version of the simulation model is a result of a lengthy process where the model has been continually evaluated and improved.

4.2. A walkthrough of the simulation model

The process of modeling the proposed response system in MS Excel started by creating a chart showing the different parts of the model and how these should be linked together through various relationships. The chart was created for two reasons. First, it was used to visualize the structure of the model in order to obtain a common understanding among the partners involved. Second, it was important to make sure that the model was structured in a way that made it possible to easily change input variables without affecting the overall structure of the model. The chart divides the model into different parts/ modules and creates proper relationships between these parts/ modules. Figure 4.2 visualizes the chart and how the model is structured. It consists of four different modules; (1) Master data, (2) Information, (3) Calculation and (4) Output, in addition to four command buttons visualized by the rectangles on the left hand side.

Figure 4.2 The structure of the simulation model

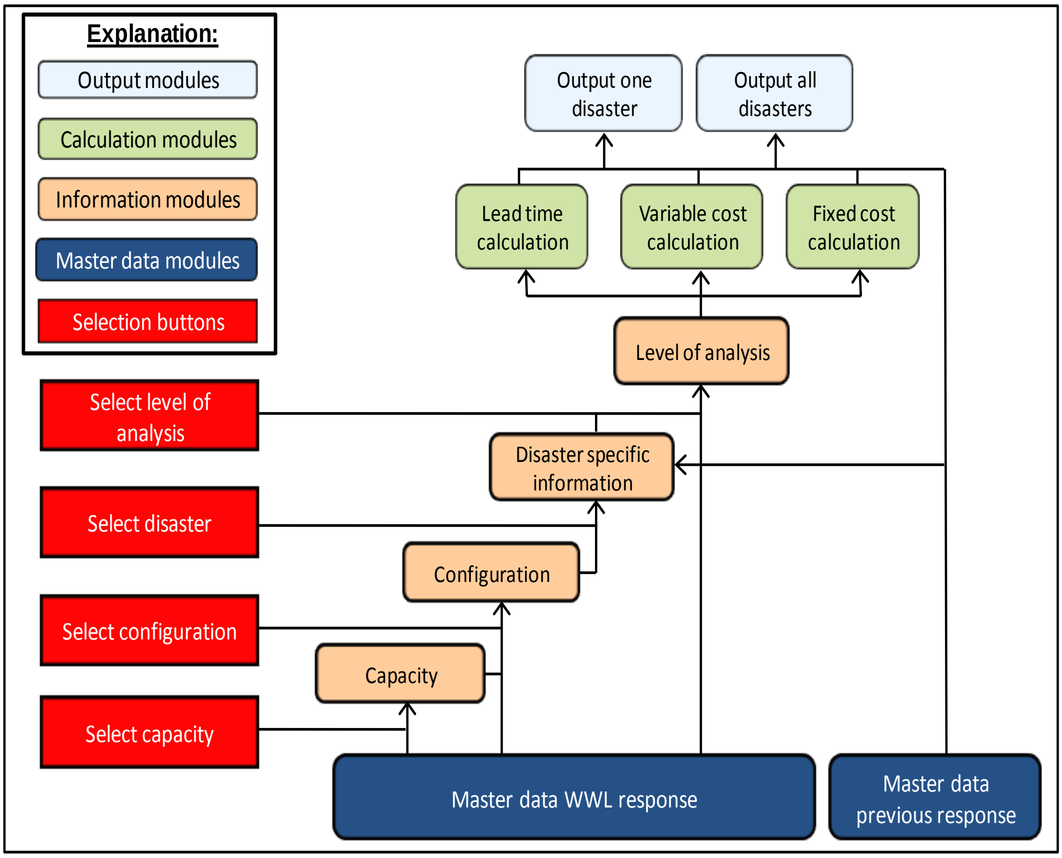
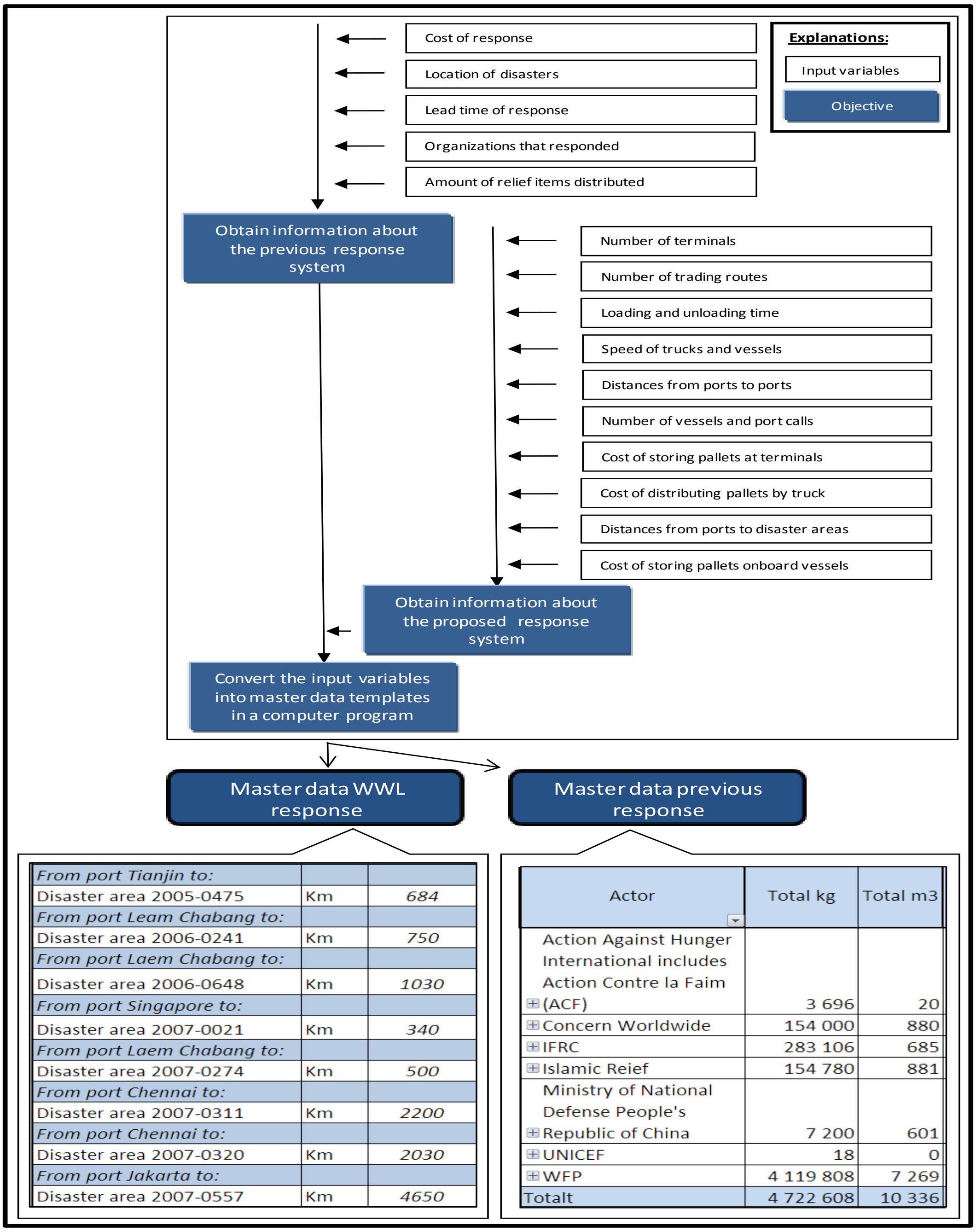


Figure 4.2 consists of two different parts. Part A, which includes the four selection buttons, the four information modules and the two output modules, is visible to the user of the simulation model. Part B includes the two master data modules and the three calculation modules and is in contrast to part A, not visible to the user. Part B provides data to part A based on the selections made by the user. As a result, part B works in the "background" and supports part A with required data. This section will continue with a description of the two master data modules before the subsequent modules are presented as it is visualized by the flow chart in Figure 4.2.

4.2.1. Master data modules

The master data is comprised of the input variables that were identified and collected as described in the previous chapter. These variables were summarized in Figure 3.7 and in the modeling phase converted into two templates in MS Excel as illustrated by Figure 4.3. This data is defined as master data, which means that it is given and should not be changed or manipulated by the user of the simulation model. As a result, the master data is not accessible for the user and its function is to provide the information-, calculation- and output- modules with requested information generated by the selections made by the user. It is important to note that the master data is given for a specific set of variables/ actors but can of course be adapted to suite any organization that wants to use the simulation model to test their own response system.

Figure 4.3 Input variables converted to master data in MS Excel



From port Tianjin to:		
Disaster area 2005-0475	Km	*684*
From port Leam Chabang to:		
Disaster area 2006-0241	Km	*750*
From port Laem Chabang to:		
Disaster area 2006-0648	Km	*1030*
From port Singapore to:		
Disaster area 2007-0021	Km	*340*
From port Laem Chabang to:		
Disaster area 2007-0274	Km	*500*
From port Chennai to:		
Disaster area 2007-0311	Km	*2200*
From port Chennai to:		
Disaster area 2007-0320	Km	*2030*
From port Jakarta to:		
Disaster area 2007-0557	Km	*4650*

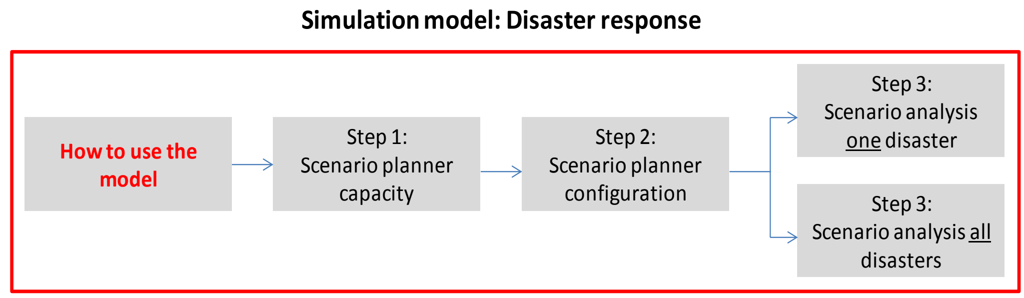
Actor	Total kg	Total m3
Action Against Hunger International includes Action Contre la Faim (ACF)	3 696	20
Concern Worldwide	154 000	880
IFRC	283 106	685
Islamic Reief	154 780	881
Ministry of National Defense People's Republic of China	7 200	601
UNICEF	18	0
WFP	4 119 808	7 269
Totalt	4 722 608	10 336

The master data is organized in two separate templates in the MS Excel workbook in which one contains input variables related to the current response system while the other is related to the proposed system (for a larger picture see the template in the attached simulation model in MS Excel). Figure 4.3 displays an extraction of the master data templates for the two different response systems created in MS Excel, where the template on the left hand side shows how the master data for the proposed response system is organized. The master data is divided into subcategories representing the different resources (vessels, routes, terminals, trucks and ports) and the distances from the ports/ terminals to the disaster areas. Each of these subcategories contains different types of information characterizing the resource (e.g. speed and capacity of vessel and cost of storing a pallet onboard the vessel/ at a terminal).

The template on the right hand side shows how the master data regarding the current response system is organized. This data contains information related to the previous 16 disasters (location of the disaster, weight and volume of the items shipped, cost of the logistical activities and the actors that responded). The two master data modules serve as a baseline in the overall simulation model, serving the selections and processes generated by the user of the model. The rest of this section provides a throughout description of how the simulation model should be used and explains in parallel both part A (the model as it appears to the user) and part B (how the model works when selections are made). With regards to part A of the simulation model (the part of the model that is visible to the user), a larger print screen of the different steps are provided in appendix 1.1 to 1.5.

On the next page, Figure 4.4 shows the front page of the simulation model when it is opened in MS Excel. It consists of a flow chart that visualizes the different steps the user goes through in order to create scenarios that can be run in the simulation model. These steps are: (1) Scenario planner capacity, (2) Scenario planner configuration, (3a) Scenario analysis one disaster and (3b) Scenario analysis all disasters. The front page do also contains a text which briefly describes how the simulation model should be used (See appendix 1.1 for a larger print screen of the front page).

Figure 4.4 The front page of the simulation model



This Excel model simulates humanitarian response to disaster affected areas in the region of Southeast Asia based on a system that utilizes WWL's network of resources.

Step 1: Scenario planner capacity determines the number of pallets to be stored in the system (supply chain) and the distribution of pallets on each of the different resources.
- Select the number of pallets to be stored on each of the five vessels that serves the routes "Intra Asia NE-SE" and "SE Asia Express". The chosen number of pallets will be equally distributed to the five vessels. Based on the number of pallets distributed to the vessels, the number of pallets in DC Singapore is calculated by default, making sure that the DC in Singapore contains exactly the number of pallets needed to reload the vessels during the 12 weeks of operation
- Select the number of pallets to be stored at the six different terminals
- Select the number of pallets to be stored at the short shipment terminal in Singapore (this selection is not available at this point in time due to the lack of a representative price)

Step 2: Scenario planner configuration determines how the response is set up and how you want the output from the simulation.
- Select which disaster the system should respond to
- Select one of the three delivery options (1) Regular routes, (2) Regular routes and terminals or (3) Short shipment directly from Singapore (this selection is not available at this point in time due to the lack of a representative price)
- Select either:
  - A detailed analysis of the response to the chosen disaster
  - An analysis of the response to all the 16 disasters simultaneously

Step 3: Scenario analysis one disaster
- This page provides a detailed summary of the response to the selected disaster in terms of cost and lead time.

Step 3: Scenario analysis all disasters
- This page provides a summary of the response to all of the 16 disasters simultaneously in terms of cost and lead time.

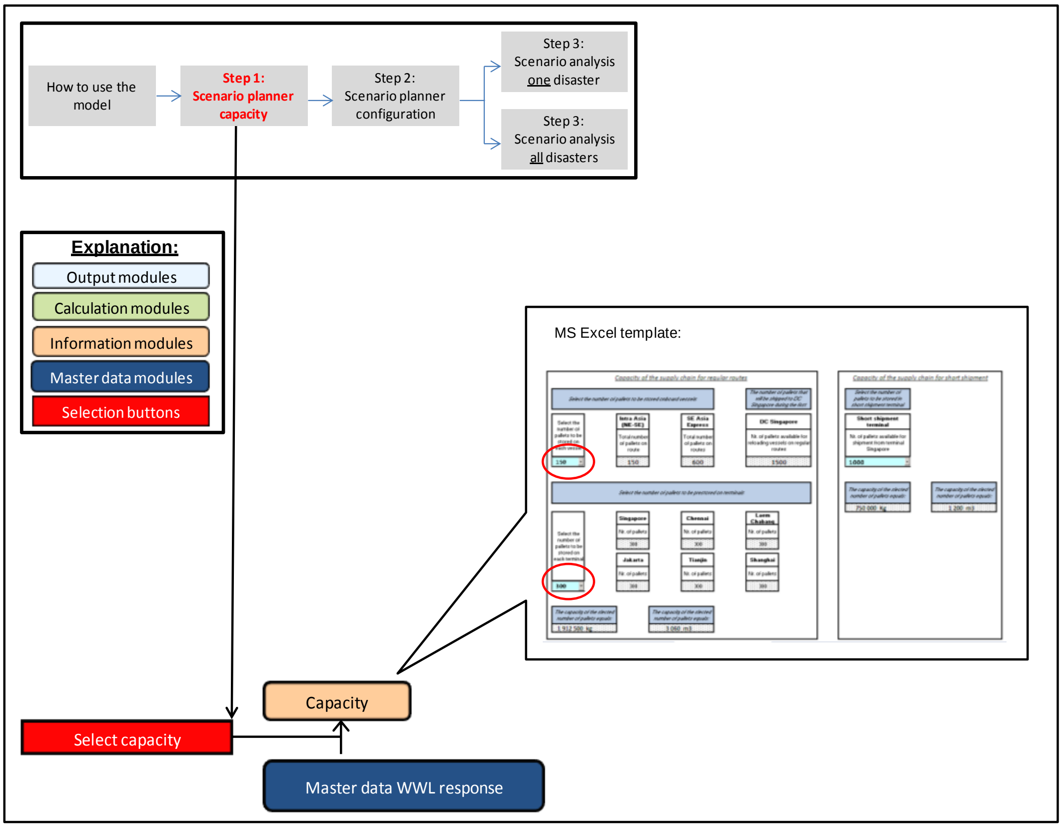
4.2.2. Selection of capacity and configuration

This subsection will describe the two first selection buttons (capacity and configuration) in Figure 4.2 which corresponds to "Step 1" and the first part of "Step 2" in Figure 4.4 above.

Selection of capacity

The capacity selection button in Figure 4.5, which is depicted on the next page, enables the user of the model to change the capacity (number of pallets) of the proposed response system. The button corresponds to "Step 1" in the simulation model and the figure visualizes how the model works when selections are made in this step. Depending on which capacity the user selects in the simulation model, the master data module will provide the information according to the users' selections and make it visible for the user in an information module as visualized in Figure 4.5.

Figure 4.5 Step 1: Scenario planner capacity



There are two different selection options within "Step 1" (indicated by the red circles in the MS Excel template in Figure 4.5): (1) select the number of pallets to be pre-stored onboard each of the vessels and (2) select the number of pallets to be pre-stored at terminals. The available choices are pre defined and limited;

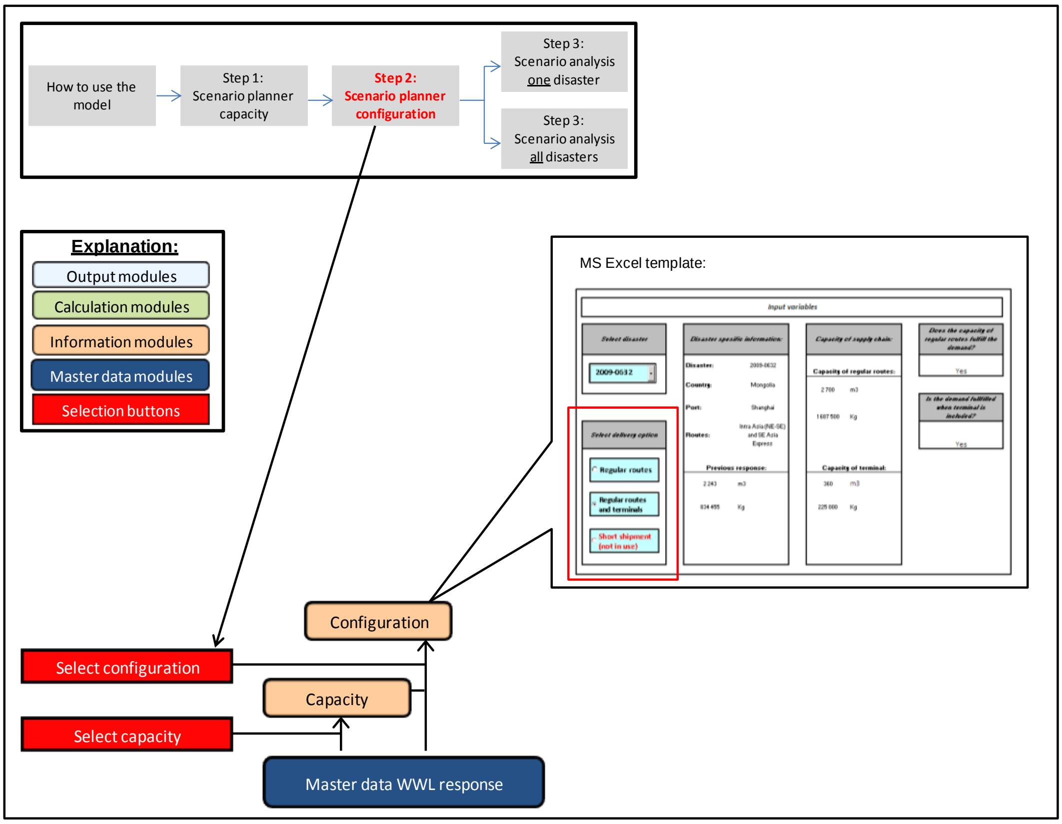
- All the vessels will have the same number of pallets onboard and the number is a set interval ranging from 75 to 375 pallets. This option button is depicted with a red circle in the upper left corner of the MS Excel template in Figure 4.5.
- The same requirement applies to the terminals where the available number of pallets is given by a pre defined list, ranging from 75 to 375 pallets, and the same number of pallets will be assigned to each of the six terminals. This option button is depicted with a red circle in the lower left corner of the template in figure 4.5.

The MS Excel template in Figure 4.5 do also provides a box showing the selected capacity of the response system in terms of kg and m3 (the maximum amount of relief items the selected number of pallets can contain). See appendix 1.2 for a larger print screen of "Step 1" in the simulation model.

Selection of configuration

The configuration of the proposed response system is part of “Step 2” in the simulation model and is represented by the second selection button in Figure 4.6.

Figure 4.6 Step 2: Scenario planner configuration



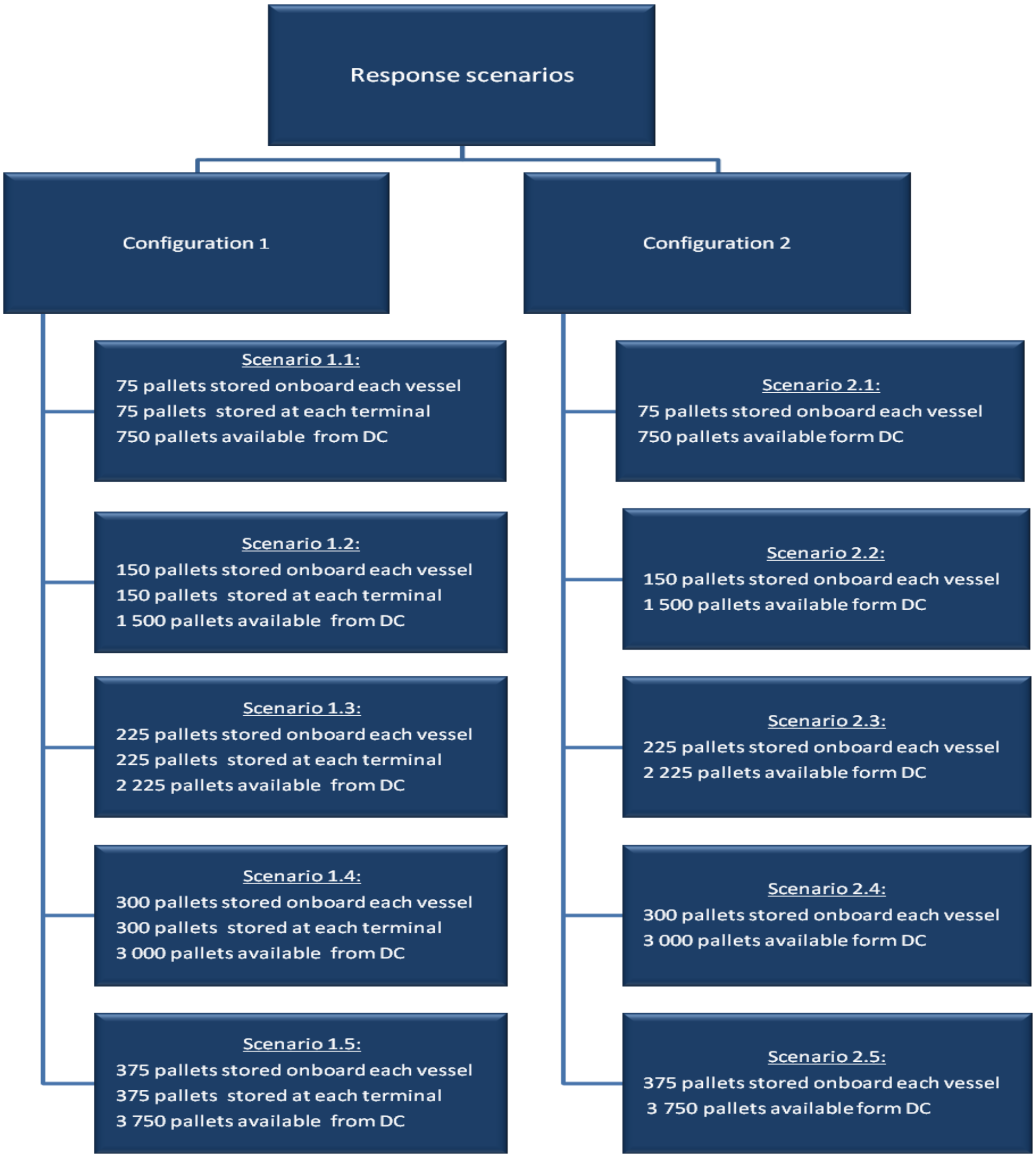
This selection enables the user to change the configuration of the system by choosing one out of the three response options (indicated by the red circle in the MS Excel template in Figure 4.6). As for capacity, depending on which configuration the user selects in the simulation model, the master data module will provide the information according to the user’s selection and make it visible in an information module as visualized in Figure 4.6.

