NCIT
The National Center for Intermodal Transportation

THE ROLE OF INTERMODAL TRANSPORTATION IN HUMANITARIAN SUPPLY CHAINS

FINAL REPORT

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1.0 Abstract

After a nature or human-made disaster, effective and efficient disaster relief support is needed. People affected by disasters should be moved away from affected areas and staff and disaster relief supplies need to be moved to destinations in time. The movement of personnel and supplies is completed by disaster relief supply chains, which directly affect the performance of humanitarian aid. Utilizing appropriate transportation modes in the relief chain is critical to effective relief operations. The main objective of this study is to identify the role and impact of intermodal transportation on the performance of response and recovery operations following a disaster. This objective will be achieved by pursuing two specific aims:

1. Identify and assess the current response operations. Determine how (if at all) and why humanitarian organizations utilize different modes of transportation to move the goods and personnel effectively and efficiently in responding to and recovering from a disaster.
2. Identify factors that will potentially improve the attractiveness of using intermodal transportation.

To achieve the aims two rounds of interview were firstly conducted, and then a large scale online survey was designed and distributed. The data was analyzed to draw conclusions that can fulfill the aims. It was found that intermodal transportation is not frequently used in disaster relief. Decision makers in disaster relief agencies consider multiple factors when choosing transportation modes. Among the factors, travel distance is mostly considered regardless of whether supplies or people are being transported. Finally, the organizations that cover larger areas and preposition supplies in their relief operations tend to use intermodal transportation more frequently.

2.0 Introduction

After the Tsunami that struck Asia and Africa, and after Hurricane Katrina, which devastated parts of some southern states in the U.S., it became apparent that complex and coordinated supply chains are required for effective relief efforts. The commercial sector has realized a few decades ago that significant cost savings can be achieved by optimizing the supply chain as a whole. However, the creation of efficient supply chain operations is not high on the agendas of humanitarian organizations (Thomas, 2005). It is not clear if and how intermodal transportation affects the operations of humanitarian organizations.

Some of the tools developed for commercial supply chains can be used in humanitarian supply chains, but there are differences in the two types of systems, such as the motivation for streamlining processes. Thus, there is an *urgent need* to understand better how to make humanitarian supply chains more effective and efficient. Studies done by the Fritz Institute, a non-profit humanitarian organization, demonstrate the need for models and tools that can be used to improve the efficiency and effectiveness of humanitarian supply chains. There is also a critical gap in the education and training of students on issues related to the challenges faced in providing relief in disasters. The majority of about 300 logisticians surveyed at major aid organizations indicated that they typically get their education and training on the job by co-workers (Thomas and Mizushima, 2005). The lack of experienced and skilled logisticians in the field due to poor education and training practices prohibits aid organizations from providing effective logistics support. Until it is known how to optimally coordinate the logistics activities of humanitarian supply chain, it is unlikely that relief efforts will become more efficient and effective than has been the case in the recent past. The purpose of this study is to gain a better understanding of

how intermodal transportation might impact the disaster response and recovery operations through the use of focus groups, surveys, and interviews with disaster relief agencies.

3.0 Literature Review

After a nature or human-made disaster, effective and efficient disaster relief support is needed. People affected by disasters should be moved away from affected areas and staff and disaster relief supplies need to be moved to destinations in time. The movement of personnel and supplies is completed by disaster relief supply chains, which directly affect the performance of humanitarian aid. Disaster relief chains are defined as the processes and systems involved in mobilizing people, resources, skills and knowledge to help vulnerable people affected by natural disasters and complex emergencies (Thomas, 2004).

A large number of research papers and agency reports address the issue of how to evaluate the performance of disaster relief operations. Both the European Community Humanitarian Office (ECHO, 1999) and Pokhrel (2001) focus on traditional, widely used criteria of efficiency, effectiveness, impact, relevance and sustainability in internal evaluation, as shown in Bold in Table 1. The traditional criteria, however, is criticized as being too restricted in humanitarian emergencies and not focused on the overall context of the humanitarian operations (Frerks, 2002). The Development Assistance Committee/ Organization for Economic Co-operation and Development (DAC/OECD, 1999) also proposed supplemental criteria, as did the Danish International Development Agency (DANIDA, 2006). These additional criteria are displayed in italic font in Table 1.

An important piece of disaster relief operations is the supply chain. The supply chain in disaster relief must support two way flows. First, people affected by natural or human-made disasters need to be moved away from affected areas. Second, relief personnel and disaster relief cargo need to be moved to the destination. To measure the performance of relief chains, several studies have recommended various criteria for evaluation. Davidson (2006) developed four indicators: appeal coverage, donation-to-delivery time, financial efficiency, and assessment accuracy. Beamon (2008) firstly compared commercial supply chains and humanitarian relief chains, then developed a detailed relief chain measurement framework, including resource performance metrics, output performance metrics, and flexibility performance metrics. The resource performance metric measures the level of efficiency in disaster relief chains, and the output performance metric indicate the level of effectiveness, and flexibility performance metric indicates the ability of disaster relief chains in response to environmental variability. The performance measurements for disaster relief chains are different from the ones that are for the operations because these measurements are more specific on the transportations in the chains and less focused on the indicators such as impact and political consideration in operation measurement.

Besides efforts to measure the performance of humanitarian supply chains, several studies have made recommendations to improve the structure of humanitarian supply chains. Özdamar (2004) provided an optimized schedule for pickup and delivery of relief vehicles and optimized quantities for emergency supply chains. Balcik (2008a) develop a maximal coverage model of a relief network and the amount and locations of distribution center, considering different coverage requirement, inventory capacity limits, and budgetary constraints. Balcik (2008b) proposed a model of delivery schedules for vehicles and equitably allocates resources minimizing transportation costs and maximizing benefits to aid recipients.

