# Research Directions in Information Systems for Humanitarian Logistics

**Esther Sangiamkul**
Department of Information Systems and Change Management, School of Management and Governance, University of Twente, Enschede, the Netherlands
e.jaiwai@utwente.nl

**Jos van Hillegersberg**
Department of Information Systems and Change Management, School of Management and Governance, University of Twente, Enschede, the Netherlands
j.vanhillegersberg@utwente.nl

## ABSTRACT

This article systematically reviews the literature on using IT (Information Technology) in humanitarian logistics focusing on disaster relief operations. We first discuss problems in humanitarian relief logistics. We then identify the stage and disaster type for each article as well as the article's research methodology and research contribution. Finally, we identify potential future research directions.

### Keywords

Humanitarian logistics, information technology, disaster relief logistics.

## INTRODUCTION

Over the last decade, the world has witnessed many disasters. There is strong evidence that natural disasters around the world are increasing in terms of frequency and impact. These can occur with little or no warning. The number of disasters has increased up to tenfold in the last century. Recent statistics show that between 1999-2008, 7,791 disasters were reported resulting in 1,273,480 casualties (IFRC, 2009). The most common disaster phenomenon is flooding follow by earthquakes/tsunamis and droughts/food insecurity (IFRC, 2009). Following the increased number of disasters, emergency relief response operations have received increased attention.

In humanitarian aid operations, logistics have always been an important factor and logistics efforts account for 80 percent of disaster relief efforts (Trunick, 2005). Logistics include the delivery of food, medicine and other necessities by railroads, motor vehicles, ocean shipping, and aviation for a considerable period. In addition to the physical distribution of final products, logistics comprises financial and information flows. More efficiency in information exchanges translates directly into better physical and financial logistics. Physical flows occur between the following relief chain processes: resource mobilization, procurement, transportation, stock asset management, and extended point of delivery. Information flows connect the following relief chain processes: preparedness; assessment and appeal; tracking and tracing; monitoring, evaluating and reporting; communicating. Financial flows take place during the subsequent processes: preparedness; assessment and appeal; procurement; and monitoring, evaluation and reporting.

Both humanitarian and business logistics encompasses a range of activities including preparedness, planning, procurement, transporting, warehousing and tracking and tracing (Thomas & Kopczak, 2005). However, humanitarian logistics differ in several ways from business logistics. Kovács and Spens (2007) present an overview of typical characteristics of humanitarian logistics (Table1). The main difference between humanitarian logistics and business logistics is that business logistics usually deals with a predetermined set of suppliers and relatively predictable demand while humanitarian logistics is concerned with a large and changing set of suppliers and very low predictability of demand (Cassidy,2003). Moreover, Business logistics aim at increasing profit while humanitarian logistics aim to mitigate the suffering of vulnerable people (Thomas &

**Reviewing Statement**: This full paper has been fully double-blind peer reviewed for clarity, relevance, significance, validity and originality.

Kopczak, 2005). Also, in most cases humanitarian logistics emphasizes time benefit over economic benefits.

| | Humanitarian Logistics |
|---|---|
| The main aim | Alleviating the suffering of vulnerable people |
| Actor structure | Stakeholder focus with no clear links to each other, dominance of NGOs and government actors |
| 3-phase setup | Preparation, immediate response and reconstruction |
| Basic features | Variability in supplies and suppliers, large-scale activities, irregular demand and unusual constraints in large-scale emergencies |
| Supply Chain philosophy | Supplies are "pushed" to the disaster location in the immediate response phase. Pull philosophy applied in reconstruction phase |
| Transportation and infrastructure | Infrastructure destabilized and lack of possibilities to assure quality of god and medical supplies |
| Time effects | Time delays may result in loss of lives |
| Bounded knowledge actions | The nature of most disasters demands an immediate response, hence supply chains need to be designed and deployed at once even though the knowledge of situation is very limited |
| Suppliers structure | Choice limited, sometimes even unwanted suppliers |
| Control aspects | Lack of control over operations due to emergency situation |

**Table 1. Characteristics of Humanitarian Logistics (Kovács & Spens, 2007)**

Moreover, there are many actors in a humanitarian supply network such as aid agencies, military agencies, logistic providers and government units that do not gain from satisfying demand. Typically, actors in the supply network have no clearly defined linkages to each other. These different actors take different perspectives on humanitarian logistics and can prepare and execute disaster relief operations differently (Kovács & Spens, 2007)

Emergency logistics is a special type of logistics that deals with emergency incidents or disaster events. It refers to supplying emergency materials to the affected areas. During a relief operation, emergency logistics is confronted with urgent and volatile situations and limited time. Therefore, it is often the largest and most complex element of relief operations.