As illustrated by Figure 4.6, three different configurations can be selected in “Step 2” in the simulation model: (1) regular route and terminals, (2) only regular route and (3) freight forwarding. The first two configurations correspond to the conceptual models described in section 3.3, while the third configuration has not yet been explained. In this configuration relief items are pre-stored in one main terminal/ warehouse located in Singapore. In the event of a disaster, WWL will hire the required capacity from a freight forwarding company and the relief items will be shipped directly from Singapore to the relevant port. Prices for freight forwarding services are continuously changing depending on market conditions and might vary substantially. This is also illustrated later in the thesis (chapter six) where the fluctuations in prices create challenges for the humanitarian organizations. A low predictability with regards to prices makes it difficult to know in advance the cost of future humanitarian interventions and to what extent an actor is able to support a given disaster is to a large degree dependent on external factors. Even though the simulation model enables the user to run the model with this configuration, the option is not included in the analysis because it was too difficult to identify a representative price and lead time for this service. However, if these variables are identified in the future, the model allows the configuration to be simulated. As a result, the freight forwarding configuration will not be used as a response option in this study.

A given combination of capacity and configuration generates a certain response scenario. These scenarios represent different combinations of the proposed response system and each of these scenarios can be tested in the simulation model in order to examine their performance. By experimenting with these combinations it is possible to get an understanding of how the system performs under different conditions. Each of these experiments represents a what-if simulation where the input variables are changed in order to examine the effects on the performance variables. Even though the simulation model can run an infinite number of scenarios, the restrictions put on the number of pallets available combined with two possible configurations, limits the number of potential scenarios. Each of the two configurations has five different levels of capacity (a set interval ranging from 75 to 375 pallets) which generates a total of 10 unique response scenarios for each of the 16 disasters.

The five response scenarios that belong to the first configuration are all utilizing both vessels and terminals when responding to disasters, where only the number of pre-stored pallets varies in each of the five scenarios. In response scenario 1.1 each of the vessels and terminals have 75 pallets pre-stored, while in the subsequent scenarios the number of pallets is increased with an interval of 75. This implies that the last scenario (scenario 1.5) has 375 pallets pre-stored on each facility. The response scenarios that belong to the second configuration are the same as the scenarios presented above except that pallets are not pre-stored at the six terminals. In scenario 2.1, 75 pallets are pre-stored on each vessel while each subsequent scenario will increase the number of pallets with 75 ending up with a total of 375 pallets on each vessel in scenario 2.5. Figure 4.7 summarizes the 10 different response scenarios that served as a starting point for the analysis which will be presented in chapter five.

Figure 4.7 Overview of the different response scenarios



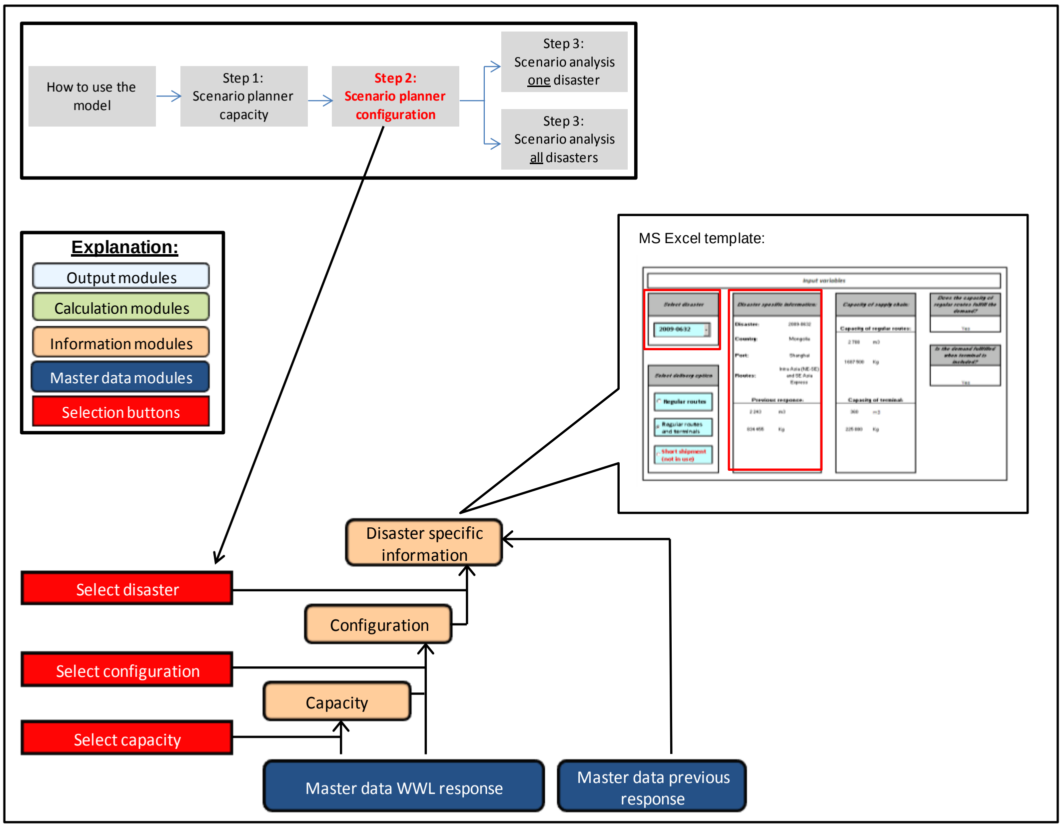
4.2.3. Selection of disaster

The third selection button in Figure 4.8 corresponds to the second selection made in "Step 2". This selection enables the user to specify which of the 16 disasters the model should simulate a response to. Depending on which disaster the user selects in the simulation model, (indicated by the small red square in the MS Excel template in Figure 4.8) the relevant disaster specific information is provided by the master data modules and makes it visible for the user in an information module (indicated by the large red square in the MS Excel template in Figure 4.8). The following disaster specific information is provided:

- The country where the disaster occurred
- Which port and route(s) that are used in the simulated response
- The amount of relief items (in terms of kg and m3) that was delivered by the current response system
- To what extent the selected capacity is able to fulfill the demand (measured as previous response).

This selection option is only necessary if the user wants detailed outputs describing a specific disaster response. If a specific disaster is not selected by the user the simulation model will provide aggregated outputs for all the 16 disasters simultaneously. This will be further explained in the next subsection.

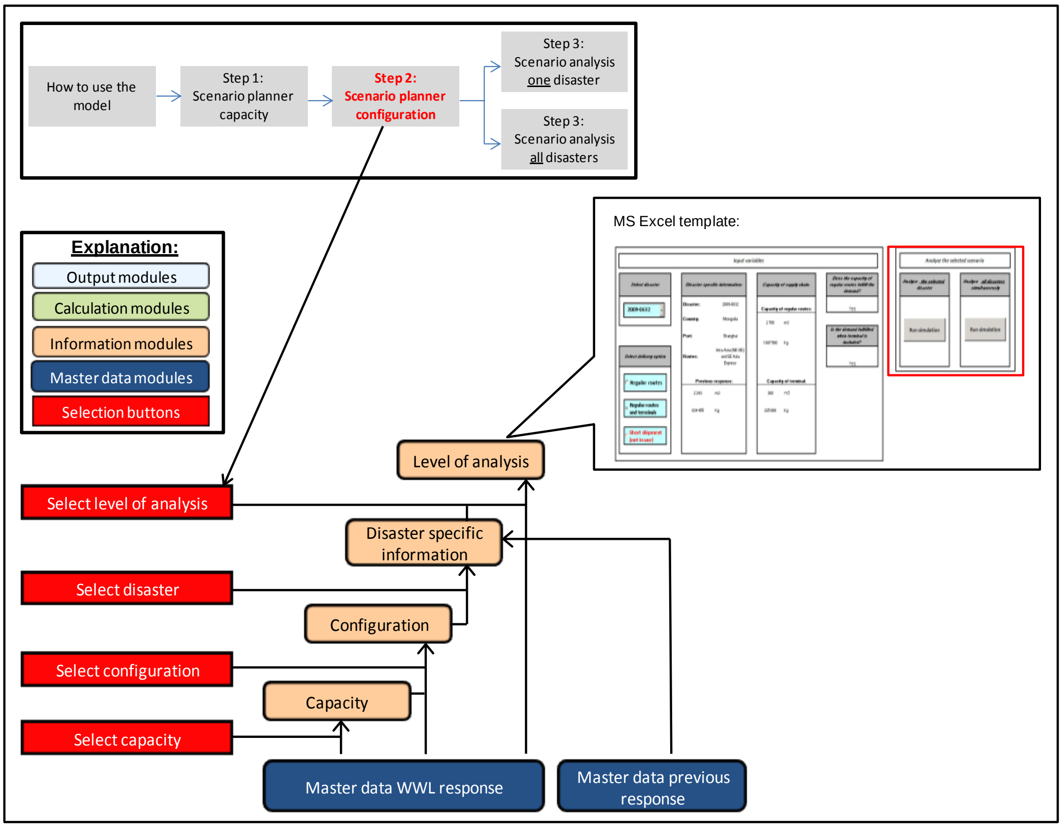
Figure 4.8 Step 2: Select a specific disaster



4.2.4. Selection of level of analysis

For the selected capacity ("Step 1") and configuration ("Step 2") the simulation model enables the user to freely choose the level of analysis; either a detailed description of one specific disaster (requires selection of a specific disaster as described in the previous section) or an aggregated analysis of all the 16 disasters simultaneously. The fourth red rectangle in Figure 4.9 represents this selection, which corresponds to the last option in "Step 2". Depending on the level of analysis the user selects in the simulation model, (indicated by the red square in the MS Excel template in Figure 4.9) the master data module will provide information to the calculation modules and an output is generated according to the user's selection.

Figure 4.9 Step 2: Select level of analysis



The simulation model is run when one out of the two option buttons in the information module in Figure 4.9 is chosen and it generates outputs automatically according to this selection (see appendix 1.3 for a larger print screen of "Step 2" in the simulation model). Hence, the outputs which is "Step 3" in the simulation model, is linked to "Step 2" through the calculation modules. The next two sections will describe the three calculation modules and the two different outputs that are available in the simulation model.

4.2.5. Calculation modules

Similar to the master data modules, the calculation modules should not be changed or manipulated by the user, its sole function is to calculate the effectiveness and the efficiency of the response system. Based on the level of analysis selected by the user in “Step 2”, the three calculation modules receive information from the master data modules and calculate the fixed- and variable-cost as well as the lead time from the disaster occurs to the relief items are delivered to the affected region. Lead time is calculated based on the time spent on sea- and land transportation, while the cost is calculated based on the fixed- and variable cost generated by the response.

Lead time sea transportation

Each of the two routes takes one month to complete (one month = 28 days). It is not possible to know in advance where a vessel is located when a disaster strikes and it is assumed that the distribution of the locations is spread equally throughout the month. One vessel serves the Intra Asia NE-SE route and has one port call per month. This implies that it takes on average 336 hours (28/2 = 14 days = 336 hours) before this vessel arrives at the WWL port located closest to the disaster area. Its second and third delivery will be completed after 1 008 hours (336 hours + 672 hours (28 days = 672 hours)) and 1 680 hours (1008 hours + 672 hours) respectively (one vessel will at the maximum be able to deliver three times during the immediate response phase of a disaster). Four vessels are serving the SE Asia Express route which implies that they have four port calls per month. As a result, it takes on average 84 hours (28/8 = 3.5 days = 84 hours) before the first vessel arrives at the WWL port located closest to the disaster area. Each of the four vessels serving this route is able to deliver relief items three times during the immediate response phase, which implies that the total number of deliveries is 12. The second delivery arrives after 252 hours (84 hours + 168 hours (28/ 4 days = 168 hours)) and the twelfth delivery will be completed after 1932 hours. Table 4.1 below summarizes these calculations.

Table 4.1 Time between each delivery for a given number of port calls

Number of port calls per month	Additional hours to the next delivery	1. delivery after (hours):	2. delivery after (hours):	3. delivery after (hours):	4. delivery after (hours):	5. delivery after (hours):	6. delivery after (hours):	7. delivery after (hours):	8. delivery after (hours):	9. delivery after (hours):	10. delivery after (hours):	11. delivery after (hours):	12. delivery after (hours):
1	672	336	1 008	1 680									
2	336	168	504	840	1 176	1 512	1 848						
3	224	112	336	560	784	1 008	1 232	1 456	1 680	1 904			
4	168	84	252	420	588	756	924	1 092	1 260	1 428	1 596	1 764	1 932

The number of hours in three months (immediate response phase) is 2,016 and all of the deliveries in Table 4.1 stop at the level next to 2,016 hours (e.g. first row: fourth delivery would be after 2,352 hours, which is beyond the immediate response phase). The time it takes to unload the vessels and complete customs clearance is set to 6 and 24 hours, respectively.

Lead time inland transportation

When the relief items arrive at the port it is assumed (in the simulation model) that the required capacity of inland transportation (trucks) is available. The time it takes to load and unload a truck is set to four hours, while transport time depends on the distance. The master data modules contain estimations of distances from the relevant ports to all of the 16 disaster areas and these distances are divided by 40 km/ h (average speed of trucks) in order to calculate the time of inland transportation.

The total lead time for a given disaster is based on the two calculations presented above. By adding the time spent on sea- and inland transportation, the calculation modules estimate the total lead time and the model makes is visible to the user in the output module.

Fixed cost

Storing one pallet at any vessel or terminal generates a certain storage cost. The model estimates a yearly storage cost based on the capacity selected by the user. This storage cost is then divided by the number of disasters, which implies that a higher turnover (higher number of responses per year) yield a lower cost per response. Further, the cost per pallet is calculated by dividing the cost per disaster with the average number of pallets delivered to each disaster.

Figure 4.10 shows how the total fixed storage costs are allocated to each pallet delivered.

Figure 4.10 Fixed cost allocation per disaster

Storage cost vessels

	Number of pallets	Fixed storage cost per day
Route 1, vessel 1	300	$675,0
Route 2, vessel 1	300	$675,0
Route 2, vessel 2	300	$675,0
Route 2, vessel 3	300	$675,0
Route 2, vessel 4	300	$675,0
Total	1500	$3 375,0

Turnover rate	16

Storage cost terminals

	Number of pallets	Fixed storage cost per day
Tianjin	0	$0,0
Shanghai	0	$0,0
Laem Chabang	0	$0,0
Singapore	0	$0,0
Jakarta	0	$0,0
Chennai	0	$0,0
DC Singapore	0	$0,0
Total	0	$0,0

Total storage cost

Fixed storage cost per day	$3 375
Fixed storage cost per year	$1 231 875
Fixed storage cost per disaster	$76 992

Allocation of fixed cost to disasters

Disaster	Country	Required capacity in pallets	Cost allocation per pallet with a yearly turnover = 16
2005-0475	China	3 926	$13,7
2006-0241	Myanmar	40	$13,7
2006-0648	Vietnam	113	$13,7
2007-0021	Malaysia	699	$13,7
2007-0274	Cambodia	155	$13,7
2007-0311	Bangladesh	8 613	$13,7
2007-0320	India	32 327	$13,7
2007-0557	Papua N.G	1 092	$13,7
2008-0329	Vietnam	625	$13,7
2008-0452	Laos	3 014	$13,7
2009-0414	Cambodia	12 569	$13,7
2009-0421	Indonesia	10 763	$13,7
2009-0434	Nepal	8 615	$13,7
2009-0611	Vietnam	5 241	$13,7
2009-0632	Mongolia	1 869	$13,7
2010-0120	Solomon Is	6	$13,7
		89 669	
		5 604	

The master data modules provide the calculation modules with information regarding the capacity, configuration and price structure, which in turn calculates the fixed cost per pallet. As illustrated by Figure 4.10, a capacity of 300 pallets pre-stored onboard each vessel generates a cost per disaster equal to $76,992. This number is then divided by 5,604 pallets (average number of pallets delivered to each disaster) which generates a cost per pallet of $13.7. This number is then multiplied with the number of pallets delivered to each of the 16 disasters.

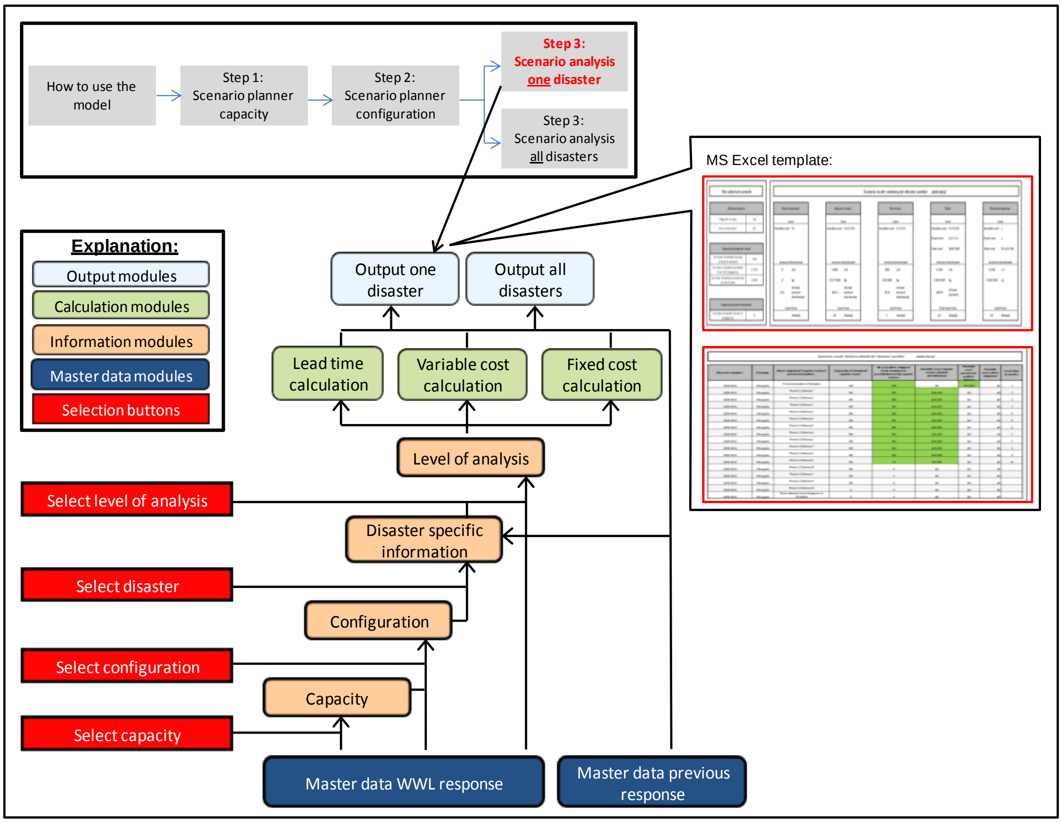
Variable cost

Whenever a disaster occurs a variable cost is generated. This cost relates to the transportation of the relief items from the port/ terminal to the disaster area. The master data modules provide the calculation modules with the location of the disaster, the required number of pallets, the distances from the relevant port/ terminal and cost of inland transportation. Based on this information, the calculation modules calculate the numbers and provide the output modules with the required data.

4.2.6. Output modules

The outputs refers to "Step 3" in the simulation model, and based on the selections made by the user in "Step 2", this module generates information on a detailed per disaster level or on an aggregated level providing information for all of the 16 disasters simultaneously. The outputs appear either as visualized by Figure 4.11 or as visualized by Figure 4.12. Figure 4.11 shows how the model works when the user selects to run a simulation for one specific disaster. When the selection is made, the master data modules provide the calculation modules with the required information, upon which these modules calculate the fixed- and variable costs as well as the lead time for the selected scenario. The results are visualized to the user through an output module as depicted in Figure 4.11.

Figure 4.11 Step 3: Scenario output one disaster



This output module provides a description of the response on a general and a specific level. The general level, indicated by the upper red rectangle in the MS Excel template in Figure 4.11, provides the following information:

- A summary of the selected scenario (capacity and configuration).
- Fixed and variable cost generated by the selected configuration (vessels or vessels and terminals), total lead time for the response as well as the percentage of demand fulfilled (measured as previous response).
- Total cost and the amount of relief items that was delivered by the current response system.

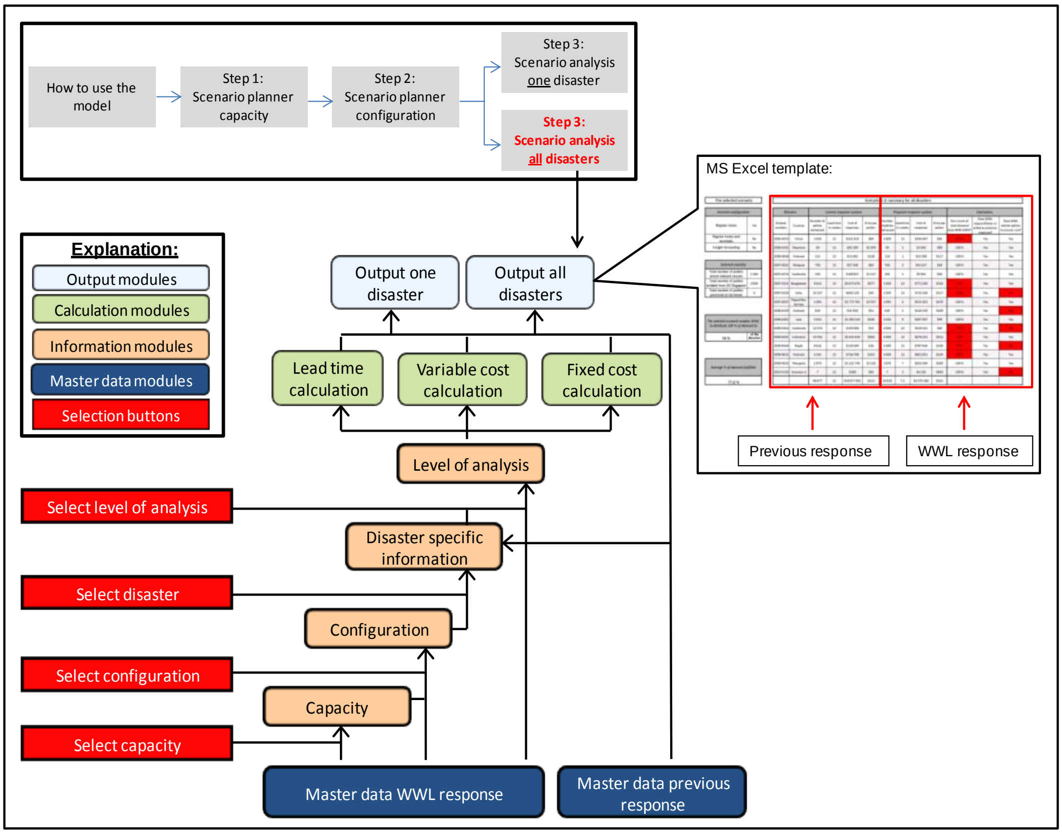
The specific level, indicated by the lower red rectangle in the MS Excel template in Figure 4.11, provides the following information:

- Which of the routes and vessels that are responding to the disaster, their capacity and the number of pallets each vessel delivers, as well as the cost and total lead time of their response.

(Appendix 1.4 provides a print screen of an example of this output).

Figure 4.12 visualizes how the model works when the model simulates a response to all of the 16 disasters simultaneously. The process is exactly the same as for the output for one disaster, where the master data modules provide information to the calculations modules according to the selection made by the user. The same scenario is automatically run for each of the 16 disasters and the outputs generated are visualized to the user through an output module as depicted in Figure 4.12

Figure 4.12 Step 3: Scenario output all disasters



Compared to the output for one disaster, this output does not provide detailed information regarding each of the vessels/ routes. Information obtained from this output is split into two parts; one regarding previous response and the other is related to the WWL response (corresponds to the two red rectangles in the MS Excel template in Figure 4.12).

The information provided by this output module is divided into four parts:

1. A summary of the selected scenario (capacity and configuration).
2. Information related to the previous response system; total number of pallets delivered, total lead time and cost of the response as well as the cost per pallet delivered to each of the 16 disasters.
3. Information related to the simulated response system; total number of pallets delivered, total lead time and cost of the response as well as cost per pallet for each of the 16 disasters.
4. A comparison of the two different response systems, revealing whether the simulated system is able to respond with a shorter lead time and/ or to a lower cost to each of the 16 disasters. In addition, it shows the percentage of demand fulfilled by the simulated response system.

(Appendix 1.5 provides a print screen of an example of this output).

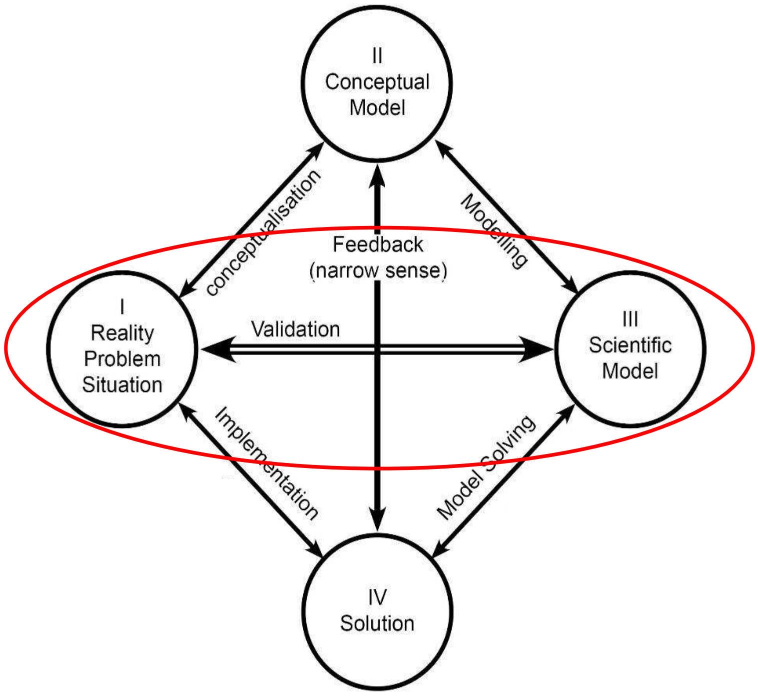
The outputs from all of the 16 disasters will be further described and presented in the next chapter, where a thorough analysis of the different scenarios is conducted. The output modules presented above enables the user of the simulation model to easily compare the performance of a given response scenario with the current response system. By running the simulation model with different combinations of capacity and configuration, it is possible to compare the performance of various scenarios. The development process of the simulation model was iterative and demanding and in order to reach a satisfactory level of model performance the simulation model has been continually validated and adjusted throughout the modeling phase, which will be described in the next section.