These studies (Davidson, 2006; Beamon, 2008; Balcik, 2008a) have identified a number of similarities between commercial supply chains and disaster relief chains, such as speed as an essential factor and supply flow via both long-haul and short-haul shipments (Beamon, 2004). Due to the similarities between the two types of chains, the factors that affect commercial supply chains might also impact humanitarian supply chains. The specific characteristics of humanitarian supply chains have also been highlighted. According to Balcik (2008a), first, the strategic goal of relief chain is to salve lives given financial constraints compared to business supply chains' objectives of cost reduction, capital reduction, and service improvement; second, the demands in relief chain are supplies and people, while in commercial chain are products and service; third, the order fulfillment is also different in relief chain, because lead times is zero in disaster strike, demand location is uncertain, and pricing from supplies increase after disaster occurs while pricing is relatively static in commercial industries; Fourth, the customers in relief chain have no choice of supplies and do not have chance to recourse.

Intermodal transportation is defined as "The shipment of cargo and the movement of people involving more than one mode of transportation during a single, seamless journey" (Jones, 2000). Studies have shown the existence of intermodal transportation in disaster relief and it adds complexity and delays to the supply chain (Prater et al., 2001). Since relief cargos are distributed from resource staging centers to points of distribution and then to different destinations in different speeds, different modes of transportations are applied (Kapucu, 2007). Angelis et al. (2007) focus on a multi-depot, multi-vehicle routing, and scheduling problem for air delivery of emergency supply deliveries, and develop a linear integer programming model to maximize the satisfaction of demand from each client. In the 2005 evacuation of New Orleans during Hurricane Katrina, there was a concerted effort to evacuate residents by means of multiple modes, including Amtrak trains, buses, aircraft, and ships (Iqbal et al. 2007), yet the transportation was still not sufficient to move all people out of the area.

As the above studies indicated, intermodal transportation plays a necessary role in transporting people and cargo during disaster relief operations. To further coordinate and improve intermodal efforts in humanitarian supply chains, it is critical to understand the decision making process used by relief agencies. The objective of this study is to investigate how the supplies and people are transported

through disaster relief chains and disclose the factors that most disaster relief agencies consider when choosing transportation modes.

Table 1. Summary of evaluation criteria

	OECD, 1991	ECHO, 1999	DAC/OECD, 1999	Pokhrel, 2001	Frerks, 2002	DANIDA, 2006
Traditional						
Relevance	√	√	√	√	√	√
Effectiveness	√	√	√	√	√	√
Efficiency	√	√	√	√	√	√
Impact	√	√	√	√	√	√
Sustainability	√	√	√	√	√	√
Supplemental						
Connectedness					√	√
Coherence			√		√	√
Coverage			√		√	√
Timeliness					√	
Appropriateness					√	
Coordination			√		√	

4.0 Project Objectives

The purpose of this project is to identify how decision makers in disaster relief agencies make decisions about transportation modes and the use of intermodal transportation in disaster relief. To achieve the aim of the study, multiple hypotheses were set under four main objectives.

4.1 Objective 1

Objective 1. Determine the frequency of use for various modes in disaster relief.

In different situations, such as transporting supplies, volunteers, and evacuating people, different transportation modes are applies. From the discussions with relief agency representatives, trucks are

frequently mentioned and other modes are rarely used when transporting supplies, therefore, H1 has been set to test whether truck is the most frequently used mode. Whether the change of transportation modes will impact the use of a certain transportation mode is also of interest. Therefore, H1b has been set. From the discussion, utilizing vans and air modes were noted as the most commonly used modes when transporting volunteers and staff members. To compare these two and other possible transportation modes, H2 is set. To examine the use of transportation modes used in evacuation, H3 is set.

H1: In delivering supplies, truck will be the most used mode and air will be the least used.

H1b: The change of modes will have effect on the frequency of use of transportation modes

H2: In transporting volunteers/staff, van/bus/car will be the most used mode and ship will be the least used. Specifically, agency owned vehicles will be used most.

H3: In evacuating affected populations, van/bus/car will be the most used mode and ship will be the least used. Specifically, agency owned vehicles will be used most.

4.2 Objective 2

Objective 2. Quantify the amount of intermodalism used in disaster relief.

To investigate the role that intermodal transportation plays in disaster relief, firstly the use of intermodal transportation should be identified. The results from the hypotheses in objective 1 can reveal the use of different transportation modes, while the change between transportation modes has not been evaluated. From the discussions with relief agency representatives most of the organizations are using only one type of transportation mode during a single trip, therefore H4 was set to test whether it is the same situation in all the surveyed organizations. Considering some international organizations transport the relief cargos from outside a country and then transport by rail or road. Combining that most organizations are using trucks for transporting supplies, H5 was set. It is also unclear whether the transportation trips that have more stops will tend to also have more transportation mode changes, so H6 was set. H7 was set to determine the places that the changes occur.

H4: Intermodal transportation is not common in disaster relief.

H5: Changes of mode is most common between truck and air.

H6: Agencies that make more stops are more likely to use intermodal transportation.

H7: Mode changes are most common at storage facilities.

4.3 Objective 3

Objective 3. Determine factors that are important to mode selection in disaster relief.

From the discussions with relief agency representatives four factors that are important for the decision makers to consider when they decide which transportation mode to use are cost, travel distance, type of

supplies (people), amount of supplies (people) and availability of roads. However, it is unclear which one is more important and which is less, therefore, H8, H12, H13 were set to identify the most important factors in transporting supplies, people and evacuating people. To better differentiate the importance of different factors, a question of overall factors ranks was designed. H9 is to prove whether importance of factors can change if the decision makers use various transportation modes.

H8: Cost is the factor that is considered most often in mode selection when transporting supplies.

H9: The importance of selection factors changes based on mode considered.

H10: Cost is the most often considered factor in mode selection when transporting volunteers/staff.

H11: Cost is the most often considered factor in mode selection when evacuating people.

4.4 Objective 4

Objective 4. Investigate whether organization type or processes impact decision making factors or modes utilized.

Different sizes of organizations are conducting relief operations, including international, national, regional, and local. Therefore, the areas that an organization covers will impact the transportation mode it chooses. To identify whether this is true, H10 and H11 were set.