4.3. Validation of the programmed simulation model

When the simulation model was developed in MS Excel it needed to be validated as illustrated by the red circle in Figure 4.13. Validation is the process of "determining whether a simulation model is an accurate representation of the system, for the particular objectives of the study" (Law and McComas 2001, 22).

However, the difficulty of the validation process increases when a version of the system does not currently exists (Law and McComas 2001).

Figure 4.13 The research process



Source: Mitroff et al. (1974)

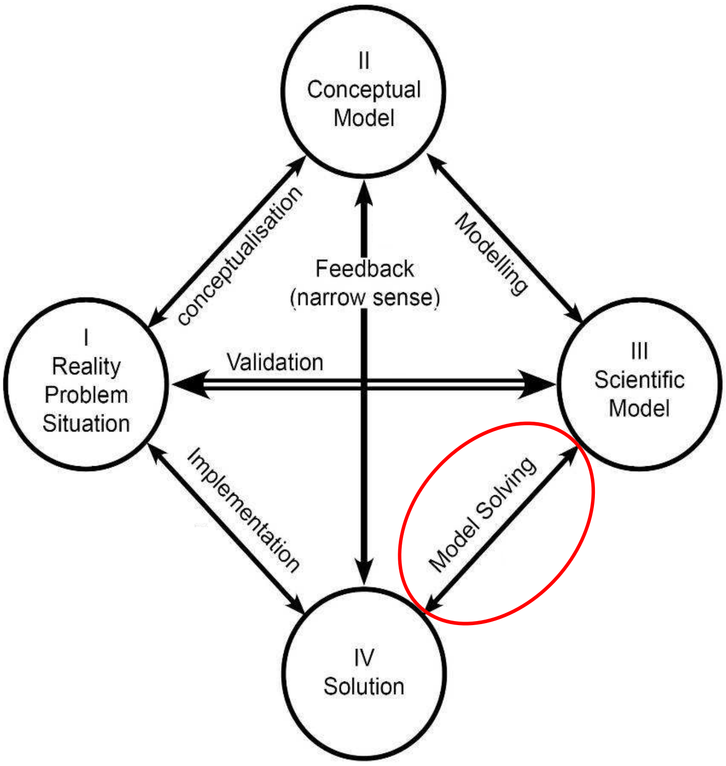
In order to test if the programmed simulation model is valid, two different measures of validity can be used: results validity and face validity (Law and McComas 2001). Results validation is obtained by comparing the output data from the simulation model with the output data collected from the actual system, and if the output data closely resembles the system simulated is considered "valid" (Law and McComas 2001). Currently there exists a humanitarian response system that is operating (the system that actually responded to the 16 disasters). However, WWL has never provided the logistical services the proposed response system required and hence, the response system presented does not currently exist. As a result, comparing the output data from the existing system with the output data from the proposed response system in order to test the validity of the results, would lead to a comparison of two completely different systems. This implies that the validity of the simulation model cannot be tested by the measure of results validity.

Face validity should and can be examined regardless of whether a version of the system currently exists (Kleijnen 1995; Law and McComas 2001; Manuj et al. 2009). According to Sargent (2007) the researchers should provide a set of subject-matter experts (SMEs) a structured walkthrough of the simulation model to review the results for reasonableness. If the results are consistent with how the SMEs perceive that the system should operate, the model is said to have face validity. In order to increase the reasonableness of the simulation model developed in this study, partners of Contribute have actively participated in order to validate the simulation model. This process has been iterative, which means that the simulation model (in terms of design, logic, functions and mathematical and causal relationships) has been changed or modified several times before the SMEs agreed that the model and its behavior were reasonable. One example of the changes made was the decision of excluding the freight forwarding configuration from the analysis, due to the lack of confidence regarding the price and the lead time for this service. The first time the simulation model was presented to the SMEs, "Step 3a" (where the simulation model automatically simulates the response to all the 16 disasters for the selected capacity and configuration) was not included in the model. This additional function/step was therefore added after the first version of the model was presented to the SMEs. This modification is another example of the changes that were made during the validity process. After several meetings where the model, its system behavior and outputs were discussed, the SMEs agreed that the simulation model is a reasonable representation of how the proposed response system would operate if it was implemented in reality. When the model was validated by the SMEs, the different response scenarios were simulated and their outputs analyzed.

5. Scenario results and analysis

The previous chapter provided both a description of how the model was structured in MS Excel and validated by different SMEs. Given combinations of capacity and configuration yields different response scenarios, and by running the simulation model the performance of each combination can be examined. The objective of this chapter is to present the outputs from each simulation run and reveal through an analysis whether any of the different scenarios presented in chapter four performs better than others. The chapter presents both the results from the different scenarios in the two configurations and an analysis of the outputs within each of the two groups. Then an analysis of the effects of adding the six terminals to the system is provided, before a discussion of whether the terminals should be included in the response system is conducted. The discussion is finalized with a presentation of the scenario that has proved to yield the best trade-off between efficiency and effectiveness.

Figure 5.1 The research process



Source: Mitroff et al. (1974)

5.1. Scenarios in the first configuration

The first configuration utilizes both vessels and terminals when responding to each of the 16 disasters. The configuration consists of five different scenarios, where the capacity of each of the resources (vessels and terminals) ranges from 75 to 375 pallets with a set interval of 75. The presentations of each of the five scenarios are supported by figures, visualizing the corresponding outputs from the simulation model in MS Excel. The boxes on the left hand side in table 5.1 below provide information regarding the capacity and the configuration, while the main box on the right hand side provides information about the current- and the proposed response systems as well as a comparison of the two systems. The simulation model do also provides detailed outputs on a per disaster level for each of the selected configurations. However, the analysis seeks to reveal whether any scenario outperforms the others on an overall basis and hence, analyzing the performance of the system on a “disaster level” would not provide the desired understanding of the system as such. As a result, the detailed outputs are only presented with an example in the appendix (appendix 1.4). The current response remains the same throughout the entire analysis, where 25 different humanitarian organizations delivered almost 90,000 pallets to an average cost of $212 per pallet.

5.1.1. Scenario 1.1

Table 5.1 visualizes the outputs from scenario 1.1, where 75 pallets of relief items are pre-stored on each of the five vessels and the six terminals.

Table 5.1 Outputs scenario 1.1

The selected scenario	
Selected configuration	
Regular routes	*No*
Regular routes and terminals	*Yes*
Freight forwarding	*No*
Selected capacity	
Number of pallets pre-stored onboard vessels	*375*
Number of pallets avilable from DC	*750*
Number of pallets pre-stored at terminals	*450*
The selected sceanrio enables WWL to distribute 100 % of demand to	
44 %	of the disasters
Average % of demand fullfilled	
55,8 %	

Scenario 1.1: summary for all disasters												
Disaster:		*Current response system:*				*Proposed response system:*				*Conclusion:*		
Disaster number:	Country:	Number of pallets delivered:	Lead time in weeks:	Cost of response:	Price per pallet:	Number of pallets delivered:	Lead time in weeks:	Cost of response:	Price per pallet:	How much of total demand does WWL fulfill?	Does WWL respond faster or as fast as previous	Does WWL deliver pallets to a lower cost?
2005-0475	China	3 926	12	$331 019	$84	975	12	$71 616	$73	25 %	Yes	Yes
2006-0241	Myanmar	40	12	$83 100	$2 078	40	1	$3 202	$80	100 %	Yes	Yes
2006-0648	Vietnam	114	12	$13 482	$118	114	1	$12 318	$108	100 %	Yes	Yes
2007-0021	Malaysia	700	12	$57 348	$82	700	5	$27 337	$39	100 %	Yes	Yes
2007-0274	Cambodia	156	12	$189 837	$1 217	156	2	$8 588	$55	100 %	Yes	Yes
2007-0311	Bangladesh	8 614	12	$4 973 076	$577	900	12	$202 547	$225	10 %	Yes	Yes
2007-0320	India	32 327	12	$660 139	$20	900	12	$187 247	$208	3 %	Yes	No
2007-0557	Papua N.G	1 093	12	$2 772 781	$2 537	1 093	12	$513 767	$470	100 %	Yes	Yes
2008-0329	Vietnam	626	12	$31 940	$51	626	7	$112 713	$180	100 %	Yes	No
2008-0452	Laos	3 014	12	$1 283 324	$426	1 200	12	$108 063	$90	40 %	Yes	Yes
2009-0414	Cambodia	12 570	12	$159 900	$13	1 200	12	$48 063	$40	10 %	Yes	No
2009-0421	Indonesia	10 763	12	$5 421 829	$504	1 200	12	$170 463	$142	11 %	Yes	Yes
2009-0434	Nepal	8 616	12	$139 584	$16	900	12	$207 047	$230	10 %	Yes	No
2009-0611	Vietnam	5 241	12	$736 708	$141	1 200	12	$150 063	$125	23 %	Yes	Yes
2009-0632	Mongolia	1 870	12	$2 122 745	$1 135	1 125	12	$292 559	$260	60 %	Yes	Yes
2010-0120	Solomon Is	7	12	$280	$40	7	1	$4 165	$595	100 %	Yes	No
		89 677	12	$18 977 092	$212	12 336	8,6	$2 119 760	$172			

The proposed response system is able to deliver 12,336 pallets to an average price of $172 while the average lead time is 8.6 weeks. The scenario provides a customer service level (CSL) of 56% (percentage of demand fulfilled), which means that the proposed system is able to respond with 56% (on average) of the required demand to each of the 16 disasters. Depending on whether both routes are serving a port and the distance from the port to the disaster area, the maximum number of pallets the system is able to deliver to any of the 16 disasters ranges from 900 to 1,200 pallets. This limits the system's ability to deliver 100% of the required demand to each of the 16 disasters. However, almost 50% of the disasters required less than 1,200 pallets which enables this scenario to fulfill 100% of the demand in 7 out of the 16 disasters. In 71% of these disasters the proposed response system was able to deliver the relief items to a lower price than the current system. This indicates that a system with 75 pallets pre-stored on each of WWL's facilities operates with a higher degree of efficiency than the current system.

5.1.2. *Scenario 1.2*

Table 5.2 provides the outputs generated by the simulation model for the second scenario where 150 pallets are pre-stored on each of the five vessels and the six terminals while 1,500 pallets are made available from the DC in Singapore.

Table 5.2 Outputs scenario 1.2

The selected scenario	
Selected configuration	
Regular routes	*No*
Regular routes and terminals	*Yes*
Freight forwarding	*No*
Selected capacity	
Number of pallets pre-stored onboard vessels	*750*
Number of pallets avilable from DC	*1 500*
Number of pallets pre-stored at terminals	*900*
The selected sceanrio enables WWL to distribute 100 % of demand to	
50 %	of the disasters
Average % of demand fullfilled	
66,5 %	

Scenario 1.2: summary for all disasters												
Disaster:		*Current response system:*				*Proposed response system:*				*Conclusion:*		
Disaster number:	Country:	Number of pallets delivered:	Lead time in weeks:	Cost of response:	Price per pallet:	Number of pallets delivered:	Lead time in weeks:	Cost of response:	Price per pallet:	How much of total demand does WWL fulfill?	Does WWL respond faster or as fast as previous	Does WWL deliver pallets to a lower cost?
2005-0475	China	3 926	12	$331 019	$84	1 950	12	$151 597	$78	50 %	Yes	Yes
2006-0241	Myanmar	40	12	$83 100	$2 078	40	1	$3 374	$84	100 %	Yes	Yes
2006-0648	Vietnam	114	12	$13 482	$118	114	1	$12 807	$112	100 %	Yes	Yes
2007-0021	Malaysia	700	12	$57 348	$82	700	3	$30 339	$43	100 %	Yes	Yes
2007-0274	Cambodia	156	12	$189 837	$1 217	156	1	$9 257	$59	100 %	Yes	Yes
2007-0311	Bangladesh	8 614	12	$4 973 076	$577	1 800	12	$412 815	$229	21 %	Yes	Yes
2007-0320	India	32 327	12	$660 139	$20	1 800	12	$382 215	$212	6 %	Yes	No
2007-0557	Papua N.G	1 093	12	$2 772 781	$2 537	1 093	7	$518 456	$474	100 %	Yes	Yes
2008-0329	Vietnam	626	12	$31 940	$51	626	3	$115 398	$184	100 %	Yes	No
2008-0452	Laos	3 014	12	$1 283 324	$426	2 400	12	$226 421	$94	80 %	Yes	Yes
2009-0414	Cambodia	12 570	12	$159 900	$13	2 400	12	$106 421	$44	19 %	Yes	No
2009-0421	Indonesia	10 763	12	$5 421 829	$504	2 400	12	$351 221	$146	22 %	Yes	Yes
2009-0434	Nepal	8 616	12	$139 584	$16	1 800	12	$421 815	$234	21 %	Yes	No
2009-0611	Vietnam	5 241	12	$736 708	$141	2 400	12	$310 421	$129	46 %	Yes	Yes
2009-0632	Mongolia	1 870	12	$2 122 745	$1 135	1 870	11	$494 319	$264	100 %	Yes	Yes
2010-0120	Solomon Is	7	12	$280	$40	7	1	$4 195	$599	100 %	Yes	No
		89 677	12	$18 977 092	$212	21 556	7,8	$3 551 071	$165			

The total number of pallets delivered in this scenario has increased from the previous 12,336 to 21,556, the maximum number of pallets delivered to each disaster ranges from 1,800 to 2,400 and the proposed system delivers 100% of the required demand to 50% of the disasters. Further, the CSL has increased to 66% and even though the total price of responding with this scenario is substantially higher than for scenario 1.1 ($3,551,071 compared to $2,119,760) the increase in number of pallets delivered reduces the price per pallet from $172 to $165. This implies that scenario 1.2 operates with a higher degree of efficiency than the system in scenario 1.1 (and the current system). The average lead time is reduced with almost one week and combined with a 75% increase in number of pallets delivered (higher CSL) improves the effectiveness of the system substantially.

5.1.3. Scenario 1.3

The outputs from the third scenario are depicted in Table 5.3, where the number of pallets pre-stored on each of the facilities has increased to 225, while 2,250 pallets are available from the DC during the immediate response phase.

Table 5.3 Outputs scenario 1.3

The selected scenario	
Selected configuration	
Regular routes	*No*
Regular routes and terminals	*Yes*
Freight forwarding	*No*
Selected capacity	
Number of pallets pre-stored onboard vessels	*1 125*
Number of pallets avilable from DC	*2 250*
Number of pallets pre-stored at terminals	*1 350*
The selected sceanrio enables WWL to distribute 100 % of demand to	
56 %	of the disasters
Average % of demand fullfilled	
73,5 %	

Scenario 1.3: summary for all disasters												
Disaster:		*Current response system:*				*Proposed response system:*				*Conclusion:*		
Disaster number:	Country:	Number of pallets delivered:	Lead time in weeks:	Cost of response:	Price per pallet:	Number of pallets delivered:	Lead time in weeks:	Cost of response:	Price per pallet:	How much of total demand does WWL fulfill?	Does WWL respond faster or as fast as previous	Does WWL deliver pallets to a lower cost?
2005-0475	China	3 926	12	$331 019	$84	2 925	12	$241 058	$82	75 %	Yes	Yes
2006-0241	Myanmar	40	12	$83 100	$2 078	40	1	$3 561	$89	100 %	Yes	Yes
2006-0648	Vietnam	114	12	$13 482	$118	114	1	$13 339	$117	100 %	Yes	Yes
2007-0021	Malaysia	700	12	$57 348	$82	700	2	$33 609	$48	100 %	Yes	Yes
2007-0274	Cambodia	156	12	$189 837	$1 217	156	1	$9 986	$64	100 %	Yes	Yes
2007-0311	Bangladesh	8 614	12	$4 973 076	$577	2 700	12	$631 835	$234	31 %	Yes	Yes
2007-0320	India	32 327	12	$660 139	$20	2 700	12	$585 935	$217	8 %	Yes	No
2007-0557	Papua N.G	1 093	12	$2 772 781	$2 537	1 093	4	$523 561	$479	100 %	Yes	Yes
2008-0329	Vietnam	626	12	$31 940	$51	626	2	$118 322	$189	100 %	Yes	No
2008-0452	Laos	3 014	12	$1 283 324	$426	3 014	11	$298 425	$99	100 %	Yes	Yes
2009-0414	Cambodia	12 570	12	$159 900	$13	3 600	12	$176 446	$49	29 %	Yes	No
2009-0421	Indonesia	10 763	12	$5 421 829	$504	3 600	12	$543 646	$151	33 %	Yes	Yes
2009-0434	Nepal	8 616	12	$139 584	$16	2 700	12	$645 335	$239	31 %	Yes	No
2009-0611	Vietnam	5 241	12	$736 708	$141	3 600	12	$482 446	$134	69 %	Yes	Yes
2009-0632	Mongolia	1 870	12	$2 122 745	$1 135	1 870	7	$503 054	$269	100 %	Yes	Yes
2010-0120	Solomon Is	7	12	$280	$40	7	1	$4 228	$604	100 %	Yes	No
		89 677	12	$18 977 092	$212	29 445	7,1	$4 814 786	$164			

The increase in number of pallets pre-stored onboard each of the vessels and terminals makes this scenario able to deliver a total of 29,445 pallets to the 16 disasters and it delivers 100% of the required demand to 9 disasters, which implies an 6% increase compared to the previous scenario. Further, the average percentage of demand fulfilled has increased with additional 8% to 74%. This scenario delivers the pallets with an average price of $164 and an average lead time of 7.1 weeks. Even though the total price of the proposed system in this scenario has increased with almost $ 1,300,000, the performance of the response is substantially increased. The efficiency is improved through a reduction in the price per pallet delivered, from $165 to $164, while the effectiveness is improved through an increase in both the number of people benefiting from the response and the reduction in lead time from 7.7 to 7.1 weeks.

5.1.4. Scenario 1.4

Table 5.4 provides the outputs from the fourth scenario where the number of pallets pre-stored on each of WWL's facilities is 300.

Table 5.4 Outputs scenario 1.4

The selected scenario	
Selected configuration	
Regular routes	*No*
Regular routes and terminals	*Yes*
Freight forwarding	*No*
Selected capacity	
Number of pallets pre-stored onboard vessels	*1 500*
Number of pallets avilable from DC	*3 000*
Number of pallets pre-stored at terminals	*1 800*
The selected sceanrio enables WWL to distribute 100 % of demand to	
56 %	of the disasters
Average % of demand fullfilled	
79,3 %	

Scenario 1.4: summary for all disasters													
Disaster:		*Current response system:*				*Proposed response system:*				*Conclusion:*		
Disaster number:	Country:	Number of pallets delivered:	Lead time in weeks:	Cost of response:	Price per pallet:	Number of pallets delivered:	Lead time in weeks:	Cost of response:	Price per pallet:	How much of total demand does WWL fulfill?	Does WWL respond faster or as fast as previous	Does WWL deliver pallets to a lower cost?
2005-0475	China	3 926	12	$331 019	$84	3 900	12	$333 674	$86	99 %	Yes	No
2006-0241	Myanmar	40	12	$83 100	$2 078	40	1	$3 686	$92	100 %	Yes	Yes
2006-0648	Vietnam	114	12	$13 482	$118	114	1	$13 698	$120	100 %	Yes	No
2007-0021	Malaysia	700	12	$57 348	$82	700	2	$35 810	$51	100 %	Yes	Yes
2007-0274	Cambodia	156	12	$189 837	$1 217	156	1	$10 477	$67	100 %	Yes	Yes
2007-0311	Bangladesh	8 614	12	$4 973 076	$577	3 600	12	$853 766	$237	42 %	Yes	Yes
2007-0320	India	32 327	12	$660 139	$20	3 600	12	$792 566	$220	11 %	Yes	No
2007-0557	Papua N.G	1 093	12	$2 772 781	$2 537	1 093	3	$526 998	$482	100 %	Yes	Yes
2008-0329	Vietnam	626	12	$31 940	$51	626	2	$120 291	$192	100 %	Yes	No
2008-0452	Laos	3 014	12	$1 283 324	$426	3 014	8	$307 902	$102	100 %	Yes	Yes
2009-0414	Cambodia	12 570	12	$159 900	$13	4 800	12	$250 355	$52	38 %	Yes	No
2009-0421	Indonesia	10 763	12	$5 421 829	$504	4 800	12	$739 955	$154	45 %	Yes	Yes
2009-0434	Nepal	8 616	12	$139 584	$16	3 600	12	$871 766	$242	42 %	Yes	No
2009-0611	Vietnam	5 241	12	$736 708	$141	4 800	12	$658 355	$137	92 %	Yes	Yes
2009-0632	Mongolia	1 870	12	$2 122 745	$1 135	1 870	6	$508 934	$272	100 %	Yes	Yes
2010-0120	Solomon Is	7	12	$280	$40	7	1	$4 250	$607	100 %	Yes	No
		89 677	12	$18 977 092	$212	36 720	6,8	$6 032 485	$164			

With an increase in the total price of $1,200,000 compared to scenario 1.3, this scenario is able to deliver almost 37,000 pallets to the 16 disasters, which implies an increase of 7,000 pallets compared to scenario 1.3. The maximum number of pallets that can be delivered to any disaster ranges from 3,600 to 4,800. The number of disasters where the proposed system delivers 100% of the required demand remains the same while the service level has increased to 79% (average percentage of demand fulfilled). Further, the average price of the pallets delivered is the same as in scenario 1.3, while the average lead time is slightly reduced from 7.1 weeks to 6.8 weeks. Even though the efficiency is not improved if the number of pallets pre-stored at each facility is increased from 225 to 300, the effectiveness is further improved by lowering the lead time and delivering more relief items to those people affected by the disasters.

5.1.5. Scenario 1.5

The last scenario within the first configuration implies a further increase in the number of pallets pre-stored on each vessel and terminal to 375. Within this scenario, the annual price has increased from $6,032,485 to $7,153,682, while the number of pallets delivered to all of the 16 disasters is 42,287, and where the maximum number of pallets delivered to any disaster ranges from 4,500 to 6,000. The number of disasters where the proposed system is able to deliver 100% of the demand has increased to 11 and the system delivers on average 83% of the required relief items. The outputs from the simulation run of this scenario are depicted in Table 5.5.

Table 5.5 Outputs scenario 1.5

The selected scenario	
Selected configuration	
Regular routes	*No*
Regular routes and terminals	*Yes*
Freight forwarding	*No*
Selected capacity	
Number of pallets pre-stored onboard vessels	*1 875*
Number of pallets avilable from DC	*3 750*
Number of pallets pre-stored at terminals	*2 250*
The selected sceanrio enables WWL to distribute 100 % of demand to	
69 %	of the disasters
Average % of demand fullfilled	
82,6 %	

Scenario 1.5: summary for all disasters													
Disaster:		*Current response system:*				*Proposed response system:*				*Conclusion:*		
Disaster number:	Country:	Number of pallets delivered:	Lead time in weeks:	Cost of response:	Price per pallet:	Number of pallets delivered:	Lead time in weeks:	Cost of response:	Price per pallet:	How much of total demand does WWL fulfill?	Does WWL respond faster or as fast as previous	Does WWL deliver pallets to a lower cost?
2005-0475	China	3 926	12	$331 019	$84	3 926	10	$352 738	$90	100 %	Yes	No
2006-0241	Myanmar	40	12	$83 100	$2 078	40	1	$3 858	$96	100 %	Yes	Yes
2006-0648	Vietnam	114	12	$13 482	$118	114	1	$14 187	$124	100 %	Yes	No
2007-0021	Malaysia	700	12	$57 348	$82	700	1	$38 813	$55	100 %	Yes	Yes
2007-0274	Cambodia	156	12	$189 837	$1 217	156	1	$11 146	$71	100 %	Yes	Yes
2007-0311	Bangladesh	8 614	12	$4 973 076	$577	4 500	12	$1 086 510	$241	52 %	Yes	Yes
2007-0320	India	32 327	12	$660 139	$20	4 500	12	$1 010 010	$224	14 %	Yes	No
2007-0557	Papua N.G	1 093	12	$2 772 781	$2 537	1 093	3	$531 686	$486	100 %	Yes	Yes
2008-0329	Vietnam	626	12	$31 940	$51	626	1	$122 976	$196	100 %	Yes	No
2008-0452	Laos	3 014	12	$1 283 324	$426	3 014	7	$320 830	$106	100 %	Yes	Yes
2009-0414	Cambodia	12 570	12	$159 900	$13	6 000	12	$338 680	$56	48 %	Yes	No
2009-0421	Indonesia	10 763	12	$5 421 829	$504	6 000	12	$950 680	$158	56 %	Yes	Yes
2009-0434	Nepal	8 616	12	$139 584	$16	4 500	12	$1 109 010	$246	52 %	Yes	No
2009-0611	Vietnam	5 241	12	$736 708	$141	5 241	11	$741 322	$141	100 %	Yes	No
2009-0632	Mongolia	1 870	12	$2 122 745	$1 135	1 870	4	$516 955	$276	100 %	Yes	Yes
2010-0120	Solomon Is	7	12	$280	$40	7	1	$4 280	$611	100 %	Yes	No
		89 677	12	$18 977 092	$212	42 287	6,3	$7 153 682	$169			

Even though both the total number of pallets available and the number of pallets delivered have increased compared to scenario 1.4, the average price per pallet has also increased, from $164 to $165. Keeping in mind the declining price structure described in chapter three, an increase in the total number of pallets delivered should in principle reduce the average price per pallet. The reason for the unexpected increase in the average price per pallet is the following; each pallet generates a yearly fixed storage cost whether or not the pallet is delivered to a disaster during the year. In order to cover the cost of storage, it is necessary to divide the total annual storage cost by the number of pallets that are actually delivered. In this scenario, the price of the additional pallets (compared to scenario 1.4) needs to be covered by an equal increase in the number of pallets delivered in order to keep the marginal cost per pallet at the same level. If not all of the additional pallets are delivered, the marginal cost of delivering one more pallet will be higher than the cost of delivering all the previous pallets and hence, the average price of all pallets delivered will increase.

The additional cost incurred by the increase in number of pre-stored pallets in scenario 1.5 compromises the efficiency of the system. This implies that the marginal effect of one more pallet in the system is diminishing, and a further increase in the number of pallets pre-stored on vessels and terminals will reduce the efficiency of the proposed response system. Even though this has a negative effect on the level of efficiency, the effectiveness is still improved compared to the other four scenarios. The lead time is reduced with 0.5 weeks compared to scenario 1.4 and the number of people benefiting from the response is increasing as the total number of pallets delivered has increased. In order to ensure that their scarce resources are utilized in the best possible way, it is important for the humanitarian organizations to be aware of this trade-off between efficiency and effectiveness and strive for a level of product availability that maximizes the use of their funding. The aim of this study is to set up the proposed system in a way that improves both the efficiency and the effectiveness compared to the current system and the analysis in the next section seeks to reveal whether any of the five scenarios presented above stand out compared to the others.

5.1.6. A comparison of the scenarios in the first configuration

Table 5.6 summarizes the main differences between the five scenarios in the first configuration and the previous response (Base).

Table 5.6 Summary of the outputs from scenario 1.1 to 1.5

Scenario number	Number of pallets pre stored onboard each vessel	Number of pallets delivered to DC Singapore in the response phase	Number of pallets pre stored on each terminal	Number of pallets avilable for each disaster	Total number of pallets delivered to 16 disasters	Percentage of disaters where the response covers 100 % of demand	Average percentage of demand fulfilled	Average lead time in weeks	Total price in $	Average price per pallet	Increase in total price compared to the previous scenario	Increase in the number of pallets delivered compared to previous sceanrio
1.1	75	750	75	1 575	12 336	44 %	56 %	8,6	$2 119 760	$172		
1.2	150	1 500	150	3 150	21 556	50 %	66 %	7,7	$3 551 071	$165	68 %	75 %
1.3	225	2 250	225	4 725	29 445	56 %	74 %	7,1	$4 814 786	$164	36 %	37 %
1.4	300	3 000	300	6 300	36 720	56 %	79 %	6,8	$6 032 485	$164	25 %	25 %
1.5	375	3 750	375	7 875	42 287	69 %	83 %	6,3	$7 153 682	$169	19 %	15 %
Base					89 677	100 %	100 %	12,0	$18 977 092	$212		

The number of pallets pre-stored on each facility has been increased with 75 in each of the five scenarios. As described in the previous paragraph, the efficiency of the system has been continually improved (as the number of pallets pre-stored has been increased) to a certain level (300 pallets) before it started to decline. This implies that the marginal effect of adding pallets to the system is negative when the number of pallets pre-stored on each facility passes 300 (implying that an additional pallet pre-stored increase the average price of all pallets delivered). As depicted by the last two columns in Table 5.6 it is a decreasing marginal effect both in terms of effectiveness and the efficiency from adding pallets to the proposed response system. By increasing the number of pallets from 75 to 150 (changing from scenario 1.1 to 1.2) it is possible to increase the number of pallets delivered with 75% while the total price increases with only 68%. This implies, in relative terms, that the increase in effectiveness (more pallets of relief items are delivered) is greater than the increase in price (75% versus 68%). As a result, the marginal cost of the additional pallets pre-stored in scenario 1.2 is lower than the average price of the pallets pre-stored in scenario 1.1 and hence, it is possible to gain from adding more pallets to the system. Even though the positive effect is diminishing, it still applies when the number of pre-stored pallets is increased from 150 to 225. There is a shift when moving from scenario 1.3 to 1.4 where both the increase in price and number of pallets delivered equals 25%. A further increase from 300 to 375 pallets incurs a 19% increase in the price while the effect in terms of pallets delivered is only 15%, which is a trend that continues when more pallets are added to the system. The efficiency of the system improves until the increase in both total price and number of pallets delivered are the same. As depicted in Table 5.6, this level is reached when the number of pallets equals 300 (25% increase in both price and number of pallets delivered).

Effectiveness relates to the extent to which customer requirements are met and this implies that a high degree of effectiveness depends on how much relief items that are successfully delivered to the affected people and the time it takes from the disaster occur to the demand is met. The more pallets that are pre-stored in the system, the more pallets can be delivered to each disaster and the higher is the average percentage of demand fulfilled. As a result, the negative marginal effect of adding more pallets to the system does not apply to this measure of effectiveness, where a continually increase in the number of pallets pre-stored in the system has a positive marginal effect (until all of the demand from each of the disasters are fulfilled). This effect can be seen in the outputs from the five scenarios, where the percentage of average demand fulfilled continues to improve when moving from scenario 1.1 to 1.5. With regards to the time it takes to fulfill the demand, the positive marginal effect of adding more pallets to the system continues until all of the required relief items are delivered in one batch, and where the lead time is governed by the distance of inland transportation. The average lead time in weeks is steadily decreasing from scenario 1.1 to scenario 1.5 with a reduction of 2.3 weeks. Figure 5.2a and 5.2b visualize the trends described above, where 5.2a depicts the relationship between the number of pallets delivered and price per pallet while 5.2b depicts the relationship between cost per pallet and lead time.

Figure 5.2a Number of pallets and price per pallet

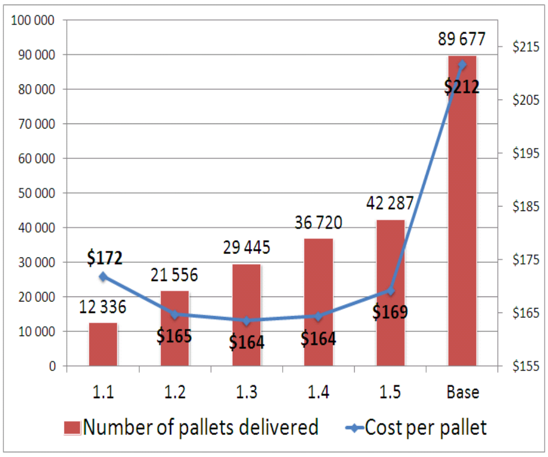
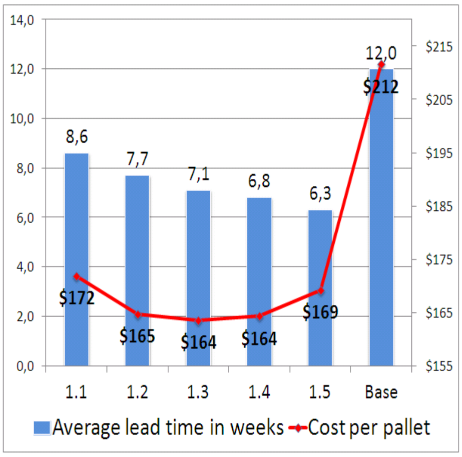


Figure 5.2b Average lead time and price per pallet



Even though the price per pallet starts to increase after a certain level (slightly above 300 pallets pre-stored at each facility) all of the five scenarios described above have a price per pallet that is 23% to 29% lower than the current price of $212. This indicates that all of the proposed systems represented by the five different scenarios can operate with a higher degree of efficiency than the current systems are able to do. When comparing these figures it is important to take into account that the current response systems delivered almost 90,000 pallets to the 16 disasters, which is more than twice as much as scenario 1.5 (the scenario that responded with the most pallets) and hence it is too early to draw a firm conclusion with regards to this performance measure. Both the current and the proposed system must be tested through sensitivity analysis before it can be conclude that the proposed system operates with a higher degree of efficiency than the current system. A sensitivity analysis will be presented as part of the discussion in the next chapter.

Table 5.6 above reveals that scenario 1.4 represents the capacity that most efficiently utilizes the available resources (the scenario where the increase in total price equals the increase in the number of pallets delivered) and hence, this capacity should be selected from an efficiency point of view. However, it is possible to further improve the effectiveness of the system by increasing the number of pallets pre-stored at each facility above 300. Whether such a capacity should be selected would again depend on the trade-off between the two performance measures.

It is important to note that the preliminary conclusion, indicating that maximum efficiency is reached when 300 pallets of relief items are pre-stored onboard each of the five vessels and the six terminals, is based on the demand generated by the 16 disasters included in this study. If the total number of pallets delivered is changed, the tipping point for the marginal effect will be skewed in one direction or the other. This implies that the conclusion drawn above only holds if the number of pallets demanded by the disasters included in this study represents the expected demand of relief items in an average year. The next section will analyze to what extent the second configuration is able to provide a better trade-off between the two performance measures than the first configuration.

5.2. Scenarios in the second configuration

The second configuration corresponds to the conceptual model in Figure 2.9, where the response system is set up without the use of the six terminals. The number of pallets pre-stored onboard vessels ranges from 75 to 375, with the same interval as in configuration one. This section presents the outputs from the simulation model with regards to the second configuration and makes a comparison of the five different scenarios in order to reveal whether any yields a better trade-off between efficiency and effectiveness than the others. Table 5.7 is similar to Table 5.6 and provides an overview of the outputs from each of the scenarios. Print screens showing the detailed outputs from MS Excel are provided in appendix 2.1 to 2.5.

Table 5.7 Summary of the outputs from scenario 2.1 to 2.5

Scenario number	Number of pallets pre stored onboard each vessel	Number of pallets delivered to DC Singapore in the response phase	Number of pallets pre stored on each terminal	Number of pallets avilable for each disaster	Total number of pallets delivered to 16 disasters	Percentage of disaters where the response covers 100 % of demand	Average percentage of demand fulfilled	Average lead time in weeks	Total price in $	Average price per pallet	Increase in total price compared to the previous scenario	Increase in the number of pallets delivered compared to previous sceanrio
2.1	75	750	0	1 125	11 618	38 %	55 %	8,8	$1 985 076	$171		
2.2	150	1 500	0	2 250	20 356	50 %	65 %	7,9	$3 341 050	$164	68 %	75 %
2.3	225	2 250	0	3 375	27 870	56 %	72 %	7,4	$4 494 354	$161	35 %	37 %
2.4	300	3 000	0	4 500	34 620	56 %	78 %	7,1	$5 575 560	$161	24 %	24 %
2.5	375	3 750	0	5 625	40 412	69 %	82 %	6,6	$6 633 245	$164	19 %	17 %
Base					89 677	100 %	100 %	12,0	$18 977 092	$212		

5.2.1. Scenario 2.1

Each of the vessels in scenario 2.1 contains 75 pallets and the DC provides a maximum of 750 additional pallets to the five vessels during the response phase. Similar to scenario 1.1 in the first configuration, this is the scenario in the second configuration that delivers the least amount of pallets to the 16 disasters (11,618 pallets), with the longest lead time (8.8 weeks) and to a price of $171 per pallet. Further, the maximum number of pallets delivered to each of the 16 disasters ranges from 900 to 1,125 and the proposed system is able to deliver 100% of required demand in 6 out of 16 disasters. The average percentage of demand fulfilled is 55. As for the five scenarios presented above, the price per pallet is well below $212, which indicates that this system is more efficient than the current response system.

5.2.2. Scenario 2.2

In the second scenario 150 pallets are pre-stored onboard each of the five vessels while 1,500 pallets are available through the DC. By doubling the number of pallets onboard the vessels it is possible to increase the number of pallets delivered with 75% to 20,356 and reducing the lead time with almost one week (from 8.8 to 7.9 weeks). However, more pallets in the system implies a higher total price, which in this scenario has increased with 68% (to $3,341,050) compared to scenario 2.1. As the number of pallets delivered increases with more than the increase in total price (75% versus 68%) the average price per pallet delivered declines from $171 to $164. Further, the increase in number of pallets stored makes it possible for the system increase the service level to 65% and respond with 100% of the relief items in 50% of the disasters. This, combined with a shorter lead time and a lower price per pallet delivered, makes the scenario both more efficient and effective than scenario 2.1.

5.2.3. Scenario 2.3

Scenario 2.3 has 225 pallets pre-stored onboard the vessels and this enables the proposed system to further increase the number of pallets delivered with 37% to 27,870 while the price for this scenario is increased with 35% to $4,494,354. The system can at its maximum deliver between 2,475 and 3,375 pallets to any disaster and as for scenario 2.2 the price per pallet continues to decrease. The average percentage of the demand fulfilled is 72 and the number of disasters where the proposed system delivers 100% of the demand has increased to 56% (9 of 16 disasters). The average lead time in this scenario is reduced to 7.4 weeks. Even though both the efficiency and the effectiveness is improved compared to scenario 2.2, the marginal effects of the additional pallets are lower when comparing the effects of moving from scenario 2.1 to 2.2.

5.2.4. Scenario 2.4

The fourth scenario in the second configuration has 300 pallets pre-stored onboard each of the five vessels and this capacity enables the response system to deliver 34,620 pallets of relief items. This implies a 24% increase in number of pallets delivered compared to scenario 2.3. Further, the total price of the response has also increased by 24%, implying that the price remains at the same level ($161 per pallet) as in the previous scenario. Even though the total number of pallets delivered has increased, the number of disasters where the proposed system fulfills 100% of the required demand, remains at the same level as in scenario 2.3 (9 of 16 disasters). Finally, the lead time continues to decrease with this scenario and it takes on average 7.1 weeks to deliver the relief items. Even though the effectiveness of the system is higher in this scenario compared to scenario 2.3 (more pallets delivered in a shorter amount of time) the level of efficiency remains the same when increasing the number of pallets from 225 to 300. This indicates the same trend as in the first configuration, where both the efficiency and the effectiveness are improved when adding more pallets to the system until the effects become negative at certain points.

5.2.5. Scenario 2.5

The number of pallets pre-stored on the vessels in the last scenario is 375, which enables the system to deliver slightly above 40,000 pallets to the 16 disasters. The increase in total price is higher than the increase in the number of pallets delivered (19% versus 15%) which implies that the average price per pallet delivered goes up compared to scenario 2.4 (from $161 to $164). This scenario also improves both the number of disasters where the system delivers 100% of the required demand as well as the average percentage of demand fulfilled. The average lead time is improved with an additional 0.5 weeks to 6.6 weeks. As the average price per pallet goes up when increasing the number of pallets from 300 to 375 the efficiency of the system is lower compared to the two previous scenarios. On the other hand, this scenario implies a higher degree of effectiveness, as both the customer service level and lead time are further improved.

The overall trend within this configuration is similar to the trend in the first configuration. The more pallets that are pre-stored onboard the vessels the more pallets can be delivered to the disasters and a higher degree of required demand is fulfilled by the system. Further, the lead time is continuously decreasing and the price per pallets declines before it starts to rise after a certain level. On the next page, Figure 5.3a and 5.3b visualize the relationship between efficiency and effectiveness by indicating the relationship between; the number of pallets delivered and average price per pallet (5.3a) and average lead time and price per pallet (5.3b).

Figure 5.3a Number of pallets and price per pallet

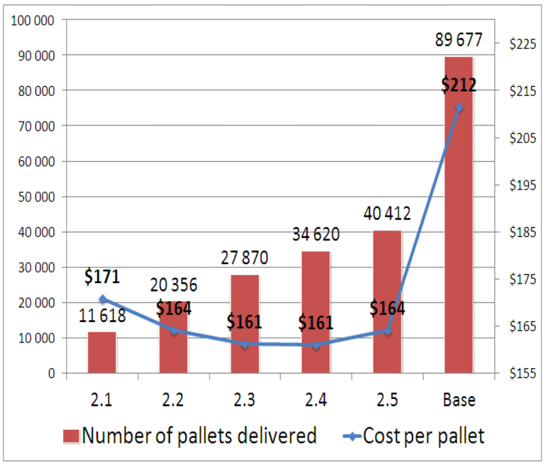
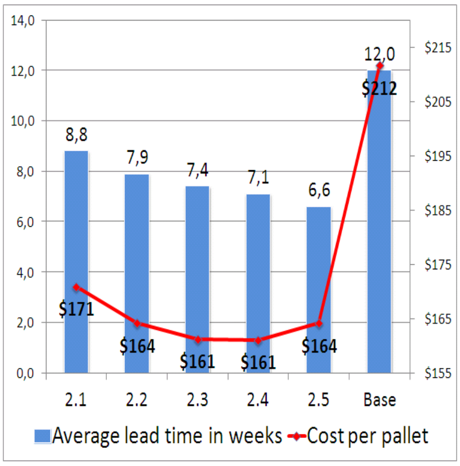


Figure 5.3b Average lead time and price per pallet



As for the scenarios in the first configuration, the maximum efficiency is gained when 300 pallets are pre-stored onboard the vessels, (where the percentage increase in total price and number of pallets delivered is equal to one another) while Table 5.3b indicates that the effectiveness continues to improve the more pallets that are pre-stored in the system. From an efficiency point of view the above analyses indicate that the number of pallets to be pre-stored on each of the vessels should be set to 300 (with an average price per pallet of $161), while the effectiveness continues to improve when exceeding this level. The ever-present question is the value of a higher level of responsiveness, and to what extent the humanitarian organizations can afford the additional cost of responding faster and with a higher service level to any disaster.

The next section will present a coherent comparison of the 10 scenarios within the two different configurations. The comparison was done in order to analyze the effects of the terminals and whether new combinations of pallets stored on vessels and terminals should be tested in the simulation model.

5.3. A comparison of the scenarios within the two configurations

Having said that the maximum number of pallets to be stored on each of WWL's facilities should be limited to 300, this subsection investigates to what extent the terminals should be included or not. By running two different groups of scenarios, where one group includes both the vessels and the terminals, while the other relies solely on the vessels, it is possible to reveal the effects of adding the six different terminals to the proposed system. These effects are depicted in Table 5.8 below.

Table 5.8 Comparison of the ten different scenarios

Comparing sceanrios in configuration 1 and 2	Comparing average price per pallet in configuration 1 and 2	Increase in the number of pallets delivered when adding the six terminals	Increase in total price when adding the six terminals	Average price per pallet of the additional pallets delivered from the six terminals	% increase in number of pallets delivered	% increase in total price	Reduction in lead time in weeks
1.1 vs 2.1	$ 172 vs $ 171	718	$134 684	$188	6 %	7 %	0,2
1.2 vs 2.2	$ 165 vs $ 164	1 200	$210 021	$175	6 %	6 %	0,2
1.3 vs 2.3	$ 164 vs $ 161	1 575	$320 432	$203	6 %	7 %	0,3
1.4 vs 2.4	$ 164 vs $ 161	2 100	$456 925	$218	6 %	8 %	0,3
1.5 vs 2.5	$ 169 vs $ 164	1 875	$520 437	$278	5 %	8 %	0,3

Column two in Table 5.8 reveals that the average price per pallet in the second configuration is below the corresponding price in the first configuration and the differences ranges from $1 to $5. When comparing scenario 1.1 versus 2.1 and 1.2 versus 2.2 the price difference is only $1 per pallet delivered, while scenario 1.3 versus 2.3 and 1.4 versus 2.4 have a price difference equal to $3. The last two scenarios, 1.5 versus 2.5, have a price difference of $5 and this indicates that the increase in average price per pallet is exponential when increasing the number of pallets stored at each terminal beyond 300. This conclusion is also supported by the prices depicted in column four, which calculates the average price of those pallets that are added to the system when the terminals are utilized. The average price of the additional pallets delivered by the terminal in scenario 1.1 is $188, while the equivalent number in scenario 1.2 is $175. When adding additional 75 pallets to the system through the terminals in scenario 1.3, the average price per pallet has increased to $203 and when looking at the corresponding numbers for scenario 1.5 the average price per pallet delivered by the terminals is $278. When comparing this trend with the changes in the price structure from the five scenarios in the first configuration (see Figure 5.2a) and the second configuration (see Figure 5.3a) it is reasonable to assume that the increase in the total average price per pallet to a large extent is due to the tremendous increase in average price for the additional pallets delivered by the terminals. This indicates, from an efficiency point of view, that the maximum number of pallets pre-stored at each of the six terminals should be 150 (where the average price of the pallets delivered by the terminals has its minimum).

The last column in Table 5.8 provides an overview of the reduction in lead time when adding the six terminals to the system where the effectiveness is improved from 0.2 to 0.3 weeks in all of the five scenarios. If the conclusion above should be upheld, the average lead time will be reduced by 0.2 weeks when 75 or 150 pallets are pre-stored in each of the six terminals. A lead time of 0.2 weeks is equivalent to 1.4 days while 0.3 weeks is equivalent to 2.1 days. Put differently, adding 225 pallets to each of the six terminals instead of 150, enables the system, on average, to reduce the lead time with 12 hours. The question is how much the humanitarian organizations are "willing" to pay for those 12 hours and again, this highlights the importance of the determining the optimal level of product availability (efficiency versus effectiveness). Based on the discussions above the following preliminary conclusion could be drawn;

1. *When increasing the number of pallets in the response system, both efficiency and effectiveness is improved. However, the trade-off between the two performance measures need to be considered, and since the marginal effect of adding more pallets to the system is negative after a certain point, it seems reasonable to limited the number of pallets pre-stored onboard each of the five vessels to 300. Hence, scenario 1.4 and 2.4 represent those combinations of capacity and configuration that should be selected in order to gain the most out of the resources employed.*
2. *The efficiency of the system is slightly reduced when including the six terminals (the average price per pallet is higher in each of the scenarios in the first configuration compared to the scenarios in the second configuration), while effectiveness is improved both in terms of an average 6% increase in number of pallets delivered to the 16 disasters and an average reduction in lead time of 0.26 weeks (see column 6 and 8 in Table 5.8). The same marginal effect as described above also applies when the number of pallets stored at each terminal is increased. Since the marginal effect on the efficiency from storing more than 150 pallets in the terminals is negative, the number of pallets pre-stored in each terminal, if they are to be included at all, should either be 75 or 150.*

These two preliminary conclusions set the scope for a further analysis, where six new scenarios were tested in the simulation model in order to reveal whether new combinations of capacity on vessels and terminals can further improve the performance of the proposed response system.

5.3.1. Scenario 3.1 to 3.6

Table 5.9 provides a summary of the six new scenarios that were created based on the preliminary conclusions above. The number of pallets pre-stored onboard the vessels in these scenarios ranges from 75 to 300, while the number of pallets stored at each of the six terminals is set to either 75 (scenario 3.1 to 3.3) or 150 (scenario 3.4 to 3.6). Pre-storing zero pallets at the terminals is already tested in the second configuration and hence not included in the new scenarios.

Table 5.9 Summary outputs 3.1 to 3.6

Scenario number	Number of pallets pre stored onboard each vessel	Number of pallets delivered to DC Singapore in the response phase	Number of pallets pre stored on each terminal	Number of pallets avilable for each disaster	Total number of pallets delivered to 16 disasters	Percentage of disaters where the response covers 100 % of demand	Average percentage of demand fulfilled	Average lead time in weeks	Total price in $	Average price per pallet	Increase in total price compared to the previous scenario	Increase in the number of pallets delivered compared to previous sceanrio
3.1	150	1 500	75	2 700	20 956	50 %	66 %	7,8	$3 448 107	$165		
3.2	225	2 250	75	3 825	28 395	56 %	72 %	7,3	$4 607 202	$162	34 %	35 %
3.3	300	3 000	75	4 950	35 145	56 %	78 %	6,9	$5 701 320	$162	24 %	24 %
3.4	75	750	150	2 025	13 011	44 %	57 %	8,3	$2 233 834	$172		
3.5	225	2 250	150	4 275	28 920	56 %	73 %	7,3	$4 710 609	$163	111 %	122 %
3.6	300	3 000	150	5 400	35 670	56 %	78 %	6,9	$5 810 939	$163	23 %	23 %
Base					89 677	100 %	100 %	12,0	$18 977 092	$212		

Scenario 3.2 and 3.3 provide the most efficient response systems with an average price per pallet equal to $162. Further, scenario 3.3 performs best with regards to effectiveness and delivers 6,750 pallets more than scenario 3.2, covers on average 78% of all demand and delivers the needed relief items faster than scenario 3.1, 3.2, 3.4 and 3.5. Scenario 3.6 provides the same degree of effectiveness, however the total price for this response system is $110,000 higher than in the response system represented by scenario 3.3. As a result, the system represented by scenario 3.3 stands out among these six new scenarios, and provides the best combination of efficiency and effectiveness.