H12: Organizations (that provide relief to larger areas) are more likely to utilize intermodal transportation.
H13: Organizations that preposition supplies are more likely to utilize intermodal transportation.

5.0 Study 1: Exploratory Interviews

To get more accurate information about relief operations from a larger base of organizations, and to guide the development of the second project study, telephone interviews were conducted with relief organizations leaders. There were two rounds of interviews: the first one is about brief information and the second round is detailed. Topics were about transportation of supplies, people and cooperation in transportation.

5.1 Methodology

5.1.1 Participants

In study 1, the research team interviewed nine organization leaders from seven disaster relief agencies. Participants represented disaster relief organizations along the U.S. Gulf Coast, including Mississippi, Louisiana, Texas, and Florida. Agency leaders are the ones who make decisions, therefore, as participants they can provide accurate information about decision making at the organizational level. The participants were selected based on recent hurricanes in the Gulf Coast, thereby providing

information from recent relief operations when they were interviewed. The majority of participants were from non-profit organizations, with only one participant representing a government organization.

5.1.2 Procedure

Two rounds of telephone interviews were conducted to investigate the transportation process and transportation modes in disaster relief chains. Most of the questions are open-ended not to bias the participants. 29 questions were designed for the interviews and interviewers can choose certain questions according to what interviewees respond. The questions are in index 1. The questions in the first round are general questions about the missions of the organizations, the assistance provided, organizations' decision making authorities, how supplies/personnel were transported to affected areas, training of transportation staff, and feedback from affected populations. Seven interviewees completed the first round of interviews. The second round interview questioned subjects on more detailed information. Out of the four interviewees in the second round, three were interviewed through telephone and one responded in email. The second round interview was more detailed, including questions from three main topics: cargo transportation, transportation of people, and potential factors. Questioning interviewees regarding transportation allowed the researchers to discover more about their use of transportation and various modes in delivering relief. The final category, potential factors, helped identify key criteria that impact their design and use of the relief chain. Example interview questions from each topic are shown in Table 1. The entire list of questions is shown in Appendix 1.

Table 1. Example Interview Questions

Cargo Transportation	**Transportation of People**	**Potential Factors**
• Has your organization encountered any problems in the transportation process? • What are the differences when transporting your cargo before and during a disaster? • How often do the supplies change transportation modes (e.g. train to truck)? How does this process work?	• Does your agency help evacuate people from disaster areas? If so, how? What transportation modes are used? • How do you transport relief workers into affected areas? What transportation modes are used?	• Have you ever cooperated with other organizations, companies, or government agencies to provide disaster relief? How so? • How does your organization receive funding? How does this influence your operations? • How are your operations evaluated? Are there a set of standards that you try to meet?

5.2 Results

Telephone interviews were recorded using a digital audio recorder and transcribed. All individual transcripts in both first and second round interviews were compiled and then summarized in two general categories: transportation process and modes and other general questions. Each general category contains several sub-categories (shown in Table 2.). The responses were categorized according to the interview questions.

Table 2. Data Analysis Categories

Transportation Process and Modes	Other General Questions
• Transportation modes to carry supplies/people to the affected area • Transportation process • What affects decisions of transportation modes	• Kinds of relief delivered • About evacuation • Cooperation in transportation • How to determine who to help • Ways to evaluate operation • How the organization is funded • Differences when transporting supplies and personnel before, during, and after the disaster • Other problems

5.2.1 Transportation Process

The majority of the organizations that talk about transportation process transport supplies to a large warehouse, using the warehouse as an intermediate distribution center to feed supplies to surrounding areas.. All organizations reported the use of private trucking companies or leased vehicles to transport cargos from large warehouse to district offices/local chapters. Cooperation for transporting supplies among the organizations also exists. Since differences exist between transportation of people and supplies, the processes will be described separately.

5.2.1.1 Transportation of People

The agencies interviewed primarily provide food and shelter, but do not perform evacuations. Therefore, questions related to transportation of people were only focused on the transportation of volunteers and staff to the affected area. For the use of air, 75% of those that discussed transporting people to affected areas mentioned use of air travel to transport personnel. In addition to air transportation, all of the agencies mentioned using ground vehicles to transport people. The vehicles used are rental or organization-owned vans or buses. Emergency Response Vehicles (ERVs) are also utilized in transporting people. However, one organization mentioned that it discouraged volunteers from driving personally-owned vehicles since it was troublesome when their vehicles broke down.

5.2.1.2 Transportation of Supplies

Regarding transportation of supplies, all of the organizations reported using trucks to transport supplies. Many varieties of trucks were utilized, including pick-up trucks, box trucks, and tractor trailer rigs. Different truck sizes are selected for different cargo loads. Mobile kitchens and mobile command centers are also used when delivering food to local people, and these are usually boxed trucks or Emergency Response Vehicles. All of the interviewed organizations mentioned hiring commercial transportation companies for transportation.

5.2.2 Factors Critical to Mode Selection

Five primary factors were identified by the organizations as being critical to the selection of transportation mode:

- Transportation cost: The organizations will do cost estimation before they transport supplies, and they all have a funding limit, therefore the cost is one of the most important factors. They do cost estimates to choose the transportation mode or transportation provider with the lowest cost estimate.
- Distance: If the distance between the starting point and the destination is far, the organization may consider the air to transport volunteers since it is much quicker to travel by air.
- Type of supplies: When transporting supplies, trucks and trailers are the most frequent modes. When transporting volunteers, air and vans are mostly used.
- Amount of supplies: If supplies are in large amount, tractor trailer rigs are usually used. If supplies are in small amount, smaller trucks are utilized.
- Availability of roads/routes: Air will be used if the road is inaccessible due to the natural disaster. Additionally, if refueling is necessary, fuel availability along the route will be considered to make sure there are enough fuel supplies.

5.2.3 Cooperation in Transportation

Most of the organizations said they cooperated with government agencies and other disaster relief organizations. Usually the organization cooperates with state emergency management agencies to get disaster information. During and immediately following a disaster, various organizations conference with state emergency management agencies. Various tasks are then allocated to participating organizations and the cooperating organizations may share volunteers and equipment.

6.0 Study 2: Quantitative Survey

Based on the interview results, an online survey was created. to obtain information from a large variety of relief organizations, from international to local organizations, and from non-profit organizations to government agencies.

6.1 Methodology

6.1.1 Participants

In phase 2 the recipients of the online survey are from all over the country. Emails of the recipients were collected before the survey and in total emails were sent to 769 recipients. Among them 145 took the survey. 42.9% of the respondents work for relief agencies that conduct international relief operations, 75.9% conduct national relief operations. For the type of the organizations, 88.0% are non-profit and 9.8% are religious and 7.5% are government related. The questions about demographic information

were designed as multiple answers since some of the answers are not exclusive from each other, for example, an agency can be both religious and non-profit and conduct both international and national operations.

6.1.2 Procedures

The second phase of the study is to develop an online survey according to the interview results from the first phase. For example, five potential factors that many affect decisions about transportation modes were obtained in interviews, and based on these factors questions about their weights in decision making have been made in the online survey. In total there are 42 questions in the survey and some of them are the same because of the logics of questions, as shown in Appendix 2. The survey includes 6 parts: introduction, background information, the use of transportation modes in transporting supplies, use of trucks in transporting supplies, transportation of people, general questions, and survey end. The online survey link was sent to 769 relief agencies representatives by emails.

6.2 Results

6.2.1 Objective 1: Determine the frequency of use for various modes in disaster relief

H1: In delivering supplies, truck will be the most used mode and air will be the least used.

The frequency options are assigned weight for calculation. Never: 1, Rarely: 2, Sometimes: 3, Most of the Time: 4, All of the time: 5. Then the frequency weight for each mode is calculated separately and recorded in Table 3, Transportation modes that are used in transporting supplies are truck, ship, air and railroad. The scores were given in three columns, mean, standard deviation, and number of counts. The frequencies are in different situations, including no change of modes, 1 change, 2 changes and more than 2 changes.

Compared to other transportation modes, truck has the highest weight in each situation. Therefore we can conclude that truck is the most commonly used transportation mode in disaster relief. Rail is the least used mode in all the situations except in the 1 change of modes. To analyze the data together, all the data was combined together and some of the incomplete values were taken off. Based on the combined data, the score of each mode is calculated. The average score of truck is 4.47, rail 1.47, ship 1.53, and air 1.94. T-tests were also conducted between each pair of transportation modes. Truck is significantly higher than air ($p<0.001$) and therefore higher than others. Air is significantly higher than ship ($p=0.016$), but there is no significant difference between rail and ship ($p=0.682$). Therefore H1 is partially right, and truck is the most used mode while the least used ones are rail and ship, instead of air in original hypothesis.

Table 3. Average use ratings by mode and number of stops (H1)*

Number of mode changes	Truck	Rail	Ship	Air
0	4.5 (4.5, 0.96, 74)	1.27 (1.27, 0.69, 45)	1.30 (1.30, 0.76, 46)	1.72 (1.72, 0.97, 50)

1	4.38 (4.38, 0.96, 24)	1.61(1.61, 1.19, 13)	1.77 (1.77, 1.36, 13)	2.11(2.11, 1.13, 18)
2	4.4 (4.4, 0.84, 10)	2.00 (2.00, 0.53, 8)	2.29 (2.29, 1.25, 7)	2.55 (2.55, 0.73, 9)
> 2	4.75 (4.75, 0.5, 4)	2.25 (2.25, 0.96, 4)	2.33 (2.33, 1.15, 3)	2.50 (2.50, 0.58, 4)
Total	4.47 (4.47, 0.90, 112)	1.47 (1.47, 0.85, 70)	1.54 (1.54, 1.01, 69)	1.94 (1.94, 1.00, 81)

**Note: numbers in cells-mean (mean, standard deviation, count number)*

H1b: The change of modes will have effect on the frequency of use of transportation modes

ANOVA was conducted for between the numbers of change of modes of the frequency of each mode (truck, rail, ship, air). Comparing all the results only for ship and air the p-value are 0.022 and 0.044 while the other two have p-values much higher than 0.05. Therefore, for the mode of ship and air, the hypothesis is right while the hypothesis does not apply to the other two transportation modes.

H2: In transporting volunteers/staff, van/bus/car will be the most used mode and ship will be the least used. Specifically, agency owned vehicles will be used most.

The transportation modes and their frequency scores are listed in Table 3. Transportation modes include van/bus/car (self-owned), van/bus/car (organization-owned), van/bus/car (rental/commercial), vehicle (all), rail, ship, air. Scores for frequencies are calculated in the same way: Never: 1, Rarely: 2, Sometimes: 3, Most of the Time: 4, All of the time: 5.Among these transportation modes, organization-owned vehicles have the highest score of 3.12, and ship is the least used one with a lowest score of 1.25. The second highest score is air and that means air is the second mostly used transportation mode for transporting volunteers. The total score for vehicles is 3.03, higher than the other modes but is closed to air. T-tests were conducted between each pair of transportation modes. Vehicle (all)'s score is not significantly higher than air (p=0.832). Air is significantly higher than rail (p=0.001) and ship. However, there is no significant difference between rail and ship (p=0.807).There is no significant difference between each type of vehicles (all p-values are more than 0.05). Therefore H2 is partially right based on above analysis that vehicle is the most used mode, however ship and rail are least used and no difference exist between types of vehicles.