Based on the discussion above, two alternative scenarios provide the highest level of effectiveness while utilizing the available resources in the most efficient way. The first scenario, 2.4, does not utilize the six terminals and 300 pallets are pre-stored on each of the five vessels, while scenario 3.3 increases, the total number of pallets in the system by placing 75 pallets on each of the six terminals.

Table 5.10 provides a comparison of these two scenarios and depicts the differences in the two performance measures.

Table 5.10 Comparison of scenario 2.4 and 3.3

Scenario number	Number of pallets pre stored onboard each vessel	Number of pallets delivered to DC Singapore in the response phase	Number of pallets pre stored on each terminal	Number of pallets avilable for each disaster	Total number of pallets delivered to 16 disasters	Percentage of disaters where the response covers 100 % of demand	Average percentage of demand fulfilled	Average lead time in weeks	Total price in $	Average price per pallet	Increase in total price compared to the previous scenario	Increase in the number of pallets delivered compared to previous sceanrio
2.4	300	3 000	0	4 500	34 620	56 %	77,6 %	7,1	$5 575 560	$161		
3.3	300	3 000	75	4 950	35 145	56 %	78,0 %	6,9	$5 701 320	$162	2,3 %	1,5 %
Base					89 677	100 %	100 %	12,0	$18 977 092	$212		

When adding 75 pallets to each of the six terminals it is possible to increase the number of pallets delivered to the 16 disasters with 1.5%, from 34,620 to 35,145. The average lead time is slightly reduced from 7.1 to 6.9 weeks, making the system in scenario 3.3 able to respond on average 34 hours faster than scenario 2.4. However, the increase in total price is higher (2.3%) than the increase in number of pallets delivered, which causes the average price per pallet to rise from $161 to $162. Even though the system response slightly faster when 75 pallets are placed on each of the six terminals the total cost for the humanitarian organization rises with $125,760 and the question is whether alternative use of this money might yield a higher return when it is spent differently. Further, when including additional resources in the supply chain, more coordination is required among the actors and the price presented above does not take into account the cost related to this coordination.

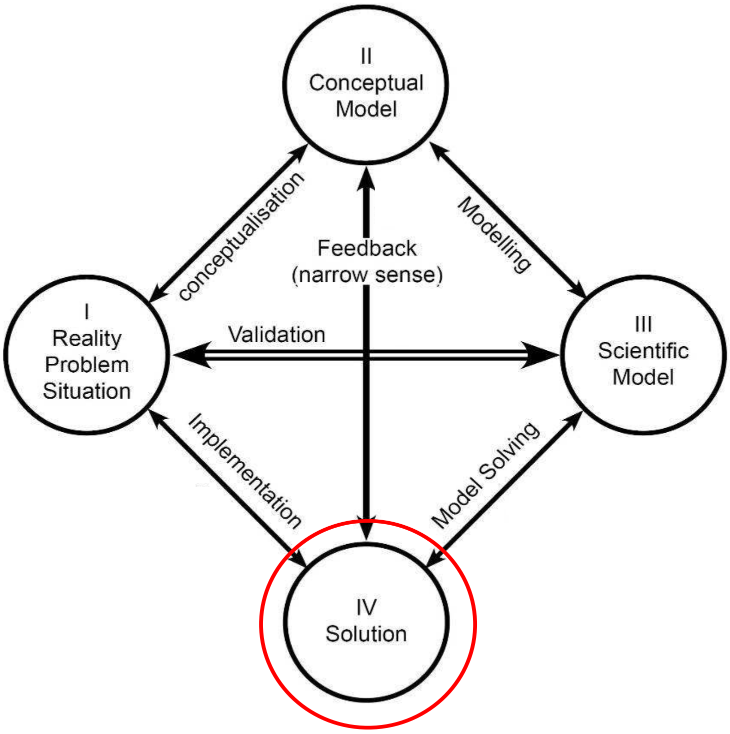
This implies that the actual cost when including the terminals might be substantially larger than estimated by the simulation model and thus it is reasonable to assume that the use of the terminals would require more pallets to be pre-stored in order to be economically efficient. Scenario 2.4 is considered to represent the best trade-off between efficiency and effectiveness and will be used in the next chapter in order to further analyze the proposed response system based on WWL's network of logistical resources.

6. Discussion and interpretation of the results

Based on the examination of the outputs generated by the simulation model in the previous chapter, it is reasonable to believe that the proposed response system can deliver relief items to areas affected by disasters more effective and efficiently than the current system is able to do. However, it is necessary to conduct further analysis in order to understand under which circumstances the proposed response system proves to be beneficial and which advantageous the humanitarian organizations can gain from cooperation with WWL. The objective of this chapter is to provide a comprehensive analysis of the results obtained from the simulation model regarding the performance of the proposed response system.

The chapter provides a discussion with regards to the average percentage of demand fulfilled (customer service level), under which circumstances the efficiency of the proposed system is higher than the current system and to what extent the geographical locations of the disasters affects the performance of the system. The chapter is finalized with some considerations regarding how the proposed response system can mitigate the challenges related to a project based humanitarian supply chain.

Figure 6.1 The research process



Source: Mitroff et al. (1974)

6.1. The performance of the proposed response system

The scenarios presented in the previous chapter provided different levels of efficiency and effectiveness, and a common trend was that the more pallets that are pre-stored in the system the higher is the responsiveness (effectiveness) and the lower is the efficiency (after a certain point). This trend was indicated by Figure 5.2a, 5.2b, 5.3a and 5.3b, which illustrated how the average price per pallet and the lead time in weeks changes when the number of pallets pre-stored in the system increases. Scenario 2.4 (the capacity and configuration that best utilizes the resources employed) has 300 pallets pre-stored on each vessel which enables the system to fulfill on average 78% of the required demand. This average amount of demand satisfied by the number of pallets pre-stored corresponds to the level of product availability (customer service level) and is one of two measures of supply chain effectiveness (responsiveness) used in this study (the other is the lead time in weeks). A high level of product availability requires large inventories (or a short lead time) which again raise the cost of operating the system and hence, any supply chain must achieve a sensible balance between the level of availability and the cost of inventory. It is two key factors that govern the optimal level of product availability; (1) cost of overstocking a product and (2) cost of understocking the same product. In commercial terms the cost of overstocking is equivalent to the economic loss incurred by a firm for each unsold unit while the cost of understocking corresponds to the margin lost for each lost sale due to the lack of inventory (Chopra and Meindl, 2010). The costs related to over- and understocking relief items in the humanitarian sector is not measured in lost profit but rather in human suffering and lost lives. This underlines the reality faced by the humanitarian organizations and the challenge they are facing when considering their level of product availability.

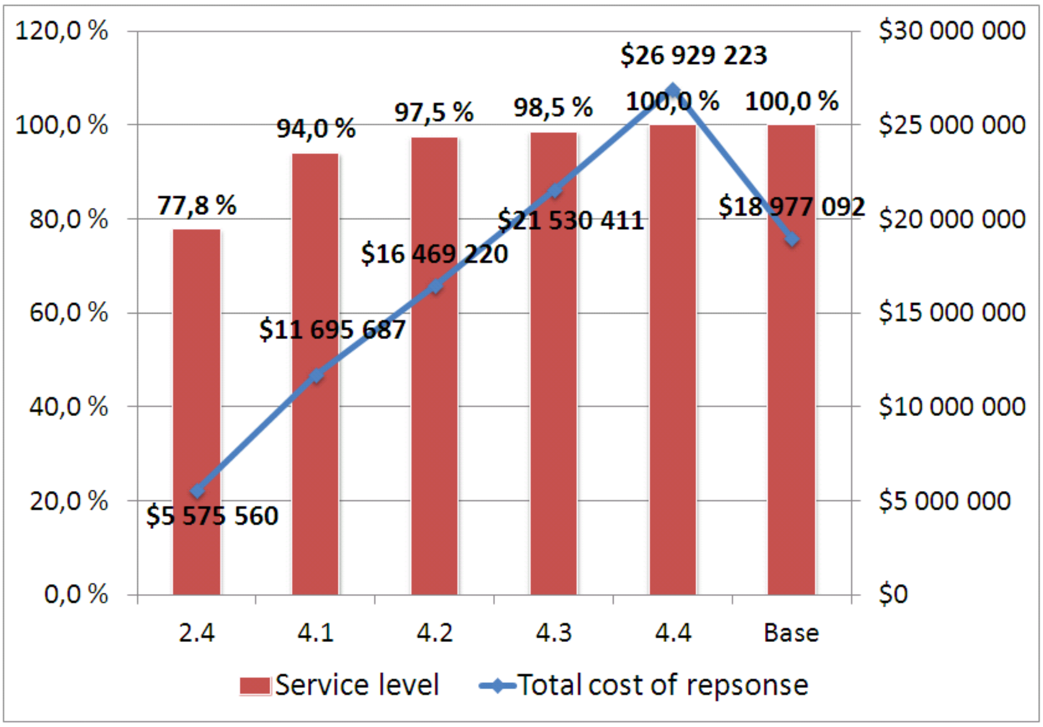
The previous chapter concluded that 300 pallets pre-stored onboard each of the five vessels is the capacity which best utilizes the available resources (scenario 2.4). This corresponds to an average product availability of 78% and a price per pallet of $161. As the potential cost of understocking is substantial, any humanitarian organizations strive to achieve the highest possible level of product availability and Table 6.1 on the next page shows how the efficiency of the response changes when the service level is moving from the initial 78% to 100%.

Table 6.1 Increase in service level

Scenario number	Number of pallets pre stored onboard each vessel	Number of pallets delivered to DC Singapore during the response phase	Number of pallets pre stored on each terminal	Number of pallets avilable for each disaster	Total number of pallets delivered to 16 disasters	Average percentage of demand fulfilled	Average lead time in weeks	Total price in $	Average price per pallet	Increase in total price compared to scenario 2.4	Increase in the number of pallets delivered compared to scenario 2.4
2.4	300	3 000	0	4 500	34 620	77,8 %	7,1	$5 575 560	$161		
4.1	750	7 500	0	11 250	63 550	94,0 %	5,6	$11 695 687	$184	110 %	84 %
4.2	1 500	15 000	0	22 500	73 850	97,5 %	3,8	$16 469 220	$223	195 %	113 %
4.3	2 250	22 500	0	33 750	82 100	98,5 %	3,1	$21 530 411	$262	286 %	137 %
4.4	3 000	30 000	0	45 000	89 677	100,0 %	2,8	$26 929 223	$300	383 %	159 %
Base					89 677	100,0 %	12,0	$18 977 092	$212		

As illustrated in Table 6.1, it is possible to enhance the service level with 16% (from 78% to 94%) when increasing the number of pallets pre-stored on each vessel from 300 to 750 (scenario 4.1). However, since the increase in total price compared to scenario 2.4 is larger than the increase in number of pallets delivered, the average price per pallet goes up from $161 to $184. Further, the table reveals that the marginal effect of adding more pallets to the system is steeply declining after this point and in order to improve the service level from 94% to 100% it is necessary to increase the number of pallets pre-stored onboard each vessel to 3,000. This again implies a 383% increase in the total price of the proposed system (from $5,575,560 to $26,929,223) compared to scenario 2.4. The increase in price is much higher than the increase in number of pallets delivered which causes the average price per pallet to change from $161 to $300. As indicated in the previous chapter, the relationship between the level of product availability and cost is exponential which implies that, as illustrated by table 6.1, it is incredibly expensive to aim for a 100% service level. The following example illustrates the effect; it would cost the humanitarian organizations $5,575,560 to increase their service level from 0% to 78%. Within this interval each additional 1% increase in service level has a cost of $71,482 (on average). A further increase in service level from 78% to 94% would cost $6,120,127 where each additional 1% increase in service level would cost $382,508. Finally, if a 100% service level where to be obtained each additional 1% increase in service level (from 94% to 100%) would cost the humanitarian organizations $2,583,923 or a total cost of $15,233,536. On the next page, Figure 6.2 illustrates this relationship and depicts how the total price changes exponentially when approaching a 100% service level.

Figure 6.2 Service level versus total cost of the response



As the figure illustrates, the total cost of the proposed response system is higher than the current system when both systems are delivering the same number of pallets (both in terms of average price per pallet and total cost of the response). Further, the price per pallet equals out (both are $212) when 1,300 pallets are pre-stored onboard each vessel and the proposed system delivers a total of 71,375 pallets.

This indicates that the proposed response system is not advantageous when the required demand exceeds a certain level and the system should not aim for a 100% service level when considering all disasters included in this study. This finding supports the preliminary conclusions from the previous chapter where the number of pallets pre-stored was limited to 300 in order to support as many people as possible with the least amount of resources.

The outputs from the scenarios presented in the previous chapter demonstrated that the price per pallet in all of the tested scenarios were 23% to 29% lower than the current system when pre-storing between 75 and 375 pallets at each of WWL's facilities. It is important to note that the total number of pallets delivered by the current system was higher than what was delivered by the proposed system in each of the scenarios, and the analysis presented above revealed that the proposed system operates with a higher cost when the two systems responds with the same number of pallets. In order to be able to conclude whether the proposed system operates with a higher degree of efficiency when the required demand is lower than what is represented by the 16 disasters a sensitivity analysis was conducted, were the number of pallets demanded was reduced by taking out an outlier from the sample.

The number of pallets delivered to each of the 16 disasters ranges from 7 to 32,327. In the majority of the disasters the humanitarian organizations delivered from 7 to 12,570 pallets while one disaster required 32,327 pallets. This disaster affects to a large extent both the total number of pallets demanded and the average price per pallet delivered, and Table 6.2 provides the outputs from the simulation model when this disaster is extracted from the sample.

Table 6.2 Reduction in the demand

Scenario number	Number of pallets pre stored onboard each vessel	Number of pallets delivered to DC Singapore during the response phase	Number of pallets pre stored on each terminal	Number of pallets stored in freight forwarding terminal Singapore	Number of pallets avilable for each disaster	Total number of pallets delivered to 16 disasters	Average percentage of demand fulfilled	Average lead time in weeks	Total price in $	Average price per pallet
2.4	300	3 000	0	0	4 500	31 320	82 %	6,8	$5 147 750	$164
5.1	900	9 000	0	0	13 500	57 350	100 %	4,6	$11 989 482	$209
Base						57 350	100 %	12,0	$18 316 953	$319

When taking out this major disaster the required number of pallets is reduced to 57,330 and hence scenario 2.4 is able to increase the service level from the initial 78% to 82%. The number of disasters where the proposed system entirely fulfills the demand has increased to 60% (9 of 15) and the percentage fulfilled ranges from 36 to 92 in those disasters where the system delivers less than 100%. Due to a small reduction in the total number of pallets delivered, the average price per pallet has increased to $164.

Table 6.2 does also show that the average price per pallet delivered by the current system (base) has increased with more than 50% to $319 when the total demand is reduced. Even though it looks like the proposed system operates with a higher degree of efficiency than the current system (when comparing $164 to $319) it is important to note that the proposed system in scenario 2.4 delivers only 31,320 pallets at a price per pallet of $164 while the current system delivers 57,350 to an average price per pallet of $319. For these measures to be compared on equal terms it is necessary to increase the service level of the proposed system to 100%. As depicted in Table 6.2, a 100% service level would require 900 pallets to be pre-stored onboard each of the vessels (scenario 5.1) which causes the average price per pallet to change from $164 to $209. Even though the average price per pallet increases when the proposed system delivers 100% of the required demand, it is still 52% lower than the price per pallet delivered by the current system ($209 versus $319) which indicates that the proposed response system operates more efficiently.

Based on these findings, it can be concluded that the proposed response system operates more efficient than the current system when the number of pallets delivered to each disaster is below a certain level. This conclusion does also support the preliminary findings from the previous chapter where a maximum of 300 pallets (scenario 2.4) are pre-stored onboard each of the vessels in order to deliver a certain amount of relief items in the most efficient way.

Keeping in mind the discussion above, there is no reason to deviate from the preliminary conclusion in chapter five where scenario 2.4 was argued to provide the best trade-off between efficiency and effectiveness. As a result, this scenario serves as the starting point for the rest of the discussion in this chapter, and the analysis in the following subsections is based on the initial sample where the outlier is included (generating a total demand of 89,677 pallets).

6.2. Location of disasters

The maximum number of pallets delivered by the response system in scenario 2.4 ranges from 3,300 to 4,500 depending on whether or not both routes are serving the appropriate port and the distance from the port to the disaster area. On the next page, Table 6.3 provides the outputs from this scenario in the simulation model and it reveal that the scenario fulfills 100% of the demand in 9 of 16 disasters. With regards to those disasters that require more than the system is able to provide, the percentage fulfilled ranges from 10% to 92%. The demand required by the 16 disasters in this study varies from 7 to 32,327 pallets, which corresponds to an average of 5,604. The selected scenario has capacity to deliver 4,500 pallets to each disaster if both routes are serving the port and, if all of the capacity is required, the distance from the port to the disaster area is not more than 1,760 km^2.

This indicates that the proposed system is best suited to serve disasters that; (1) occur in certain areas (where both routes are operating), (2) where the distances from the ports to the disaster areas are limited and (3) where the requested demand of relief items is no more than 4,500 pallets.

Table 6.3 Outputs scenario 2.4

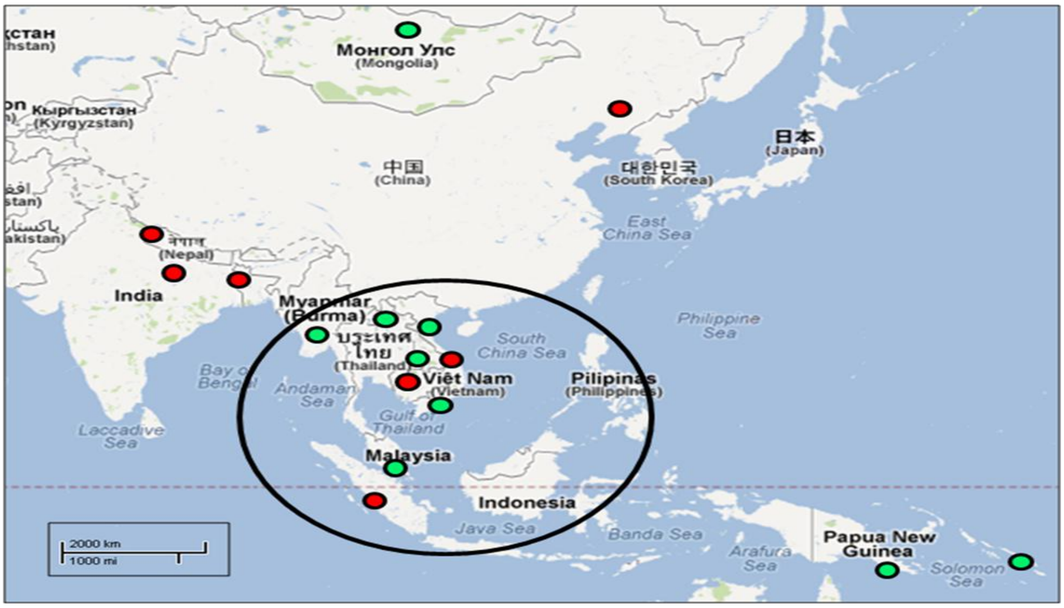
The selected scenario	
Selected configuration	
Regular routes	*Yes*
Regular routes and terminals	*No*
Freight forwarding	*No*
Selected capacity	
Number of pallets pre-stored onboard vessels	*1 500*
Number of pallets avilable from DC	*3 000*
Number of pallets pre-stored at terminals	*0*
The selected sceanrio enables WWL to distribute 100 % of demand to	
56 %	of the disasters
Average % of demand fullfilled	
77,6 %	

Scenario 2.4: summary for all disasters												
Disaster:		*Current response system:*				*Proposed response system:*				*Conclusion:*		
Disaster number:	Country:	Number of pallets delivered:	Lead time in weeks:	Cost of response:	Price per pallet:	Number of pallets delivered:	Lead time in weeks:	Cost of response:	Price per pallet:	How much of total demand does WWL fulfill?	Does WWL respond faster or as fast as previous	Does WWL deliver pallets to a lower cost?
2005-0475	China	3 926	12	$331 019	$84	3 600	12	$295 697	$82	92 %	Yes	Yes
2006-0241	Myanmar	40	12	$83 100	$2 078	40	1	$3 550	$89	100 %	Yes	Yes
2006-0648	Vietnam	114	12	$13 482	$118	114	1	$13 308	$117	100 %	Yes	Yes
2007-0021	Malaysia	700	12	$57 348	$82	700	2	$33 417	$48	100 %	Yes	Yes
2007-0274	Cambodia	156	12	$189 837	$1 217	156	1	$9 943	$64	100 %	Yes	Yes
2007-0311	Bangladesh	8 614	12	$4 973 076	$577	3 300	12	$771 336	$234	38 %	Yes	Yes
2007-0320	India	32 327	12	$660 139	$20	3 300	12	$715 236	$217	10 %	Yes	No
2007-0557	Papua N.G	1 093	12	$2 772 781	$2 537	1 093	4	$523 261	$479	100 %	Yes	Yes
2008-0329	Vietnam	626	12	$31 940	$51	626	3	$118 150	$189	100 %	Yes	No
2008-0452	Laos	3 014	12	$1 283 324	$426	3 014	9	$297 597	$99	100 %	Yes	Yes
2009-0414	Cambodia	12 570	12	$159 900	$13	4 500	12	$219 321	$49	36 %	Yes	No
2009-0421	Indonesia	10 763	12	$5 421 829	$504	4 500	12	$678 321	$151	42 %	Yes	Yes
2009-0434	Nepal	8 616	12	$139 584	$16	3 300	12	$787 836	$239	38 %	Yes	No
2009-0611	Vietnam	5 241	12	$736 708	$141	4 500	12	$601 821	$134	86 %	Yes	Yes
2009-0632	Mongolia	1 870	12	$2 122 745	$1 135	1 870	7	$502 540	$269	100 %	Yes	Yes
2010-0120	Solomon Is	7	12	$280	$40	7	2	$4 226	$604	100 %	Yes	No
		89 677	12	$18 977 092	$212	34 620	7,1	$5 575 560	$161			

The map depicted by Figure 6.3 on the next page shows the location of the 16 disasters included in this study. The proposed system was able to fulfill 100% of the demand to those disasters that are visualized by the green spots, while the red spots refers to disasters where the system responded with less than 100% of the required demand.

[2] The last (12^{th}) delivery arrives at a given port 1,932 hours after a disaster occurs. The time it takes to unload the vessel, conduct customs clearance and load/ unload the trucks takes on average 40 hours, which implies that the trucks (with an average speed of 40 km/ h) can drive for 44 hours before the immediate response phase is over (12 weeks = 2016 hours). Hence the maximum distance the trucks can drive is 40 km/ h * 44 hours = 1,760 km.

Figure 6.3 Map of disasters included in the study



In scenario 2.4, 67% of the disasters, where 100% of the demand was fulfilled by the proposed response system, are located within the area of South-Eastern Asia bounded by the black circle in Figure 6.3 and Table 6.4 below provides a summary of the outputs from these six disasters generated by the simulation model.

Table 6.4 Outputs from the six disasters

Disaster:		*Current response system:*				*Proposed response system:*				*Conclusion:*		
Disaster number:	Country:	Number of pallets delivered:	Lead time in weeks:	Cost of response:	Price per pallet:	Number of pallets delivered:	Lead time in weeks:	Cost of response:	Price per pallet:	How much of total demand does WWL fulfill?	Does WWL respond faster or as fast as previous response?	Does WWL deliver pallets to a lower cost?
2006-0241	Myanmar	40	12	$83 100	$2 078	40	1	$3 550	$89	100 %	Yes	Yes
2006-0648	Vietnam	114	12	$13 482	$118	114	1	$13 308	$117	100 %	Yes	Yes
2007-0021	Malaysia	700	12	$57 348	$82	700	2	$33 417	$48	100 %	Yes	Yes
2007-0274	Cambodia	156	12	$189 837	$1 217	156	1	$9 943	$64	100 %	Yes	Yes
2008-0329	Vietnam	626	12	31940	51,022	626	3	118150	188,7	1	Yes	No
2008-0452	Laos	3 014	12	$1 283 324	$426	3 014	9	$297 597	$99	100 %	Yes	Yes
		4 650	12	$1 659 031	$357	4 650	2,8	$475 964	$102			

The average number of pallets delivered to each of these disasters is 775 (4,650/ 6) which is substantially lower than the available capacity of the system and the average lead time from the disasters occur and until 100% of the demand is fulfilled is 2.8 weeks. Even though the previous section showed that it is very costly to aim for a 100% service level it is possible to avoid this cost by segmenting the customers. By narrowing the response to minor areas and those disasters where the required demand is limited, it is possible to deliver a high degree of responsiveness (both in terms of service level and lead time) to a relatively low price.

The average price per pallet for these six disasters is $102 which is way below both the average price per pallet for all of the 16 disasters combined ($161) and the average price per pallet in the current response system ($357 when considering these six disasters). This supports the conclusion in section 6.1 which claims that the proposed system operates more efficiently than the current system when the number of pallets demanded is limited (both systems provides a 100% service level).