Table 4. Average use ratings of mode for transportation of people (H2 and H3)*

	Transport Personnel	Evacuation Transport
Van/Bus/Car (Self-owned)	2.99 (2.99, 1.09, 79)	3.22 (3.22, 1.39, 9)
Van/Bus/Car (organization-owned)	3.12 (3.12, 1.03, 83)	3.75 (3.75, 1.06, 12)
Van/Bus/Car (Rental/Commercial)	2.99 (2.99, 1.12, 81)	3.00 (3.00, 1.15, 10)
Vehicle (all)	3.03 (3.03, 1.08, 243)	3.35(3.35, 1.20, 31)
Railroad	1.28 (1.28, 0.56, 73)	1.50 (1.50, 0.55, 6)
Ship	1.25 (1.25, 0.60, 59)	1.33 (1.33, 0.52, 6)
Air	3.00 (3.00, 1.26, 83)	2.70 (2.70, 1.49, 10)

**Note: numbers in cells-mean (mean, standard deviation, count number)*

H3: In evacuating affected populations, van/bus/car will be the most used mode and ship will be the least used. Specifically, agency owned vehicles will be used most.

The transportation modes and their frequency scores are listed in Table 3 including Van/Bus/Car (self-owned) , Van/Bus/Car (organization-owned), Van/Bus/Car (rental or commercial), Vehicle (all),Rail, Ship, Air. Among these transportation modes, organization-owned vehicles have the highest score of 3.75, and ship is the least used one with a lowest score of 1.33. The second highest score is self-owned vehicles and that means self-owned vehicle is the second mostly used transportation mode for evacuation.

6.2.2 Objective 2: Quantify the amount of intermodalism used in disaster relief.

H4: Intermodal transportation is not common in disaster relief.

The options of the number of stops are 0, 1, 2, and more. More is substituted as 3 for analysis. The standard deviation of the result is 0.91, the mean is 1.19. 22.9% of the respondents report they never stop, 45.8% report they stop once, 20.6% report stopping twice and 10.7% report stopping for more than once. Therefore we can conclude that in most situations the relief agencies stop once during the trip.

The options of the number of mode changes are 0, 1, 2, and more. More is substituted as 3 for analysis. The standard deviation of the result is 0.90, the mean is 0.62. 60.5% report they never change transportation mode, 23.3% report they stop once, 10.1% report stopping twice and 6.2% report stopping for more than once. Therefore 39.5% of the respondents change transportation mode at least one time during the trip.

H5: Changes of mode is most common between truck and air.

The numbers of change from one mode to another are listed below: truck to truck 2, truck to air/air to truck 8, truck to ship/ship to truck 3, rail to truck/truck to rail 2, total changes: 34. Compared to other mode changes, changes between trucks are the most common. Truck to air/air to truck is the second most among all the changes. If changes between different trucks are not considered as transportation mode changes, then the hypothesis is correct, that truck to air/air to truck is the most common mode changes.

H6: Agencies that make more stops are more likely to use intermodal transportation.

Two questions were related to this hypothesis. One is about the number of stops and another one is the number of mode changes. ANOVA was conducted to test whether number of stops has impact on number of transportation mode changes. Independent variable is number of stops and dependent variable is the number of changes. $F=10.99$, $P< 0.001$. Therefore, number of stops has a significant impact on the number of mode changes. Regression was done to find out the relationship between number of stops and number of mode changes. The regression equation is changes = 0.10 + 0.45 stops. From the model we can conclude that more stops is related to more transportation mode changes. For the number of stops, $p<0.001$, therefore it is a significant model. However, since R-square is 20.6%, the model is not a good fit model.

H7: Mode changes are most common at storage facilities.

According to the open ended questions about mode changes locations, 18 out of 24 answers were at storage facilities such as warehouses, distribution sites and so on. We can conclude that mode changes occur mostly at storage facilities and H7 is correct.

6.2.3 Objective 3: Determine factors that are important to mode selection in disaster relief.

H8: Cost is the factor that is considered most often in mode selection when transporting supplies.

Summing all the counting of factors respondents considered in each transportation mode, 43.39% considered cost, and 62.73% considered travel distance, 47.64% considered type of supplies, 51.42% considered amount of supplies and 48.10% considered availability of roads. Therefore, people consider travel distance most and it is the most often considered factor when transporting supplies. The original hypothesis is not true.

H9: The importance of selection factors changes based on mode considered.

The importance was rated with 1 to 5 scales, with 5 the highest and 1 the lowest. The average score for cost is 4.37 (4.37, 0.98, 102) distance 4.26 (4.26, 0.08, 104), type of supplies 4.15 (4.15, 0.09, 100), amount of supplies 4.27 (4.27, 0.07, 104), availability of roads/routes 4.20 (4.20, 0.09, 104). T- tests were conducted between each pair of factors. There is no significant difference between the highest average, cost and the lowest average, type of supplies ($p=0.088$), and there is no difference between any other pairs, therefore, there is no evidence supporting H9.

H10: Cost is the most often considered factor in mode selection when transporting volunteers/staff.

Summing all the counting of factors respondents considered in each transportation mode, 37.22% considered cost, and 70.55% considered travel distance, 12.30% considered type of people, 50.16% considered number of people and 29.77% considered availability of roads. Therefore, people consider travel distance most and it is the most frequently considered factor when transporting volunteers. The original hypothesis is not true.

H11: Cost is the most often considered factor in mode selection when evacuating people.

Summing all the counting of factors in each transportation mode, 42.00% considered cost, and 40.00% considered travel distance, 16.00% considered type of people, 50.00% considered number of people and 38% considered availability of roads. Therefore, decision makers consider number of people most and it is the most often considered factor when evacuating people. The original hypothesis is not true.

6.2.4 Objective 4: Investigate whether organization type or processes impact decision making factors or modes utilized.

H12: Organizations (that provide relief to larger areas) are more likely to utilize intermodal transportation.

Two questions were related to this hypothesis. One is the area a disaster relief agency is covering: international, national, regional or local. The categories were coded as follows: International organization (4), national (3), regional (2), and local (1). Each organization can get more than one score in the rating. The score of an organization is the maximum one among the multiple scores it has got. For example, if an organization is conducting both international and national relief operations, its score is 4. Average area score 3.11 (3.11, 0.99, 129). Another question is about the times of transportation modes changes, from 0 to 3. ANOVA was conducted to test the hypothesis. Independent variable is organization covering area score and dependent variable is the number of changes $F= 6.13$, $p=0.001$. Therefore, the area that an organization covers has a significant impact on the number of change of transportation modes. The original hypothesis is correct. Regression is also done to see the relationship between the two variables. The regression equation is number of stops = - 0.27 + 0.29*size. For the coefficient of size, $p<0.001$, and R square is 10.0%. This is a significant model while not a good fit model. Yet we can still conclude that the number of stops is positively correlated to the area an organization is covering.