It is important to note that the average price per pallet for these six disasters requires that the total number of pallets delivered during a year remains the same. Hence, if the number of pallets delivered during a given year was reduced (e.g. if it was decided to only deliver to those disasters that occurred in a minor area within the region of Asia) the price per pallet would increase if the same capacity was to be maintained (a higher percentage of the total storage cost would be assigned to each pallet delivered). Further, it is important to keep in mind that the average lead time in the current response system is set by default to 12 weeks and hence it is not correct to compare the lead time of the two systems (2.8 weeks versus 12 weeks). Based on the average amount of relief items delivered to each of these six disasters it is reasonable to believe that the lead time of the current system is less than 12 weeks when responding to these six disasters.

The disasters in Table 6.4 above have two common characteristics that should be emphasized. First, the areas affected by the disasters utilize ports that are served by both of the two routes (Intra Asia NE-SE and SE Asia Express). This implies that the total number of port calls is five per month (four vessels serves the Intra Asia NE-SE route and one vessel serves the SE Asia Express route) which in turn increases the frequency of deliveries, and combined with relative short distances of inland transportation enables the system to reduce the lead time significantly. Second, the required demand is sufficiently low, which implies that the capacity of each vessel enables the system to fulfill the demand with a limited number of port calls, which also contributes to a reduction in the lead time.

The improvements in efficiency and effectiveness when responding to these six disasters indicate that the proposed response system is best suited to serve disasters that occur close to the areas where WWL is operating and when the distance from the port to the disaster area is limited.

The remaining three disasters where WWL was able to fulfill 100% of demand are located outside the black circle in Figure 6.3 (Mongolia, Papa New Guinea and the Solomon Island). WWL is not currently serving the remote areas of Papa New Guinea and the Solomon Island and the two disasters required additional short shipments from Jakarta. The distance from China (Shanghai) to Mongolia is extensive and the lead time in these three disasters varies from 2 to 7 weeks. The system is able to respond with 100% of the needed relief items to these disasters due to limited required demand. However, the long distances from the areas where WWL has its regular operations disfavor disasters that are scattered throughout a wider region. This is also supported by the low efficiency of these three responses where the average price per pallet delivered was $347.

Based on the discussions above it is reasonable to conclude that the proposed system should focus its response within the area of South-Eastern Asia (when considering the 16 disasters included in this study).

Even though the system has a limited capacity, (a maximum of 4,500 pallets delivered to a single disaster) there is no reason that the system should not respond to disasters that require more than what WWL is able to deliver. The proposed system must be considered to be a supplement and not a replacement of the existing response system, where a high level of delivery flexibility enables the system to efficiently and effectively cover the immediate needs when a disaster strikes. By activating the “dormant” humanitarian response system within WWL’s permanent network when a disaster strikes, it is possible to deliver the first batch of relief items within the first week (assuming the response area is restricted by the black circle in Figure 6.3). The number of port calls per month within the area of South-Eastern Asia is five, and the first vessel will deliver 300 pallets of relief items (the capacity of the suggested scenario) after 84 hours (3.5 days). The time between the subsequent arrivals is on average 132 hours (5.5 days) and the vessels can continue to deliver batches of relief items up to 15 times within the first 12 weeks (see detailed calculations provided in Table 4.1). If the total assessed demand proves to be larger than what WWL's capacity is able to fulfill, further deliveries should be sent directly from the suppliers/ other sources to the disaster area in larger batches. This combination is illustrated by the conceptual model in Figure 6.4, where the proposed system delivers the requested demand from the first week, and if needed, it is supported by shipments directly from suppliers or other main storage facilities in the region.

Figure 6.4 The proposed system

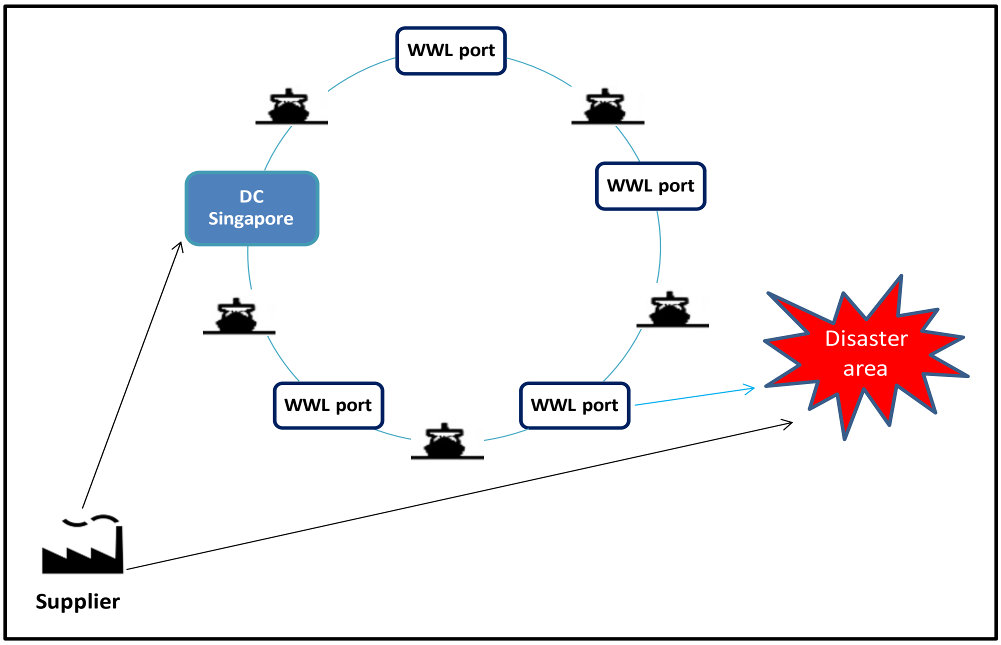


Table 6.5 below provides a summary of the outputs for the nine disasters (of the 16) that are located within the region of South-Eastern Asia.

Table 6.5 Disasters within South-Eastern Asia

Disaster:		*Current response system:*				*Proposed response system:*				*Conclusion:*		
Disaster number:	Country:	Number of pallets delivered:	Lead time in weeks:	Cost of response:	Price per pallet:	Number of pallets delivered:	Lead time in weeks:	Cost of response:	Price per pallet:	How much of total demand does WWL fulfill?	Does WWL respond faster or as fast as previous	Does WWL deliver pallets to a lower cost?
2006-0241	Myanmar	40	12	$83 100	$2 078	40	1	$3 550	$89	100 %	Yes	Yes
2006-0648	Vietnam	114	12	$13 482	$118	114	1	$13 308	$117	100 %	Yes	Yes
2007-0021	Malaysia	700	12	$57 348	$82	700	2	$33 417	$48	100 %	Yes	Yes
2007-0274	Cambodia	156	12	$189 837	$1 217	156	1	$9 943	$64	100 %	Yes	Yes
2008-0329	Vietnam	626	12	$31 940	$51	626	3	$118 150	$189	100 %	Yes	No
2008-0452	Laos	3 014	12	$1 283 324	$426	3 014	9	$297 597	$99	100 %	Yes	Yes
2009-0414	Cambodia	12 570	12	$159 900	$13	4 500	12	$219 321	$49	36 %	Yes	No
2009-0421	Indonesia	10 763	12	$5 421 829	$504	4 500	12	$678 321	$151	42 %	Yes	Yes
2009-0611	Vietnam	5 241	12	$736 708	$141	4 500	12	$601 821	$134	86 %	Yes	Yes
		33 224	12	$7 977 468	$240	18 150	5,9	$1 975 429	$109			

With regards to effectiveness, the lead time has increased (compared to the outputs in Table 6.4) from 2.8 to 5.9 weeks, and the reason for this increase is the continual response to those disasters that required more than the response system was able to deliver (lasted for 12 weeks). If the proposed system was used as it is intended, as a supplement to existing systems, it would not necessarily continue to deliver for 12 weeks but rather stop when larger batches of relief items are shipped directly in from suppliers/ other sources. As described above, the system can start to deliver 300 pallets to each of the disasters listed in table 6.5 after (on average) 3.5 days (in addition to inland transportation) and continue to deliver successive batches with an interval of 5.5 days. Further, the price per pallet delivered by the proposed system is $109, which is substantially lower than the corresponding price in the current response system ($240). When looking closer on these numbers, Table 6.5 reveals that the price per pallet in those disasters where WWL is able to respond with 100% of the requested demand, is lower compared to the current system in 5 out of 6 disasters. The equivalent numbers in the three disasters where WWL responded with less than 100% is 2 out of 3. This supports the previous preliminary findings which concluded that the proposed system operates with a higher degree of efficiency and can deliver the requested relief items to a lower cost than the current system.

The average price of $109 requires that the total number of pallets delivered during a given year is the same, which implies that a reduction in number of pallets delivered (due to a limitation in the geographical scope and/ or the time frame) must be compensated with a higher frequency of deliveries. The question then is whether the number of disasters within the region of South-Eastern Asia is sufficient to make the proposed system able to perform with a higher degree of effectiveness and efficiency than the current system. On the next page, Table 6.6 provides statistics showing the number of natural disasters that has occurred within this region over the last 32 years.

Table 6.6 Number of disasters in South-Eastern Asia (1980-2012)

Year: 2010-2011

Country	Number of disasters	Simple %
Cambodia	2	1.9 %
Indonesia	24	22.6 %
Laos	2	1.9 %
Malaysia	2	1.9 %
Myanmar	4	3.8 %
Philippines	51	48.1 %
Thailand	9	8.5 %
Viet Nam	12	11.3 %
Total	106	100 %
Average per year	53	

Year: 2000-2009

Country	Number of disasters	Simple %
Cambodia	16	3.1 %
Indonesia	152	29.5 %
Laos	9	1.7 %
Malaysia	34	6.6 %
Myanmar	14	2.7 %
Philippines	145	28.1 %
Singapore	2	0.4 %
Thailand	54	10.5 %
Timor-Leste	8	1.6 %
Viet Nam	82	15.9 %
Total	516	100 %
Average per year	52	

Year: 1990-1999

Country	Number of disasters	Simple %
Brunei Dar.	1	0.3 %
Cambodia	13	3.8 %
Indonesia	80	23.6 %
Laos	15	4.4 %
Malaysia	20	5.9 %
Myanmar	8	2.4 %
Philippines	116	34.2 %
Singapore	1	0.3 %
Thailand	37	10.9 %
Viet Nam	48	14.2 %
Total	339	100 %
Average per year	34	

Year: 1980-1989

Country	Number of disasters	Simple %
Cambodia	1	0.5 %
Indonesia	78	36.8 %
Laos	6	2.8 %
Malaysia	4	1.9 %
Myanmar	3	1.4 %
Philippines	87	41.0 %
Thailand	11	5.2 %
Viet Nam	22	10.4 %
Total	212	100 %
Average per year	21	

Source: EM-DAT (2012b)

The data above is obtained from EM-DAT (2012b) and shows the distribution of disasters in the region of South-Eastern Asia from 1980 to 2011, as well as the total and average number of disasters per year[3]. The total number of disasters per year has been steadily increasing over the last 30 years, with an average of 52 since the year 2000. The performance of the proposed system in scenario 2.4 supposes that WWL delivers approximately 35,000 pallets to 16 disasters during a given year.

The nine disasters within the area of South-Eastern Asia required 33,224 pallets (even though WWL was only able to deliver 18,150) which indicates that an average of 52 disasters per year should be sufficient to match the required number of pallets delivered in order to make the proposed system advantageous. In addition, if the trend observed in Table 6.6 continues, it is reasonable to believe that the numbers of disasters in this region will increase in the future and subsequently requiring more relief items to be delivered each year.

6.3. *Increased predictability through cooperation*

The analysis in the previous subsections indicates that a proposed response system that combines the use of WWL's network of logistical resources with parts of the existing response system (supported by suppliers/ producers of relief items) enables the humanitarian organizations to utilize their scarce resources in a more efficient way and to a larger extent fulfill (part of) the requested demand in a

[3] According to EM-DAT's requirements the disasters fit at least one of the following criteria; (1) 10 or more people killed, (2) 100 or more people affected, (3) declaration of a state of emergency or (4) call for international assistance.

shorter amount of time. Cooperation with a large commercial logistics service provider like WWL would also allow the humanitarian organizations to mitigate the challenges related to a humanitarian project based supply chain and benefit from other features and advantages such an actor possesses. The analysis of WWL in chapter two revealed that the characteristics of their logistical resources makes them suitable to serve the humanitarian sector and provide the organizations with logistical solutions that could further improve the efficiency and effectiveness of their disaster operations.

An extensive network of facilities and business units throughout the world, combined with advanced information systems, enables WWL to provide a single point of contact solution to their customers. This service implies that WWL is responsible for storage, sea transportation, custom clearance, technical services and inland transportation for their customers. Letting one actor be responsible for all these activities, allows for a better coordination of the different activities which again facilitates an effective flow of goods and information through the supply chain. The proposed response system presented in this thesis assumes that WWL takes over the responsibility for all of the logistical activities from the relief items are delivered to the DC in Singapore, (which is done by the suppliers/ producers) until the items are delivered to the disaster area. This solution would provide the humanitarian organizations with full transparency of their existing capacity (assuming that the items can be labeled allowing for WWL's system to track and trace the goods throughout the entire response system). This, combined with pre-signed agreement ahead of disasters, makes the humanitarian organizations able to overcome some of the major challenges related to a project based humanitarian supply chain. The proposed response system would add predictability to situations where uncertainty is omnipresent, by letting the humanitarian organizations in advance of and during response operations be aware of their cost, capacity and responsiveness (service level and lead time).

6.3.1. Mitigation of challenges in a project based response system

Setting up a project based humanitarian response system is recognized by a high degree of uncertainty related to time, cost and capacity. The capacity of the system is to a large extent governed by local market conditions and, as for any other markets, when the demand for transportation and warehouse facilities exceeds the supply the market price for these services increases (Jahre and Heigh 2008; Maon et al. 2009; Pettit and Beresford 2009; Balcik et al. 2010). Those humanitarian organizations that have not pre-signed agreements with logistical service providers or other actors that provide the required capacity will often experience a limited availability of key resources and prices that restrict their availability to provide much needed relief items. In addition, valuable time is lost due to the demanding process of mobilizing and setting up the system in the aftermath of a disaster, time that should have been spent on serving those people affected by the disaster. The proposed response system provides an innovative solution where a project based supply chain is integrated as a part of a permanent service provided by WWL, which combines the advantages gained from a permanent network, with the benefits obtained from a highly flexible project based supply chain. "(…) innovative supply chains are based on a combination of flexibility and integration to obtain low cost and high customer service and to be still adaptable to changes" (Fabbe-Costes and Jahre 2009, 2). The dormant part of the proposed response system becomes activated when a disaster strikes, enabling the humanitarian organizations to immediately start the response process. The proposed system is superior with regards to delivery flexibility and the combination of floating warehouses and an extended push-phase enables the system to gain advantages from speculation while keeping the uncertainty with regards to location of disasters at acceptable levels.

The system provides a high level of agility where the flexibility obtained allows the humanitarian organization to set up a project based response system anywhere within a bounded geographical area in the shortest amount of time. A flexible response system set up in advance of a disaster can save precious time where all of the mobilized resources can be directed towards those affected by the disaster.

The outputs from the simulation model provided in the previous subsections reveal a high fluctuation in the price per pallet delivered to the 16 disasters by the current response system, which ranges from $13 (disaster 2009-0414 Cambodia) to $2,537 (disaster 2007-0557 Papa New Guinea). These figures indicate that there is a low level of predictability related to future prices and it is difficult (without pre-signed agreements) to know the price for a logistical capacity in advance. As a result, to what extent a humanitarian organization can contribute to a certain response operation, is largely determined by external factors. The corresponding figures related to the proposed response system show a price per pallet that ranges from $48 to $604, and if only the geographical area of South-Eastern Asia is included, the fluctuations in price per pallet will be further reduced to range from $48 to $189.

Through collaboration with WWL it is possible to significantly reduce the uncertainty related to the future price for storing and transportation, which again makes it possible to predict the amount of relief items a humanitarian organization can expect to deliver to any disaster within the selected region. This again makes it easier for the humanitarian organization to better plan their activities and provide their donors with information that disclose their level of efficiency.

It is increasingly important for the humanitarian organizations to be aware of and communicate their level of efficiency in order to be prioritized among a growing number of actors. "Donors will increasingly monitor the performance of humanitarian logistics as an indicator on which to base future funding decisions" (Majewski et al. 2010, 15). Further, the cost of setting up a response system is lower when it is conducted ahead of disasters, and entering into a partnership with WWL at the forefront, mitigates the abnormal cost of setting up the system after disasters have occurred.

The proposed solution does also provide the humanitarian organizations with a holistic and coherent view of their assigned capacities. This entails both the amount of relief items that is stored at each of the different facilities (vessels and terminals) and what kind of items that is available for immediate delivery. Based on the obtained information, combined with knowledge related to their cost of storing the items, organizations will be aware of their potential contribution to any future humanitarian interventions before the disasters occur. Again, this allows for better planning and more efficient and effective response when a disaster strikes. The system would also provide the organizations with information related to the lead time, where it is possible to calculate the elapsed time from a disaster strikes and until the first delivery of relief items is expected to be in place. WWL will be able to calculate these numbers for any potential future destination within the selected area and hence letting the organization be aware of their response time before deciding to intervene. It is crucial for any humanitarian organization (or company) to be aware of their costs, their capacity to deliver and the time it takes to satisfy customers' needs. All this information can be obtained from the proposed system, allowing the humanitarian organization to continually monitor the current state of the system and their future performance. Equally important is the systems ability to make sure that the response operation is highly efficient and effective. The next section will therefore elaborate on how the system can improve the performance of humanitarian interventions through information sharing.

6.3.2. Increased responsiveness through information sharing

Both the commercial and the humanitarian sectors are aware of the importance of coordination of information and material flow throughout their supply chains in order to be able to deliver the requested goods in an efficient and effective way. However, due to various challenges (e.g. high degree of uncertainty and the lack of resources, technology and knowledge) is it difficult for the humanitarian organizations to coordinate their activities and it has "continued to be one of the fundamental weaknesses of humanitarian action" (Rey 2001, 103). Based on experience from the commercial sector, a lack of coordination has proved to "increase the inventory costs, lengthen delivery times, and compromise customer service (Balcik et al. 2010, 22). This highlights the importance of efficient coordination among the actors participating in the response system. Further, the ability to coordinate the physical flow in a supply chain depends heavily on to what extent information is shared among the partners (the availability of information) and how efficient the information flows within the supply chain (Van Wassenhove 2006). Information sharing is a key success factor for any humanitarian response system, where a lack of centralized information makes it difficult to match the supply with the needs of those affected by disasters.

The predictability described above would not be possible without an information system that provides those actors involved with data on the current state of the response system. IT assists in integrating activities and provides information to allow for a more efficient and effective disaster response. Long (1997, 27) argues that information systems are "the single most important factor in determining the success of an emergency logistics operation". WWL possesses the resources that enable a customized IT solution including Advanced Track and Trace (ATT) and Electronic Data Interchange (EDI) programs. The ATT solution would provide the humanitarian organization with a full visibility with regards to the amount, type and place of their stored relief items which allows for a coherent view of the flow of relief items in their supply chain. Further, it is argued that the use of IT to track and trace relief items "has the potential to significantly improve the effectiveness of aid delivery and minimize waste" (Pettit and Beresford 2009, 458). This system, combined with EDI software which transfers data electronically between the different layers and facilities in the system, would make it possible for the humanitarian organizations to be both better prepared when disasters strikes and improve their effectiveness during a response.

Any response operation is characterized by a high degree of uncertainty, both in terms of demand and supply. Even though it is challenging to predict the future demand, is it possible to substantially improve the supply through better planning and implementation/ use of new technology. The performance of the proposed response system would to a large degree depend on the utilization of the ready-made information systems (ATT and EDI) provided by WWL. The system supports the ongoing operation with real time information about the position of the requested relief items, the amount and type of items that is on its way towards the disaster area and the expected time of arrival. Further, the system would provide information on subsequent deliveries enabling the actors to plan their activities according to the arrival of new batches of relief items. This obtained information allows for better coordination of activities, which ensures an effective and smooth flow of goods through the response system providing those affected by the disaster with much needed relief items.

Due to the immediate needs of an affected population, the current response system is to a large extent dependent on airborne supplies in the immediate aftermath of a devastating disaster. This, combined with a lack of knowledge with respect to the most urgent needs, creates some main obstacles in the flow of relief items. When too many actors respond to a humanitarian intervention without carefully considering their contributions, it is challenging to maintain a well functioning response system. Airplanes get stuck in the pipeline, unable to land and unload their cargo and those that get access to the runway might not be the planes carrying the most needed relief items. Too many relief items provided at once, combined with so called “unsolicited donations”, create bottlenecks in the supply chain (Tomasini and Van Wassenhove 2009) and prevents the most needed items to be delivered, causing unnecessary suffering for the people affected by the disaster. As in any commercial supply chain, the success of the response system depends on to what extent customer needs are satisfied, measured as quality of the response. “The common elements present in any supply chain of getting the right goods, at the right time, to the right place and distributed to the right people are still applicable in the humanitarian context” (Van Wassenhove 2006, 480).

The challenges related to the quality of the response could be mitigated through the proposed system. Firstly, the system does not rely on airplanes and hence it is not dependent on the capacity of airfields in order to deliver the requested demand. Vessels are to a minor extent utilized in the immediate aftermath of a disaster and thus the number of vessels arriving in the appropriate port is limited. Each of the vessels have the capacity to carry significantly more relief items than an airplane, which implies that fewer vessels are needed to provide the same amount of relief items. In addition, the RoRo vessels are not dependent on cranes to unload the cargo and hence, they are well suited to support a disaster even though the infrastructure of the port is damaged. Secondly, due to the high level of flexibility in the system, it is possible to adapt the flow of relief items to the progressions made within the affected area. The amount and type of items delivered could be changed when demand is assessed by the organizations in charge of the intervention (e.g. the third delivery (vessel) can pick up additional/ other kinds of relief items at the DC in Singapore (based on updated information from the field) before proceeding towards the disaster area). This would mitigate the problem of unwanted relief items in the supply chain. Finally, the system facilitates a flow of goods that are better adapted to the capacity possessed by the actors in charge on the field. This implies that smaller batches of relief items can be shipped in, making sure that the receivers are able to handle the supplies in proper ways before new shipments arrives. By providing relief items “bit by bit” it is possible to enhance the control and the coordination of the operations and hence avoid bottlenecks in the supply chain. Such an increase in the quality of the response is to a large extent determined by the use of advanced information systems. “Information management is crucial in disaster management and the speed with which it is used can have a critical impact on the effectiveness of the response” (Pettit and Beresford 2009, 458).

6.3.3. Implications of the research

We believe that the study presented in this thesis can contribute to valuable insight from a theoretical, practical and methodological perspective. The previous discussion indicated that cooperation between commercial logistics service providers and the humanitarian organizations could have numerous positive effects. Due to the limited amount of funding available to the humanitarian sector a significant reduction in the organizations logistical costs related to storage, transportation and coordination would improve the efficiency of their scarce resources. This would enable the humanitarian organizations to release financial resources that can be utilized to improve their internal processes and capacities as well as reduce the turnover and attract more qualified personnel. These improvements will contribute to a sustainable long run development of humanitarian organizations, making them able to handle more complex humanitarian interventions in the future. Further, those humanitarian actors that seek to improve their overall operating performance will have an advantage in terms of funding over those that do not implement new technology and efficient solutions. As funding becomes more competitive among the organizations, “humanitarian logistics units will face increasing pressure to measure and justify their costs and seek lower costs but higher-quality alternatives” (Majewski et al. 2010, 15). Organizations that performance with a low degree of efficiency and effectiveness will find it hard to attract much needed funding while those organizations that continuously seek to improve their operations will most likely be prioritized among a wealth of humanitarian actors.

Over the recent decades there has been a growing awareness of the relationship between human activity and climate change, and it is claimed that “(…) climate change is intensifying the hazards that affect human livelihoods, settlements and infrastructure” as well as “(…) weakening the resilience of livelihood systems in the face of increasing uncertainty and frequent disasters (O’Brien et al. 2006, 68). Keeping our future in mind, aiming for reduced carbon emissions should be on any organizations agenda. With regards to humanitarian organizations, which aim to assist victims of disasters, it is contradictive to utilize modes of transportation with high levels of environmental emissions if an alternative mode with lower emissions could be used. Utilizing vessels, rather than transporting relief items by aircrafts, makes it possible for the humanitarian organizations to reduce their carbon emissions related to logistics activity. Implementing logistical solutions that aims to reduce the level of emissions will have positive effects on the humanitarian organization's reputation and thus increase their credibility and trustworthiness. Such enhance in reputation could also create advantages with respect to future funding.

For a given amount of funding, reducing the proportion spent on logistics operations will free up resources that can be allocated to the victims of disasters. Keeping in mind that only two-thirds of the required assistance is provided each year (Majewski et al. 2010), an improvement in the performance of logistics operations has the potential to significantly improve the service level (increasing the average percentage of demand fulfilled). Further, with regards to the commercial sector it has been an increasing interest to become involved in the humanitarian sector. This study could form the basis for a business case where WWL and humanitarian organizations together form collaboration that test in reality the conceptual models presented in this thesis. If the results prove to be beneficial, relationships with humanitarian organizations would contribute to strengthen WWL's reputation as a responsible company.