H13: Organizations that preposition supplies are more likely to utilize intermodal transportation.

A question was about whether a relief organization preposition supplies before a disaster. This question was associated with number of transportation mode changes to see whether staging supplies will affect the use of intermodal transportation. The independent variable is whether or not an organization prepositions supplies and the dependent variable is number of changes. ANOVA was conducted, demonstrating that prepositioning of supplies does have an impact on transportation modes changes, with $F=3.12$, $p=0.080$. The regression equation is mode changes = 0.250 + 0.423 preposition with $p=0.080$ for the coefficient and R square is 2.4%. Therefore, we cannot conclude this is a good fit model or a strongly significant model. Although the p-value in ANOVA is slightly higher than 0.05, we can still conclude that propositioning supplies has an impact on transportation mode changes, and that this relationship might become more apparent with more data.

6.2.5 Exploratory Results

Description of truck types used

Different types of trucks are used in transporting supplies, and the frequency of use of each type is described in the following: large: 2.89247 (2.89, 1.84, 93), medium: 3.5579 (3.56, 1.16, 104), small: 3.29897 (3.30, 1.74, 97). Large trucks include semi-trucks and tractor trailers; medium trucks include box trucks and delivery trucks; and small trucks include personal trucks (e.g. Ford F-150). The data above is compiled in the format of mean (mean, standard deviation, count number).The mean is the frequency rating provided by the respondents, with five scales: never, rarely, sometimes, most of the time and all the time. For the convenience of analysis, 1 to 5 scales were used to represent the original scales, and 1 is the never and 5 is all the times with others in between. Generally, medium trucks are most frequently used. However, the results of a t-test show that no significant difference in frequency of use exists

between medium and small trucks (p= 0.117), but small trucks are used more often than large trucks (p=0.019) and medium trucks are also used more often than large trucks (p<0.001).

Impact of cooperation/sharing loads on truck loading to full capacity

In the online survey a question was designed to test the impact of load sharing. ANOVA was conducted to investigate whether load sharing will have an effect on loading a truck to full capacity. The frequency of cooperation and loading to full capacity were rated separately with five scales: never (1), rarely (2), sometimes (3), most of the time (4), and all the time (5). It proves to be that the independent variable does not have a significant impact on the dependent variable since p= 0.547, F= 0.71.

Overall ranking of factors

The respondents were required to rate the overall importance of the factors using a scale from 1 to 5, with 1 the least important and 5 the most. The average score of each factor is shown in Table 5. Cost seems to be the most important one according to the average. Paired T-tests were conducted between each pair of rating averages, P-values are all much higher than 0.05. Therefore there is no statistically significant difference between the factors.

Another question was designed to rank the factors to differentiate the importance between the factors. 51% of the respondents chose cost as the most important one while 32% of the respondents chose type of supplies as the least important one. Although in the above question no significant difference exist between the factors,

Table 5. Average rank of factors*

Average rank of factors	
Cost	4.37(4.37, 0.98, 102)
Distance	4.26 (4.26, 0.86, 104)
Type of supplies	4.15 (4.15, 0.86, 100)
Amount of supplies	4.27 (4.27, 0.75, 101)
Availability of roads/routes	4.20 (4.20, 0.93, 104)

*Note: numbers in cells-mean (mean, standard deviation, count number)

7.0 Discussion

Objective 1

For the transportation of supplies, trucks are used most frequently regardless of number of stops. The use of trucks is significantly higher than the use of any other mode. Rail and ship are the least used modes, and no significant difference in frequency exists between these two modes in the summarized data. Since truck is the mostly used transportation mode, the use of different types of trucks was also surveyed. Medium trucks and small trucks are used most frequently. During the transportation of people, no matter whether in the trip of transporting volunteers or evacuating people, air and vehicle are most frequently used while ship or rail are least used.

The reason that organizations prefer to use trucks to transport supplies most frequently could be due to the fact that transportation by trucks is of low cost in medium distances. Additionally, trucks are more well-known to most people. Availability of trucks can also lead to the high frequency of use since commercial transportation companies use mostly trucks. The reason that this phenomenon needs to be examined is that some of the transportation modes used currently might not be the most cost-efficient mode or the most effective mode. There exists a strong need to educate the organizations' transportation decision makers to expand modes used to ensure efficient transport network.

Objective 2

Most organizations only stop once during each trip, and with mostly only one mode change. Among the change of transportation modes, changes between truck types are most common, much more frequently than other combinations. This also means that it is necessary to study how the organizations choose type of trucks to examine whether their decision process is reasonable.

There is a relationship showing that more stops are correlated with more mode changes. The reason can be that for supplies trucks are most used, so usually only trucks are involved in most changes. Not many changes were made overall because not many stops occurred or transportation modes were used (see objective 1). It is important to learn that not many changes because of the same reason in objective 1 that current use of modes may not be the most efficient ones. Also, if we aim to model transportation networks to inform the design and development of improved networks, it is critical to have an accurate depiction of current mode use.

Objective 3

Distance is considered most often in mode selection in the transportation of supplies, however, all factors (travel distance, cost, type of supplies, and availability of roads) were considered of equal importance (by rating and by ranking). The possible reason that distance is the mostly considered factor is that distance has a great impact on price, time, and other factors. Organizations firstly need to consider distance to determine the related price, delivery time, and other outcomes. Distance makes some modes more/less feasible in certain conditions. For example, it makes more sense to use trucks instead of air if the distance is fairly short.