The majority of the studies conducted within the field of humanitarian logistics have been case-studies and conceptual reviews and less attention has been paid to empirical and analytical studies (Kovács and Spens 2011). This study contributes to the latter category where the objective has been to provide existing and potential actors within the humanitarian logistics sector with a simulation model that can evaluate the performance of alternative humanitarian response systems. The way logistical resources are utilized in the simulation model is somewhat different from what has been seen in the literature and hence, the study contributes with innovative ideas and thoughts with regards to future deployment of logistical resources in humanitarian operations.

From a methodological perspective this study has utilized an OR technique which is less common among researchers within the field of humanitarian logistics. Through what-if simulation it has been possible to test and examine the performance of a proposed response system before any investments are made and the system is implemented in reality. The study provides a comprehensive description of how simulation models can be utilized within the area of humanitarian logistics and how such a model can be developed and structured in MS Excel. Even though the simulation model presented in this thesis is specific to WWL and their network of logistical resources it is possible to adapt the model to any commercial actor by changing the input data.

6.4. Conclusion

The outputs generated by the simulation model indicate that an alternative humanitarian response system based on a network of floating warehouses and sea transportation has the ability to improve the performance of the current response system. The system combines the advantages gained from an extended permanent commercial supply chain with the flexibility achieved through a project based humanitarian response system. The system allows the humanitarian organization to set up a project based response system anywhere within a bounded geographical area in the shortest amount of time. This, combined with enhanced effort ahead of disasters, can save precious time where all of the mobilized resources can be directed towards those affected by the disasters.

The proposed system presented in this thesis should not be seen as an alternative to the existing systems but rather as a supplement. A response system that combines the use of WWL's network of logistical resources with parts of the existing response system (supported by suppliers/ producers of relief items) enables the humanitarian organizations to utilize their scarce resources in a more efficient way and to a larger extent fulfill (part of) the requested demand in a shorter amount of time.

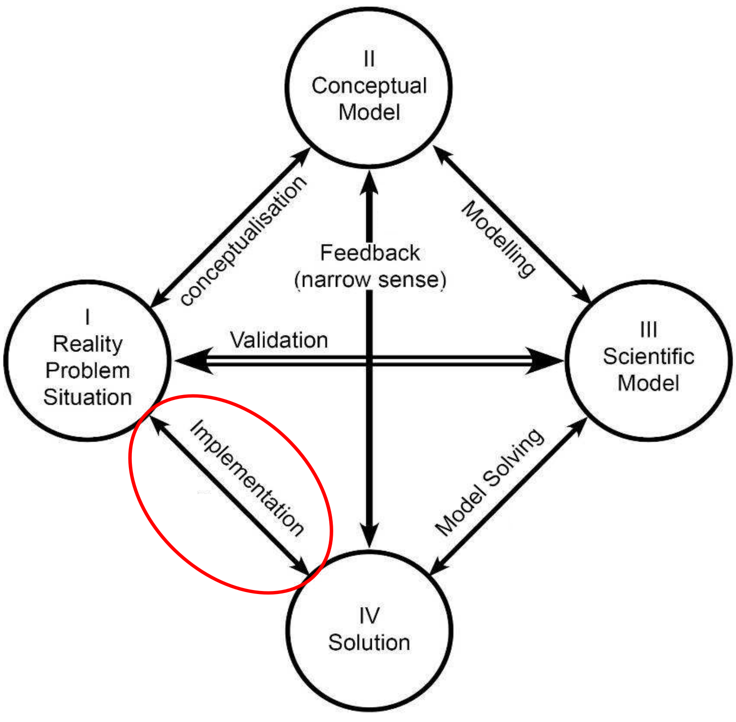
Implementation of the proposed response system is beyond the scoop of this research. However, the final chapter will present some considerations and recommendations that should be taken into account if the system is to be implemented in the future.

7. Recommendations for future implementation

It was concluded in chapter six that the proposed response system operates more efficiently than the current system when the response is focused to certain areas and when the demand is below certain levels. This segmentation of disasters does also make it possible to enhance the systems' service level without negatively affecting the efficiency, which implies a higher level of effectiveness (both in terms of average demand fulfilled and the time it takes to deliver the requested demand). The discussion in the previous chapter did also highlight additional advantages related to increased predictability that would be possible to achieve if a collaboration between WWL and humanitarian organizations were to be established in the future.

Implementation of the proposed response system as visualized by the red circle in the research process indicated by Figure 7.1 is beyond the scope of this study. The objective is to provide WWL and humanitarian organizations with an analytical tool that can support decisions with regards to future cooperation. This final chapter will provide those in charge of such a decision with some considerations and recommendations that should be taken into account if the proposed response system where to be implemented in reality.

Figure 7.1 The research process



Source: Mitroff et al. (1974)

7.1. Horizontal cooperation between humanitarian organizations

The analysis and the discussion presented in chapter six indicate that the best trade-off between effectiveness and efficiency is achieved by a combination of capacity and configuration as represented by scenario 2.4. In this scenario 300 pallets are pre-stored onboard each of the five vessels which corresponds to 14 20ft. containers (if the pallets can be stacked on top of each other). Keeping in mind the humanitarian organizations' scarce resources, it might be unrealistic for a single humanitarian organization to have such a high amount of capital tied up in inventory. In addition, it could be other factors that govern the prioritization of the resources, which implies that one humanitarian organization finds such an amount of pre-stored pallets inappropriate. As a result, horizontal cooperation between the humanitarian organizations should be considered in order to utilize WWL's standardized resources in an optimal way.

According to Schulz and Blecken (2010, 641) "cooperation has the general objective of realizing cost, time and quality improvements through economies of scale and scope as well as process improvements possible through the consolidation of the logistics tasks of different humanitarian organizations". In order to obtain these advantages, it is necessary for the humanitarian organizations to coordinate their logistical activities through horizontal cooperation in order to utilize WWL's network of resources in an optimal way. One of the main problems related to the current response system is according to Majewski et al. (2010, 16) "the lack of coordination and collaboration among various actors involved in humanitarian assistance" which "continues to limit the efficiency and effectiveness of humanitarian logistics." The proposed system, where WWL facilitates a common resource platform for consolidated response for different humanitarian organizations, would contribute to a mitigation of the problems stated above.

Even though the selected scenario (2.4) requires 300 pallets to be pre-stored onboard each vessel, it is important to note that all of the tested scenarios yield a higher level of performance compared to the current response system. This implies that it is not necessary to have 300 pallets pre-stored for the proposed system to be advantageous. However, when the number of pallets pre-stored in the system increases, more efficient and effective responses could be attained and hence, humanitarian organizations should aim to consolidate their response through WWL's network of logistical resources. Further, enhanced cooperation across organizations is also encouraged by the donors who are increasingly putting pressures on the humanitarian actors to consolidate their activities and come up with collaborative funding proposals in order to avoid duplication and coordination challenges (Majewski et al. 2010). In this way, the proposed system can serve as common platform for joint initiatives among several actors and through consolidation develop long term relationships with donors in order to enhance the predictability with regards to future funding.

The initial support to the 16 disasters included in this study was provided by 24 different humanitarian organizations. When the actors was ranked based on total amount of relief items delivered in terms of kg or m3 the five biggest actors contributed with almost 86% of the grand total while the rest of the actors (19 organizations) delivered on average 0.32% of the total demand. This implies that the law of the vital few is also applicable within the humanitarian sector, where 20% (5 of 24) actors contribute with more than 80% of the deliveries. These findings have several important implications;

1. The majority of the response is provided by a few important actors and for the proposed system to be able to utilize WWL's resources in a way that makes the system advantageous it is necessary to establish collaboration with one or more of these main actors. Without any of these organizations onboard it might be difficult to obtain sufficient volumes to make the proposed system able to enhance the performance of the humanitarian logistics operations.
2. The number of actors that needs to coordinate activities in order to consolidate the majority of the response is limited and they are all large professional organizations within the humanitarian sector (e.g. IFRC, WFP, UNICEF and World Vision Int.). With a limited number of actors involved makes it easier to coordinate the flow of relief items and information throughout the supply chain.
3. Even though the majority of the actors (80%) delivered only a fraction of the total volume it is equal important to include these organizations when considering cooperation with humanitarian organizations. The more response that is consolidated through one main actor the better is the

coordination and the higher is the possibility that duplication of activities is avoided. This would again enhance the quality of the response by making the humanitarian organizations able to provide those affected by disasters with the right type of items at the point and time where they are needed.

Consolidated action is highly necessary for several reasons and the proposed response system can facilitate a common platform for several organizations and substantially improve the performance of their joint operations.

7.2. Integration of information technology

In order for WWL to consolidate the storage, handling, transportation and management of the relief items for multiple humanitarian organizations, it is necessary to maintain a close relationship with all of the different organizations. This relationship can be obtained through an integration of information systems which would facilitate an efficient flow of information across firm boundaries (Balcik et al. 2010). As discussed in chapter six, information sharing is a prerequisite for efficient coordination of activities (both those conducted by WWL and the humanitarian organizations) leading to an effective flow of relief items within the response system. For the proposed response system to become effective, it is required that the humanitarian organizations provide WWL with data related to demand through EDI or Internet-based exchanges, bar-coding and scanning. Through integration of information systems is it possible for the humanitarian organizations to achieve all of the advantages that the proposed response system can provide.

7.3. Responsibility for logistical activities

Before the proposed response system can be implemented in reality, it is crucial to have clarified who is responsible for the different logistical activities that are to be carried out. There are no clear roles set out in the simulated response system, and it is outside the scope of this study to analyze and determine a proper organizational solution that best suites a collaboration between humanitarian organizations and WWL. However, an allocation of responsibilities should take into account the advantages that could be gained from the knowledge and technology possessed by WWL. WWL has access to state of the art IT, which enables them to efficiently coordinate and control their customers' entire outbound logistics, and these resources should be utilized in order to gain the most from a partnership as proposed in this thesis. Assuming that information systems can be integrated as described above, it is recommended that WWL is responsible for storing and transporting the relief items from the DC in Singapore to the affected area, while the humanitarian organization(s) will provide WWL with demand information regarding the location of the disaster as well as the type and amount of relief items that should be delivered.

The simulation model does not include the deliveries of relief items from the suppliers to the DC in Singapore and it is assumed that the suppliers are responsible for the replenishment of this storage facility. If a single point of contact solution is established in the proposed system, it would be advantageous to let WWL also include this first part of the response system, and hence be responsible for the replenishment of relief items to the DC. By letting one actor be responsible for the entire system, from the suppliers to the disaster area, it is possible to improve the coordination of logistical activities even further. If this solution was to be implemented, WWL would serve as a mediator by having a daily contact with both the suppliers and the humanitarian organizations in order to coordinate the entire flow of information and relief items. Even though one actor, WWL, should have the overall responsibility for the entire response system, it would be necessary to set up a team consisting of employees from the suppliers, WWL and the humanitarian organizations. Such a cross-company team should, combined with integration of information systems, facilitate the coordination of activities across firm boundaries and continually improve the performance of the operations.

7.4. The use of forecasting

The proposed response system assumes that it is possible to plan the humanitarian operations before the disasters occur. This implies that the number of pallets, as well as the type and amount of relief items, are determined in the preparedness phase of a humanitarian intervention in order to meet the immediate needs of those affected by a disaster. To be able to pre-store the right composition of relief items at the different facilities, it is necessary to utilize forecasting techniques. Even though many studies have put forward that unpredictability makes it difficult to estimate the future demand for relief items, (e.g. Beamon and Kotleba

2006; Oloruntoba and Gray 2006; Van Wassenhove 2006; Day et al. 2009; Balcik et al. 2010; Salmerón and Apte 2010) the research project Contribute has challenged this assumption by developing a baseline that can be used to forecast the future demand of relief items in different regions of the world (Everywhere et al. 2011). This unique tool should be utilized by WWL and the humanitarian organization(s) in order to determine what type and amount of relief items that should be pre-stored in the proposed response system.

Even though the analysis presented in the previous chapter indicates that the use of terminals only had a limited contribution to the overall performance of the system, it is important to note that this conclusion is based on the analysis of 16 disasters. It should be considered to conduct an analysis of the use of terminals where more data is included in order to determine the effects of the terminal when responding to a broader range of disasters. This analysis must be based on forecasts of future disaster patterns and the second version of the annual index developed by Contribute will enable the user to make such a forecast. Both the locations and the number of pallets pre-stored should be evaluated in order to see whether a smaller number of terminals but with a higher number of relief items stored at each location is appropriate. Such an allocation has the ability to generate economies of scale and combined with strategic positioning improve the flexibility, effectiveness and efficiency of the proposed system.

7.5. Limitations and further research

Due to the selected geographical scope of this study, only the disasters within Asia that the research project Contribute had collected detailed information about, were included in the simulation model. The analyses in the previous chapter concluded that it would be appropriate to further limit the geographical scope to the region of South-Eastern Asia (when considering the 16 disasters) and according to EM-DAT (2012b) the annual average number of disasters that has occured within this region is 52 (in the period of 2000-2012). The 16 disasters included in this study represent only a fraction of the reported annual number, and even though the analysis indicates that the proposed response system is able to improve the performance of the current system, we believe it is necessary to extend the analysis before any decision regarding implementation is taken. Hence, the simulation model should be run for more disasters in order to get a better understanding of the conditions that govern the performance of the proposed response system. Even though the study itself is not enough to decide whether or not to implement and test a real pilot project, the simulation model is designed in a way that enables the user to easily add new data in order to simulate the response to additional disasters. By adding the geographical location and the demand of relief items, it is possible to simulate a response to any disaster (real or fictive) within the region of Asia. The performance of the response can also be compared to any previous response if the efficiency and effectiveness of the previous response is known. As a result, the simulation model itself is of great value when further research is to be conducted.

Even though the geographical region was limited to Asia in this study, WWL possesses the same type of resources (e.g. vessels, terminals, ports and trucks) in other parts of the world where disasters often occur (e.g. the Americas). It should be considered to conduct the same type of analysis with these areas in focus in order to reveal whether any other regions are more suited when implementing a future pilot project. Further, WWL has sister companies (EUKOR and ARC) that can increase the total capacity and the number of port calls per month tremendously if they were to be included. A response system that utilizes these additional resources could potentially provide an even higher level of performance, where the total number of pre-stored pallets could be scattered out on more vessels, allowing for both a higher level of delivery flexibility and subsequent shorter response time. In order to investigate the full potential of WWL's network of logistical resources it should be considered to also include these companies in the simulation model.

The objective of this study was to develop and provide WWL and their humanitarian counterpart with a decision support tool that can be used to examine the possibility of improving the current humanitarian response systems. Both the simulation model and the analysis presented in this thesis should be taken into account and utilized when a future implementation of the system is discussed. However, we recommend that the final decision should be based on additional analysis/ findings from further studies or ongoing partnerships between humanitarian organizations and commercial actors. If further studies where to be undertaken we suggests that WWL establish a project in cooperation with one of the main humanitarian actors and conduct an in depth case study on a limited number of disasters where this organization responded. By conducting a case study in collaboration with a major humanitarian actor it would be possible to get access to accurate response data in terms of volume shipped, the average demand fulfilled and the time it took to deliver the relief items which again would facilitate a more precise examination of the two different response systems.

As a concluding remark it is important to keep in mind that;

- The objective of this study was not to decide whether or not the system should be implemented in reality but rather provide insight on the potential improvements that can be gained from a new and innovative humanitarian response system that is based on a network of floating warehouses and sea transportation.
- In order to gain the most from WWL's network of logistical resources it is probably necessary to consolidate response from different humanitarian organizations and the examination of the proposed system did not take into account the costs related to coordination of activities among several actors.

Millions of people are affected by natural disasters every year and we hope that the results from the study can encourage to further research on the ideas presented in this thesis and that both commercial and humanitarian actors are inspired to develop future collaborations in order to mitigate the despair and suffering these disasters causes all over the world.

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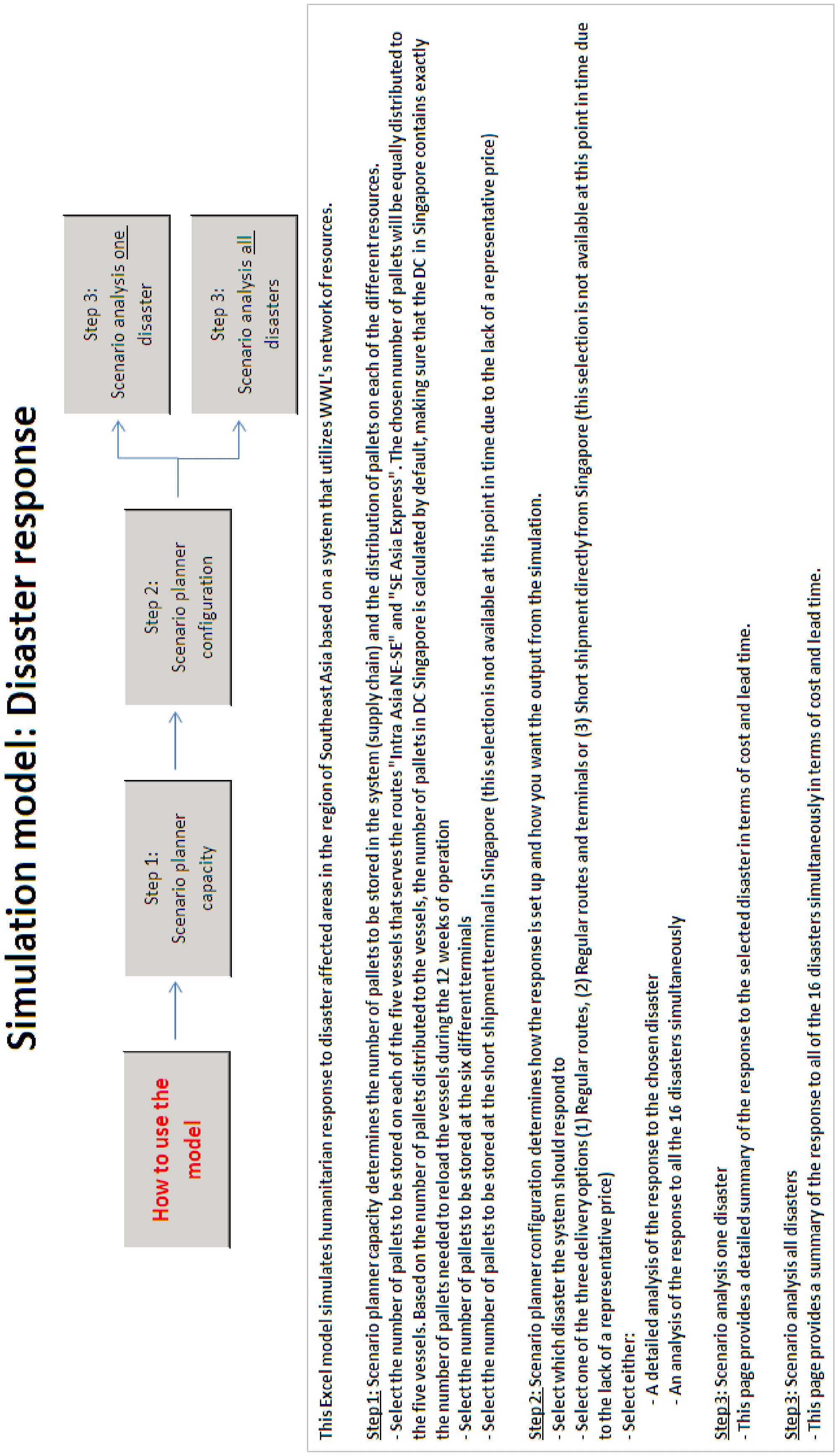
9. Appendices

Appendix 1.1 The front page of the simulation model


Simulation model: Disaster response

How to use the model → Step 1: Scenario planner capacity → Step 2: Scenario planner configuration → Step 3: Scenario analysis one disaster / Step 3: Scenario analysis all disasters

This Excel model simulates humanitarian response to disaster affected areas in the region of Southeast Asia based on a system that utilizes WWL's network of resources.

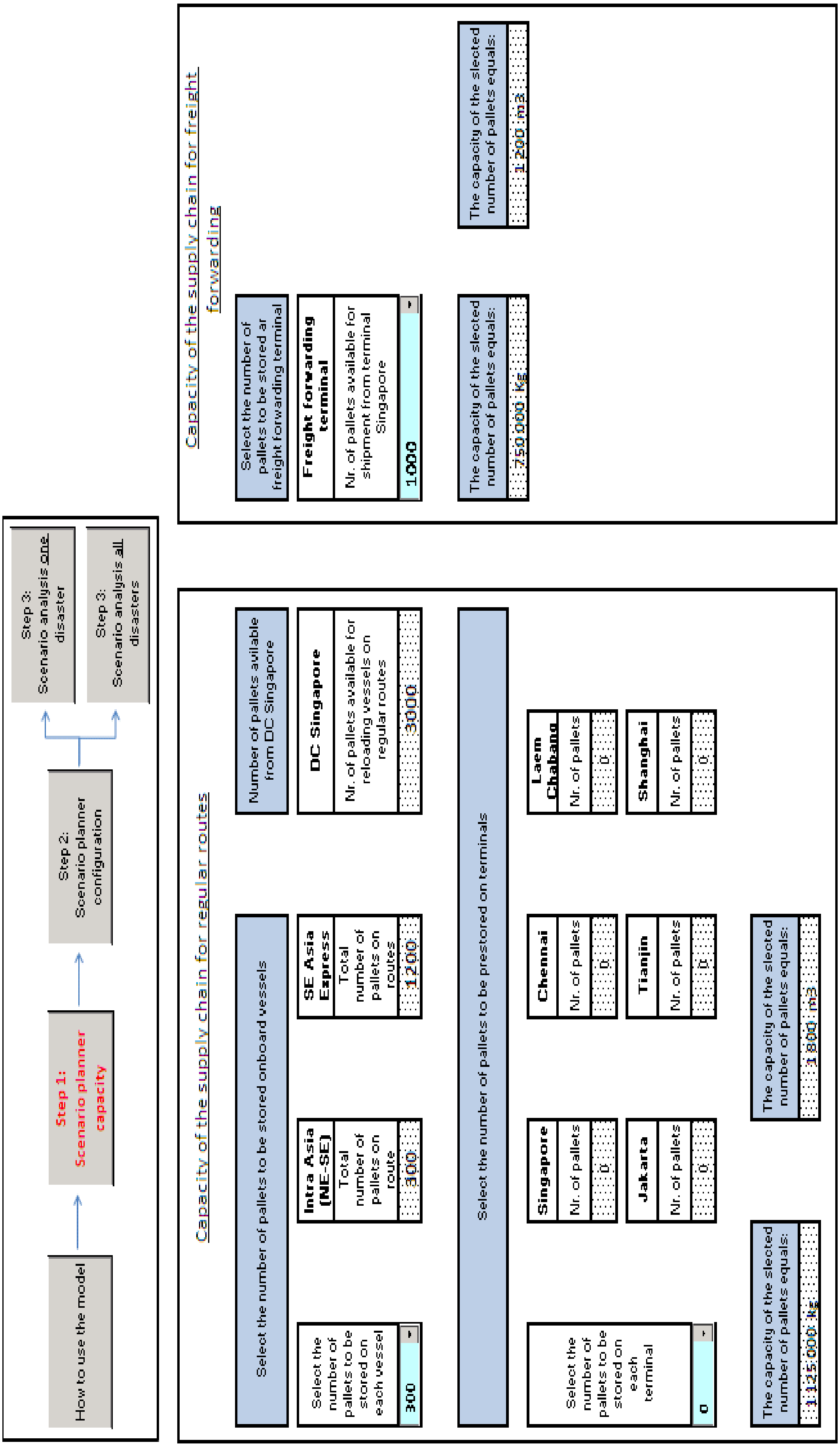
Step 1: Scenario planner capacity determines the number of pallets to be stored in the system (supply chain) and the distribution of pallets on each of the different resources.
- Select the number of pallets to be stored on each of the five vessels that serves the routes "Intra Asia NE-SE" and "SE Asia Express". The chosen number of pallets will be equally distributed to the five vessels. Based on the number of pallets distributed to the vessels, the number of pallets in DC Singapore is calculated by default, making sure that the DC in Singapore contains exactly the number of pallets needed to reload the vessels during the 12 weeks of operation
- Select the number of pallets to be stored at the six different terminals
- Select the number of pallets to be stored at the short shipment terminal in Singapore (this selection is not available at this point in time due to the lack of a representative price)

Step 2: Scenario planner configuration determines how the response is set up and how you want the output from the simulation.
- Select which disaster the system should respond to
- Select one of the three delivery options (1) Regular routes, (2) Regular routes and terminals or (3) Short shipment directly from Singapore (this selection is not available at this point in time due to the lack of a representative price)
- Select either:
  - A detailed analysis of the response to the chosen disaster
  - An analysis of the response to all the 16 disasters simultaneously

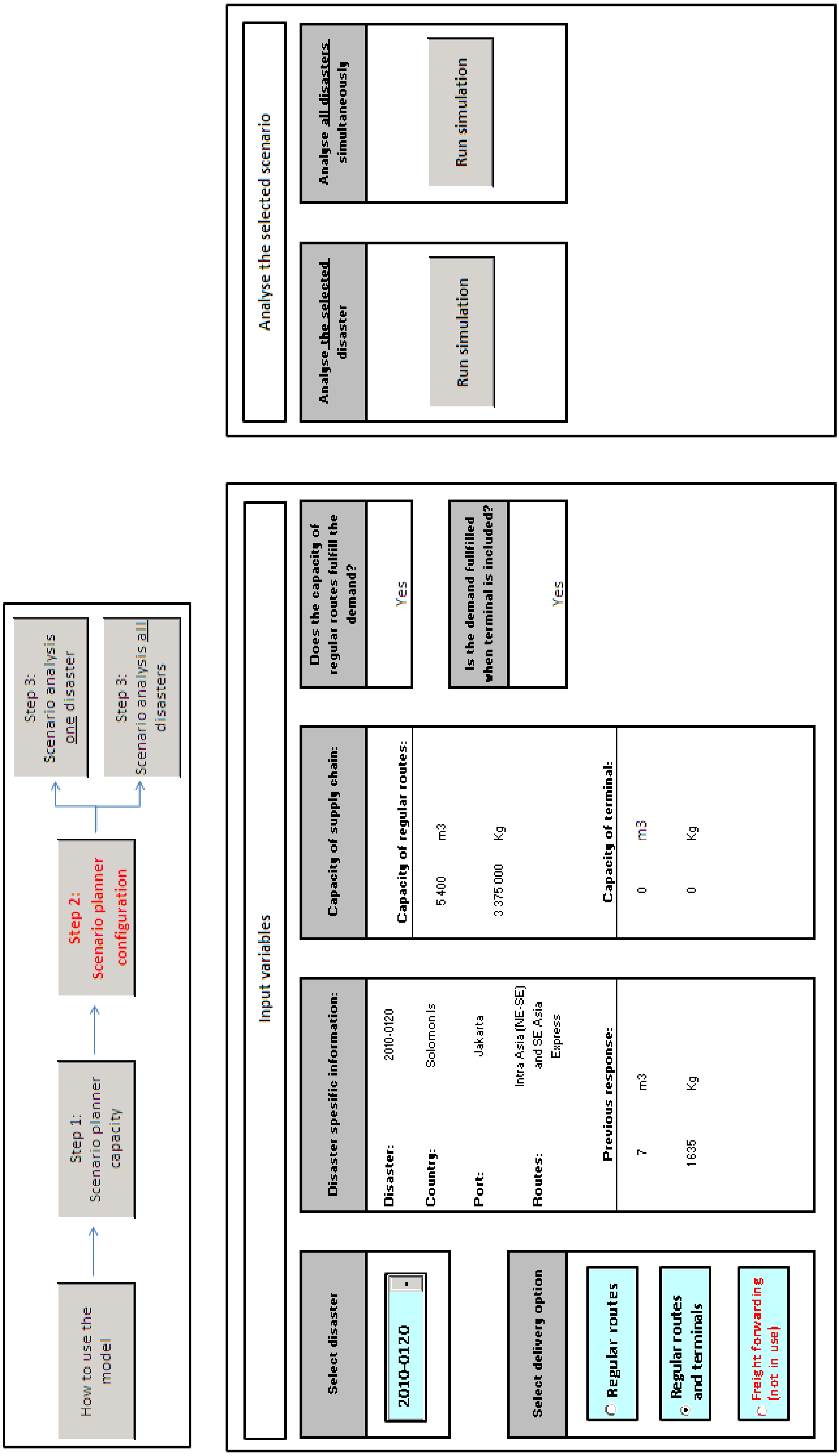
Step 3: Scenario analysis one disaster
- This page provides a detailed summary of the response to the selected disaster in terms of cost and lead time.