It is important to know the factors that the organizations consider mostly since it is the key to understand decision making process and why modes are chosen. Therefore, if we want to encourage intermodalism among the organizations, we should address all of the factors in their choice of transportation modes, with an emphasis on distance.

Objective 4

Usually the organizations with larger coverage area will make more stops in the transportation process. Also, prepositioning impacts the number of mode changes, though the relationship between the two was not significantly related. This can be due to the transportation network design. If an organization covers a large area, it usually distributes the supplies at staging areas, and therefore involving more

transportation modes. Objective 4 is important because it is important to consider agency factors for more use of different transportation modes. Some agencies that cover larger areas may be more likely to use intermodal transportation than others that with smaller coverage area.

8.0 Conclusions and Future Work

Generally speaking, in the transportation of supplies and people in disaster relief, there is a clear lack of intermodalism. Also, relief organizations have limited use of modes with an emphasis on truck and air. Decision makers consider many factors when choosing modes, including travel distance, cost, type of supplies, and availability of roads for transporting supplies and travel distance, cost, type of people, availability of roads for transporting people. The frequencies that organizations consider the above factors are also investigated in the project. Findings should be considered when designing/improving disaster relief chains. The current findings have shown that optimal networks may not be used by agencies; therefore, it is important to consider how they make decisions

Future work in this area includes developing a training and education program to inform disaster relief agencies and their decision makers about the availability and benefits of intermodal transportation. The current analysis was constrained to domestic (United States) disaster relief. Expanding the study to include international relief may highlight increased use of intermodal transportation when delivering relief. The findings in this study should also be validated using historical data. Finally, the survey findings can be incorporated into disaster relief chain design and optimization.

9.0 References

1. Balick, B. (2008). Last mile distribution in humanitarian relief. *Journal of Intelligent Transportation Systems* , 12(2), 51–63.
2. Beamon, B. M. (2004). Humanitarian relief chains: issues and challenges. *Proceedings of the 34th International Conference on Computers and Industrial Engineering.* San Francisco.
3. Beamon, B. M., & Balcik, B. (2008). Performance measurement in humanitarian relief chains. *International Journal of Public Sector Management* , 21(1), 4-25.
4. DAC/OECD. (1999). *Guidance for evaluating humanitarian assistance in complex emergencies.* Paris: Organisation for Economic Co-operation and Development.
5. Danida. (2006). *Evaluation guidelines.* Copenhagen: Evaluation Department, Ministry of Foreign Affairs.
6. Davidson, A. L. (2006, May 19). Key performance indicators in humanitarian logistics. Engineering Systems Division, MIT.
7. ECHO. (1999). *Manual for the evaluation of humanitarian aid.* Retrieved 6 30, 2009, from ReliefWeb: http://www.reliefweb.int/rw/lib.nsf/db900sid/LGEL-5CYGNQ/$file/echo-manual-1999.pdf?openelement
8. Frerks, G. (2002). *New issues in refugee research.* UNHCR.
9. Iqbal, Q. (2007). *Comparison of Disaster Logistics Planning and Execution for 2005 Hurricane Season.* Midwest Transportation Consortium (MTC).

10. Jones, W. B. (2000). *Developing a standard definition of Intermodal Transportation.* NCIT.
11. Kapucu, N. (2007). Logistics and staging areas in managing disasters and emergencies. *Journal of Homeland Security and Emergency Management , 4* (2), 1-17.
12. Özdamar, L. (2004). Emergency logistics planning in natural disasters. *Annals of Operations Research* , 129 (1-4), 217–245.
13. Pokhrel, B. (2001, April). *Prepared for CARE Nepal projects.* Retrieved Nov. 26, 2008, from Relief Web: http://reliefweb.int/rw/lib.nsf/db900sid/LHON-5VGJ3V/$file/CARE_Evaluation.pdf?openelement
14. Prater, E. (2001). International supply chain agility. *International Journal of Operations & Production Management* , 823-839.
15. Refugees, U. H. (2002, Sep). *UNHCR's evaluation policy.* Retrieved June 30, 2009, from ReliefWeb: http://www.reliefweb.int/rw/lib.nsf/db900sid/LHON-5UBLVL/$file/UNHCR_evaluation_sept2002.pdf?openelement
16. Thomas, A. (2005). "Humanitarian Logistics: Matching recognition with responsibility." *Asia-Pacific Development Review: Freight & Logistics*.
17. Thomas, A., and Mizushima, M. (2005). "Fritz Institute: Logistics training: necessity or luxury?" *Forced Migration Review*, 22, 60-62.

10.0 Project Dissemination

This project has not yet received any awards, matching funds, or additional funding to date. However, additional funding was awarded through NCIT to continue this line of research by developing an intermodal transportation training tool for disaster relief agencies. Additionally, a proposal is in development for submission to the National Science Foundation (NSF) this fall, using project findings as justification for further research.

Project results have been disseminated in many forms, including conference papers (2), conference presentations/posters (5), and a report of survey results for disaster relief agencies. This allowed for dissemination to both academic and practitioner communities. Additionally, the results of the project are being included in a journal article that is currently in preparation.

Papers/Reports

- Strawderman, L., *Zhang, H., *Jackson, B., *Kolb, B., & Eksioglu, B. (2009). How do disaster relief agencies choose transportation modes? A report to agency representatives.
- Strawderman, L., *Zhang, H., *Jackson, B., *Kolb, B., & Eksioglu, B. (2009). Investigating Decision Criteria Regarding Intermodal Transportation in Humanitarian Supply Chains, *Proceedings of the 2009 Industrial Engineering Research Conference.*
- *Zhang, H., Strawderman, L. (2009). Macroergonomics Analysis of Disaster Relief Chains in Non-profit Organizations. Triennial Meeting of the International Ergonomics Association (IEA), August 2009.

Presentations/Posters

- Strawderman, L., *Zhang, H., *Jackson, B., *Kolb, B., & Eksioglu, B. (2009). INFORMS Annual Meeting, October 2009.

- *Zhang, H., Strawderman, L. (2009). Macroergonomics Analysis of Disaster Relief Chains in Non-profit Organizations. Triennial Meeting of the International Ergonomics Association (IEA), August 2009.
- Strawderman, L., *Zhang, H., *Jackson, B., *Kolb, B., & Eksioglu, B. (2009). Investigating Decision Criteria Regarding Intermodal Transportation in Humanitarian Supply Chains, *Proceedings of the 2009 Industrial Engineering Research Conference.*
- *Zhang, H., Strawderman, L., *Jackson, B., *Kolb, B., & Eksioglu, E. (Feb 2009). "Investigating the Use of Intermodal Transportation in Humanitarian Supply Chains." *Humanitarian Logistics Conference*, Georgia Tech University.
- *Zhang, H., Strawderman, L., *Jackson, B., *Kolb, B., & Eksioglu, E. (Feb 2009). "Humanitarian Supply Chains: Do Relief Agencies Utilize Intermodal Transportation?" *MSU Transportation Workshop*, MSU.

1. Would you consider your project to be basic research, advanced research, or applied research?	**Applied Research**
2. Number of transportation research reports/papers published	**3**
3. Number of transportation research papers presented at academic/professional meetings	**5**
4. Number of students participating in transportation research projects	**1 graduate** **3 undergraduate**
5. Number of transportation seminars, symposia, distance learning classes, etc. conducted for transportation professionals	**0**
6. Number of transportation professionals participating in those events	**0**

APPENDIX 1

Interview Questions

Cargo Transportation

1. What types of supplies do you deliver during a relief effort?
2. Where do you purchase these supplies?
3. Where are your suppliers located? Do you have any overseas?
4. What sort of budget do you follow for getting supplies?
5. How do you transfer supplies from the supplier to the disaster area?
6. How large is the area your agency responsible for relief action?
7. Do you use distribution centers? If so, where are they located?
8. What is the most costly part of delivering supplies?
9. Has your organization encountered any problems in the transportation process?
10. If your agency distributes supplies directly to victims, how is the distribution structured?
11. What are the differences when transporting your cargo before and during a disaster?
12. What do the trucks or other transportation tools do after transporting certain cargo to the destination? Would they transport anything/anybody back?
13. How often do the supplies change transportation modes (e.g. train to truck)? How does this process work?
14. Has your organization encountered any difficulties in transferring supplies between transportation modes?
15. How do you evaluate the effectiveness of transportation choices? Cost? Time?
16. Does your current method meet your organization's needs with respect to cost? Time?
17. How long do supplies generally stay in inventory or at a distribution center?
18. How long does it take to transport good from the distribution center to the disaster area?
19. What sort of technology is used to help in transportation and logistics?

Transportation of People

1. Does your agency help evacuate people from disaster areas? If so, how? What transportation modes are used?
2. How do you transport relief workers into affected areas? What transportation modes are used?

Potential Factors

1. Have you ever cooperated with other organizations, companies, or government agencies to provide disaster relief? How so?
2. Have you ever coordinated with others with regards to transportation of supplies or personnel?
3. How does your organization receive funding? How does this influence your operations?
4. How do you determine who to help?
5. How do you know if you delivered the right amount of aid to the right people?
6. How are your operations evaluated? Are there a set of standards that you try to meet?
7. Does your organization consider past performance when planning future operations?
8. Is there anyone or any organization outside of your agency that evaluates your operations? When?

APPENDIX 2

Survey Questions

1. Would you like to proceed with the survey?
2. In what areas does your organization provide relief? Please select all that apply.
3. What kind of organization would you classify your organization to be? Please select all that apply.
4. When delivering supplies, how often does your organization use each of the following modes?
5. For each transportation mode, which of the following factors impact your decision to use (or not to use) that mode? Please select all that apply.
6. In transferring supplies from one mode to another, which modes are typically included?
7. Where do the changes of transportation modes occur?
8. Why do your supplies change transportation modes?
9. When delivering supplies, how often does your organization use each of the following modes?
10. For each transportation mode, which of the following factors impact your decision to use (or not to use) that mode? Please select all that apply.
11. Please describe which transportation modes are used between each stop.
12. Why do these changes of transportation modes occur?
13. When delivering supplies, how often does your organization use each of the following modes?
14. For each transportation mode, which of the following factors impact your decision to use (or not to use) that mode? Please select all that apply.
15. Consider the delivery of supplies in which you used trucks. How often does your organization use each of the following types of trucks?
16. When transporting supplies, how often is the truck loaded to full capacity before delivery?
17. During an entire trip, do the supplies ever get transferred from one type of truck to another (e.g. semi-truck to box truck)?
18. Since you transfer supplies between different types of trucks, please describe where you transfer the supplies, and what types of trucks you are using in each phase.
19. Why do you transfer supplies between different truck types?
20. Since you only use one type of truck, why did your organization decide to use this type of truck?
21. Does your organization transport volunteers/staff to the affected areas?
22. When transporting volunteers/staff to the affected areas, how often does your organization use each of the following modes?
23. For each transportation mode, which of the following factors impact your decision to use (or not to use) that mode? Please select all that apply.
24. Does your organization evacuate people from affected areas?
25. When evacuating people out of the affected areas, how often does your organization use each of the following modes?
26. For each transportation mode, which of the following factors impact your decision to use (or not to use) that mode? Please select all that apply.
27. How often does your organization share loads when cooperating with other organizations during transporting supplies?
28. Please rate the following factors according to their importance when your organization makes decisions about using different transportation modes.
29. Which factor would you consider to be most important? Which would you consider to be least important?
30. If there are any other factors that are important to your transportation process, please explain below.

31. Feel free to make any other comments about your transportation process here.
32. Once the data collection is completed, researchers will compile a summary of the responses. Would you like to receive a copy of this summary report via email?
33. After the survey is closed, we will be randomly drawing the names of 4 respondents who will each win a $50 Wal-Mart gift card. Would you like to be included in this drawing?
34. Since you indicated that you would like to receive the survey results and/or be entered into the drawing, please type your name and email address so that we may contact you.