Step 3: Scenario analysis all disasters
- This page provides a summary of the response to all of the 16 disasters simultaneously in terms of cost and lead time.

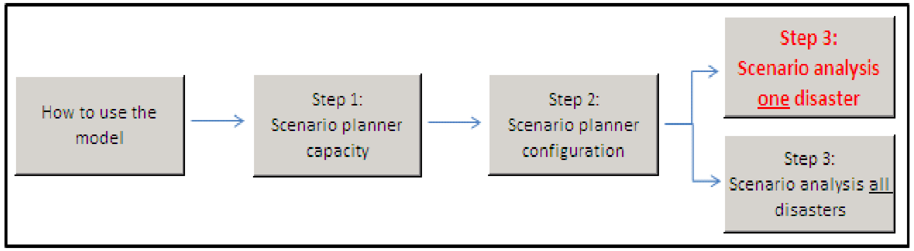
Appendix 1.2 Step 1: Scenario planner capacity



Appendix 1.3 Step 2: Scenario planner configuration



Appendix 1.4 Step 3: Example of scenario output one disaster (1 of 2)



The selected scenario

Delivery option	
Regular routes	Yes
Short shipment	No

Capacity of regular route	
Number of pallets stored onboard vessels	1 500
Number of pallets avilable from DC Singapore	3 000
Number of pallets prestored at terminals	0

Capacity of freight forwarding	
Number of pallet stored in Singapore	0

Scenario result: summary for disaster number 2010-0120

	Freight forwarding:	Regular routes:	Terminals:	Total:	Previous response:
Cost:					
Variable cost:	$0	$0	$4 130	$4 130	-
Fixed cost:				$100	-
Total cost:				$4 230	$280
Amount distributed:					
m3	0	0	8	8	8
kg	0	0	5 250	5 250	5 250
of total amount distributed / of total demand	0 %	0 %	100 %	100 % (of total demand)	
Lead time (Total lead time)	- Week(s)	- Week(s)	1 Week(s)	1 Week(s)	12 Week(s)

Step 3: Example of scenario output one disaster (2 of 2)

Scenario result: delivery details for disaster number 2009-0632

Disaster number:	Country:	Short shipment/ regular routes/ prestored pallets:	Capacity of terminal/ regular route:	Nr of pallets shipped from terminal to port/delivered by regular routes:	Variable cost regular routes (inland distribution):	Variable cost prestored pallets (inland distribution):	Variable cost freight forwarding	Lead time in weeks:
2009-0632	Mongolia	Prestored pallets in Shanghai	0	0	$0	$0	$0	
2009-0632	Mongolia	Route 2; Delivery 1	300	300	$76 500	$0	$0	2
2009-0632	Mongolia	Route 2; Delivery 2	300	300	$76 500	$0	$0	3
2009-0632	Mongolia	Route 1; Delivery 1	300	300	$76 500	$0	$0	3
2009-0632	Mongolia	Route 2; Delivery 3	300	300	$76 500	$0	$0	4
2009-0632	Mongolia	Route 2; Delivery 4	300	300	$76 500	$0	$0	5
2009-0632	Mongolia	Route 2; Delivery 5	300	300	$76 500	$0	$0	6
2009-0632	Mongolia	Route 2; Delivery 6	300	70	$17 850	$0	$0	7
2009-0632	Mongolia	Route 1; Delivery 2	300	0	$0	$0	$0	
2009-0632	Mongolia	Route 2; Delivery 7	300	0	$0	$0	$0	
2009-0632	Mongolia	Route 2; Delivery 8	300	0	$0	$0	$0	
2009-0632	Mongolia	Route 2; Delivery 9	300	0	$0	$0	$0	
2009-0632	Mongolia	Route 2; Delivery 10	300	0	$0	$0	$0	
2009-0632	Mongolia	Route 1; Delivery 3	300	0	$0	$0	$0	
2009-0632	Mongolia	Route 2; Delivery 11	300	0	$0	$0	$0	
2009-0632	Mongolia	Route 2; Delivery 12	0	0	$0	$0	$0	
2009-0632	Mongolia	Short shipment from Singapore to Shanghai	0	0	$0	$0	$0	

Appendix 1.5 Step 3: Scenario output all disasters

The selected scenario	
Selected configuration	
Regular routes	Yes
Regular routes and terminals	No
Freight forwarding	No

Selected capacity	
Total number of pallets stored onboard vessels	1 500
Total number of pallets avilable from DC	3 000
Total number of pallets prestored at terminals	0

The selected sceanrio enables WWL to distribute 100 % of demand to	
56 %	of the disasters

Average % of demand fullfilled
77,6 %

Scenario 2.4: summary for all disasters

Disaster:		Current response system:				Proposed response system:				Conclusion:		
Disaster number:	Country:	Number of pallets delivered:	Lead time in weeks:	Cost of response:	Price per pallet:	Number of pallets delivered:	Lead time in weeks:	Cost of response:	Price per pallet:	How much of total demand does WWL fulfill?	Does WWL respond faster or as fast as previous response?	Does WWL deliver pallets to a lower cost?
2005-0475	China	3 926	12	$331 019	$84	3 600	12	$295 697	$82	92 %	Yes	Yes
2006-0241	Myanmar	40	12	$83 100	$2 078	40	1	$3 550	$89	100 %	Yes	Yes
2006-0648	Vietnam	114	12	$13 482	$118	114	1	$13 308	$117	100 %	Yes	Yes
2007-0021	Malaysia	700	12	$57 348	$82	700	2	$33 417	$48	100 %	Yes	Yes
2007-0274	Cambodia	156	12	$189 837	$1 217	156	1	$9 943	$64	100 %	Yes	Yes
2007-0311	Bangladesh	8 614	12	$4 973 076	$577	3 300	12	$771 336	$234	38 %	Yes	Yes
2007-0320	India	32 327	12	$660 139	$20	3 300	12	$715 236	$217	10 %	Yes	No
2007-0557	Papua New Guinea	1 093	12	$2 772 781	$2 537	1 093	4	$523 261	$479	100 %	Yes	Yes
2008-0329	Vietnam	626	12	$31 940	$51	626	3	$118 150	$189	100 %	Yes	No
2008-0452	Laos	3 014	12	$1 283 324	$426	3 014	9	$297 597	$99	100 %	Yes	Yes
2009-0414	Cambodia	12 570	12	$159 900	$13	4 500	12	$219 321	$49	36 %	Yes	No
2009-0421	Indonesia	10 763	12	$5 421 829	$504	4 500	12	$678 321	$151	42 %	Yes	Yes
2009-0434	Nepal	8 616	12	$139 584	$16	3 300	12	$787 836	$239	38 %	Yes	No
2009-0611	Vietnam	5 241	12	$736 708	$141	4 500	12	$601 821	$134	86 %	Yes	Yes
2009-0632	Mongolia	1 870	12	$2 122 745	$1 135	1 870	7	$502 540	$269	100 %	Yes	Yes
2010-0120	Solomon Is	7	12	$280	$40	7	2	$4 226	$604	100 %	Yes	No
		89 677	**12**	**$18 977 092**	**$212**	**34 620**	**7,1**	**$5 575 560**	**$161**	-	-	-

Appendix 2.1 Outputs scenario 2.1

The selected scenario

Selected configuration	
Regular routes	*Yes*
Regular routes and terminals	*No*
Freight forwarding	*No*

Selected capacity	
Total number of pallets stored onboard vessels	*375*
Total number of pallets avilable from DC	*750*
Total number of pallets prestored at terminals	*0*

The selected sceanrio enables WWL to distribute 100 % of demand to	
38 %	*of the disasters*

Average % of demand fullfilled
54,7 %

Scenario 2.1: summary for all disasters

Disaster:		*Current response system:*				*Proposed response system:*				*Conclusion:*		
Disaster number:	Country:	Number of pallets delivered:	Lead time in weeks:	Cost of response:	Price per pallet:	Number of pallets delivered:	Lead time in weeks:	Cost of response:	Price per pallet:	How much of total demand does WWL fulfill?	Does WWL respond faster or as fast as previous response?	Does WWL deliver pallets to a lower cost?
2005-0475	China	3 926	12	$331 019	$84	900	12	$65 338	$73	23 %	Yes	Yes
2006-0241	Myanmar	40	12	$83 100	$2 078	40	1	$3 168	$79	100 %	Yes	Yes
2006-0648	Vietnam	114	12	$13 482	$118	114	2	$12 221	$107	100 %	Yes	Yes
2007-0021	Malaysia	700	12	$57 348	$82	700	5	$26 738	$38	100 %	Yes	Yes
2007-0274	Cambodia	156	12	$189 837	$1 217	156	3	$8 455	$54	100 %	Yes	Yes
2007-0311	Bangladesh	8 614	12	$4 973 076	$577	825	12	$184 963	$224	10 %	Yes	Yes
2007-0320	India	32 327	12	$660 139	$20	825	12	$170 938	$207	3 %	Yes	No
2007-0557	Papua New Guinea	1 093	12	$2 772 781	$2 537	1 050	12	$492 658	$469	96 %	Yes	Yes
2008-0329	Vietnam	626	12	$31 940	$51	626	7	$112 178	$179	100 %	Yes	No
2008-0452	Laos	3 014	12	$1 283 324	$426	1 125	12	$100 347	$89	37 %	Yes	Yes
2009-0414	Cambodia	12 570	12	$159 900	$13	1 125	12	$44 097	$39	9 %	Yes	No
2009-0421	Indonesia	10 763	12	$5 421 829	$504	1 125	12	$158 847	$141	10 %	Yes	Yes
2009-0434	Nepal	8 616	12	$139 584	$16	825	12	$189 088	$229	10 %	Yes	No
2009-0611	Vietnam	5 241	12	$736 708	$141	1 125	12	$139 722	$124	21 %	Yes	Yes
2009-0632	Mongolia	1 870	12	$2 122 745	$1 135	1 050	12	$272 158	$259	56 %	Yes	Yes
2010-0120	Solomon Is	7	12	$280	$40	7	2	$4 159	$594	100 %	Yes	No
		89 677	**12**	**$18 977 092**	**$212**	**11 618**	**8,8**	**$1 985 076**	**$171**	-	-	-

Appendix 2.2 Outputs scenario 2.2

The selected scenario	
Selected configuration	
Regular routes	*Yes*
Regular routes and terminals	*No*
Freight forwarding	*No*

Selected capacity	
Total number of pallets stored onboard vessels	*750*
Total number of pallets avilable from DC	*1500*
Total number of pallets prestored at terminals	*0*

The selected sceanrio enables WWL to distribute 100 % of demand to	
50 %	*of the disasters*

Average % of demand fullfilled
65,4 %

Scenario 2.2: summary for all disasters

Disaster:		***Current response system:***				***Proposed response system:***				***Conclusion:***		
Disaster number:	Country:	Number of pallets delivered:	Lead time in weeks:	Cost of response:	Price per pallet:	Number of pallets delivered:	Lead time in weeks:	Cost of response:	Price per pallet:	How much of total demand does WWL fulfill?	Does WWL respond faster or as fast as previous response?	Does WWL deliver pallets to a lower cost?
2005-0475	China	3 926	12	$331 019	$84	1 800	12	$136 858	$76	46 %	Yes	Yes
2006-0241	Myanmar	40	12	$83 100	$2 078	40	1	$3 305	$83	100 %	Yes	Yes
2006-0648	Vietnam	114	12	$13 482	$118	114	1	$12 612	$111	100 %	Yes	Yes
2007-0021	Malaysia	700	12	$57 348	$82	700	3	$29 143	$42	100 %	Yes	Yes
2007-0274	Cambodia	156	12	$189 837	$1 217	156	2	$8 991	$58	100 %	Yes	Yes
2007-0311	Bangladesh	8 614	12	$4 973 076	$577	1 650	12	$375 593	$228	19 %	Yes	Yes
2007-0320	India	32 327	12	$660 139	$20	1 650	12	$347 543	$211	5 %	Yes	No
2007-0557	Papua New Guinea	1 093	12	$2 772 781	$2 537	1 093	7	$516 587	$473	100 %	Yes	Yes
2008-0329	Vietnam	626	12	$31 940	$51	626	4	$114 328	$183	100 %	Yes	No
2008-0452	Laos	3 014	12	$1 283 324	$426	2 250	12	$208 423	$93	75 %	Yes	Yes
2009-0414	Cambodia	12 570	12	$159 900	$13	2 250	12	$95 923	$43	18 %	Yes	No
2009-0421	Indonesia	10 763	12	$5 421 829	$504	2 250	12	$325 423	$145	21 %	Yes	Yes
2009-0434	Nepal	8 616	12	$139 584	$16	1 650	12	$383 843	$233	19 %	Yes	No
2009-0611	Vietnam	5 241	12	$736 708	$141	2 250	12	$287 173	$128	43 %	Yes	Yes
2009-0632	Mongolia	1 870	12	$2 122 745	$1 135	1 870	11	$491 122	$263	100 %	Yes	Yes
2010-0120	Solomon Is	7	12	$280	$40	7	2	$4 183	$598	100 %	Yes	No
		89 677	**12**	**$18 977 092**	**$212**	**20 356**	**7,9**	**$3 341 050**	**$164**	-	-	-

Appendix 2.3 Outputs scenario 2.3

The selected scenario

Selected configuration	
Regular routes	*Yes*
Regular routes and terminals	*No*
Freight forwarding	*No*

Selected capacity	
Total number of pallets stored onboard vessels	*1125*
Total number of pallets avilable from DC	*2250*
Total number of pallets prestored at terminals	*0*

The selected sceanrio enables WWL to distribute 100 % of demand to	
56 %	*of the disasters*

Average % of demand fullfilled
72,3 %

Scenario 2.3: summary for all disasters

Disaster:		*Current response system:*				*Proposed response system:*				*Conclusion:*		
Disaster number:	Country:	Number of pallets delivered:	Lead time in weeks:	Cost of response:	Price per pallet:	Number of pallets delivered:	Lead time in weeks:	Cost of response:	Price per pallet:	How much of total demand does WWL fulfill?	Does WWL respond faster or as fast as previous response?	Does WWL deliver pallets to a lower cost?
2005-0475	China	3 926	12	$331 019	$84	2 700	12	$215 591	$80	69 %	Yes	Yes
2006-0241	Myanmar	40	12	$83 100	$2 078	40	1	$3 458	$86	100 %	Yes	Yes
2006-0648	Vietnam	114	12	$13 482	$118	114	1	$13 047	$114	100 %	Yes	Yes
2007-0021	Malaysia	700	12	$57 348	$82	700	3	$31 814	$45	100 %	Yes	Yes
2007-0274	Cambodia	156	12	$189 837	$1 217	156	1	$9 586	$61	100 %	Yes	Yes
2007-0311	Bangladesh	8 614	12	$4 973 076	$577	2 475	12	$572 835	$231	29 %	Yes	Yes
2007-0320	India	32 327	12	$660 139	$20	2 475	12	$530 760	$214	8 %	Yes	No
2007-0557	Papua New Guinea	1 093	12	$2 772 781	$2 537	1 093	5	$520 758	$476	100 %	Yes	Yes
2008-0329	Vietnam	626	12	$31 940	$51	626	3	$116 717	$186	100 %	Yes	No
2008-0452	Laos	3 014	12	$1 283 324	$426	3 014	11	$290 696	$96	100 %	Yes	Yes
2009-0414	Cambodia	12 570	12	$159 900	$13	3 375	12	$156 763	$46	27 %	Yes	No
2009-0421	Indonesia	10 763	12	$5 421 829	$504	3 375	12	$501 013	$148	31 %	Yes	Yes
2009-0434	Nepal	8 616	12	$139 584	$16	2 475	12	$585 210	$236	29 %	Yes	No
2009-0611	Vietnam	5 241	12	$736 708	$141	3 375	12	$443 638	$131	64 %	Yes	Yes
2009-0632	Mongolia	1 870	12	$2 122 745	$1 135	1 870	8	$498 259	$266	100 %	Yes	Yes
2010-0120	Solomon Is	7	12	$280	$40	7	2	$4 210	$601	100 %	Yes	No
		89 677	**12**	**$18 977 092**	**$212**	**27 870**	**7,4**	**$4 494 354**	**$161**	-	-	-

Appendix 2.4 Outputs scenario 2.4

The selected scenario	
Selected configuration	
Regular routes	Yes
Regular routes and terminals	No
Freight forwarding	No

Selected capacity	
Total number of pallets stored onboard vessels	1500
Total number of pallets avilable from DC	3000
Total number of pallets prestored at terminals	0

The selected sceanrio enables WWL to distribute 100 % of demand to	
56 %	of the disasters

Average % of demand fullfilled
77,6 %

Scenario 2.4: summary for all disasters

Disaster:		*Current response system:*				*Proposed response system:*				*Conclusion:*		
Disaster number:	Country:	Number of pallets delivered:	Lead time in weeks:	Cost of response:	Price per pallet:	Number of pallets delivered:	Lead time in weeks:	Cost of response:	Price per pallet:	How much of total demand does WWL fulfill?	Does WWL respond faster or as fast as previous response?	Does WWL deliver pallets to a lower cost?
2005-0475	China	3 926	12	$331 019	$84	3 600	12	$295 697	$82	92 %	Yes	Yes
2006-0241	Myanmar	40	12	$83 100	$2 078	40	1	$3 550	$89	100 %	Yes	Yes
2006-0648	Vietnam	114	12	$13 482	$118	114	1	$13 308	$117	100 %	Yes	Yes
2007-0021	Malaysia	700	12	$57 348	$82	700	2	$33 417	$48	100 %	Yes	Yes
2007-0274	Cambodia	156	12	$189 837	$1 217	156	1	$9 943	$64	100 %	Yes	Yes
2007-0311	Bangladesh	8 614	12	$4 973 076	$577	3 300	12	$771 336	$234	38 %	Yes	Yes
2007-0320	India	32 327	12	$660 139	$20	3 300	12	$715 236	$217	10 %	Yes	No
2007-0557	Papua New Guinea	1 093	12	$2 772 781	$2 537	1 093	4	$523 261	$479	100 %	Yes	Yes
2008-0329	Vietnam	626	12	$31 940	$51	626	3	$118 150	$189	100 %	Yes	No
2008-0452	Laos	3 014	12	$1 283 324	$426	3 014	9	$297 597	$99	100 %	Yes	Yes
2009-0414	Cambodia	12 570	12	$159 900	$13	4 500	12	$219 321	$49	36 %	Yes	No
2009-0421	Indonesia	10 763	12	$5 421 829	$504	4 500	12	$678 321	$151	42 %	Yes	Yes
2009-0434	Nepal	8 616	12	$139 584	$16	3 300	12	$787 836	$239	38 %	Yes	No
2009-0611	Vietnam	5 241	12	$736 708	$141	4 500	12	$601 821	$134	86 %	Yes	Yes
2009-0632	Mongolia	1 870	12	$2 122 745	$1 135	1 870	7	$502 540	$269	100 %	Yes	Yes
2010-0120	Solomon Is	7	12	$280	$40	7	2	$4 226	$604	100 %	Yes	No
		89 677	**12**	**$18 977 092**	**$212**	**34 620**	**7,1**	**$5 575 560**	**$161**	-	-	-

Appendix 2.5 Outputs scenario 2.5

The selected scenario

Selected configuration	
Regular routes	Yes
Regular routes and terminals	No
Freight forwarding	No

Selected capacity	
Total number of pallets stored onboard vessels	1875
Total number of pallets avilable from DC	3750
Total number of pallets prestored at terminals	0

The selected sceanrio enables WWL to distribute 100 % of demand to	
69 %	of the disasters

Average % of demand fullfilled
81,6 %

Scenario 2.5: summary for all disasters

Disaster:		Current response system:				Proposed response system:				Conclusion:		
Disaster number:	Country:	Number of pallets delivered:	Lead time in weeks:	Cost of response:	Price per pallet:	Number of pallets delivered:	Lead time in weeks:	Cost of response:	Price per pallet:	How much of total demand does WWL fulfill?	Does WWL respond faster or as fast as previous response?	Does WWL deliver pallets to a lower cost?
2005-0475	China	3 926	12	$331 019	$84	3 926	11	$335 958	$86	100 %	Yes	No
2006-0241	Myanmar	40	12	$83 100	$2 078	40	1	$3 687	$92	100 %	Yes	Yes
2006-0648	Vietnam	114	12	$13 482	$118	114	1	$13 700	$120	100 %	Yes	No
2007-0021	Malaysia	700	12	$57 348	$82	700	2	$35 821	$51	100 %	Yes	Yes
2007-0274	Cambodia	156	12	$189 837	$1 217	156	1	$10 479	$67	100 %	Yes	Yes
2007-0311	Bangladesh	8 614	12	$4 973 076	$577	4 125	12	$978 337	$237	48 %	Yes	Yes
2007-0320	India	32 327	12	$660 139	$20	4 125	12	$908 212	$220	13 %	Yes	No
2007-0557	Papua New Guinea	1 093	12	$2 772 781	$2 537	1 093	3	$527 015	$482	100 %	Yes	Yes
2008-0329	Vietnam	626	12	$31 940	$51	626	2	$120 300	$192	100 %	Yes	No
2008-0452	Laos	3 014	12	$1 283 324	$426	3 014	7	$307 948	$102	100 %	Yes	Yes
2009-0414	Cambodia	12 570	12	$159 900	$13	5 625	12	$293 471	$52	45 %	Yes	No
2009-0421	Indonesia	10 763	12	$5 421 829	$504	5 625	12	$867 221	$154	52 %	Yes	Yes
2009-0434	Nepal	8 616	12	$139 584	$16	4 125	12	$998 962	$242	48 %	Yes	No
2009-0611	Vietnam	5 241	12	$736 708	$141	5 241	11	$718 922	$137	100 %	Yes	Yes
2009-0632	Mongolia	1 870	12	$2 122 745	$1 135	1 870	5	$508 963	$272	100 %	Yes	Yes
2010-0120	Solomon Is	7	12	$280	$40	7	2	$4 250	$607	100 %	Yes	No
		89 677	**12**	**$18 977 092**	**$212**	**40 412**	**6,6**	**$6 633 245**	**$164**	-	-	-