Information Technology is crucial to humanitarian relief efforts. Long (1997) argues that information systems are the single most important factor in determining the success or failure of a disaster relief operation. The use of IT in humanitarian assistance is diverse. To create a strong link between the humanitarian supply chain units, humanitarian logistics information systems can improve the effectiveness of the flow of information among the partners. In recent years, many systems have been developed to support humanitarian logistics. Examples include electronic crisis mapping systems for identifying places where help is needed, information systems for healthcare, satellite imaging and GIS as communication tools for donors and aid workers, crisis early warning systems, etc. These technologies have the potential to help improve the quality of the response to the crisis.

While several of these systems have been developed and reported on in literature, a systematic overview of how IT can support humanitarian logistics is lacking. In this article, we perform a systematic literature review to identify how information systems are used in disaster relief operations. The systematic literature was carried out following the guidelines of Webster and Watson (2002). We survey existing literature in order to get an overview of current research in information systems in humanitarian logistics. For the review, the following question has been set: "How can information systems be used to enhance humanitarian logistics and supply chains management?" In addition, specific questions have been created, which will guide the systematic review.

1. How can the use of information technology in humanitarian logistics be categorized in the literature?
2. What is the problem that humanitarian logisticians face and how can information systems help?
3. How can the supply-chain operations reference model (SCOR) support humanitarian logistics processes?

## METHODOLOGY FOR IDENTIFYING ARTICLES FOR REVIEW

We have collected literature primarily through journals and conference proceedings that are in the areas of humanitarian operations management, disaster management, humanitarian supply chain, operations research and information systems. To gather bibliographic data, several databases were utilized including Scopus, IEEE Xplore and Emerald Text. We also included dissertations, textbooks, working papers and conference proceedings papers. To search these database sources, we constructed a set of search strings: **“(***humanitarian* ***OR*** *aid* ***OR*** *relief* ***OR*** *disaster* ***OR*** *crisis* ***OR*** *emergency* ***OR*** *response****) AND (****logistics* ***OR*** *supply chain* ***OR*** *supply chain management OR transportation)* ***AND (****information* ***OR*** *system* ***OR*** *systems* ***OR*** *technology***)”**

The application of these search strings, returned 2227 papers. After we limited the results to the areas of computer science, decision science, social science, supply chain management, internet, software, information systems, networking and broadcasting, signal processing and analysis, general topics for engineers (math, science and engineering), transportation, robotics and control systems and performed the exclusion process the result set was reduced to 775 papers. Then, abstracts and keywords were assessed manually to test subject relevance resulting in further elimination to 195 papers that deal with information systems in disaster operational management. This type of research is cross-functional. Therefore, these articles appear in a wide variety of academic journals. Finally, to answer our main research question we focused on logistics and supply chain activities. From 195 papers we found only 22 papers that are related to logistics and supply chain activities.

## RESULTS OF LITERATURE REVIEW

We employed several different classification methods and also identified to which stage of an event an article is concerned. Papers are classified based on research methodology, research contribution and disaster type.

### Characteristics of Articles

Our search resulted in 22 articles, with 17 of them published in operation research or transportation systems related journals including the Journal of Intelligent Transportation Systems, European Journal of Operational Research, Disaster, Expert Systems with Applications, Computers & Industrial Engineering, Computers & Operations Research, International Journal of Production Economics and Transportation Research. Only five articles were found in conference proceedings.

Table 2 shows that the most frequently utilized research method is mathematical programming followed by stochastic programming. These two methods are mostly used to solve vehicle routing problems and inventory control problems. There are four stages in the disaster management cycle: mitigation, preparedness, response and recovery. Ninety-six percent of the articles deal with the preparedness and response stages. We found that most of the studies do not focus on specific types of disasters but earthquake and tsunami incidents seem to be the most addressed in the reviewed papers.

### Phases of Emergency Management

Following the lead of the National Governors' Association, emergency management is commonly described in terms of four phases: mitigation, preparedness, response, and recovery. Mitigation activities aim to minimize the effect of the impact or reduce the probability of a disaster. Preparedness activities involve planning, warning and training activities. This phase will prepare a community to respond when a disaster occurs. Response activities minimize the hazards created by a disaster and include all activities undertaken during the disaster, for example evacuation, mobilization, search and rescue activities. Recovery activities are carried out after the disaster. This phase aims to return the affected community to its normal situation; it can be short term or long-term restoration, for example temporary housing, financial assistance, mental health support and medical care. Table 2 lists articles in our literature review based on the stages of the disaster management cycle. About 64% of all papers reviewed address the response stage and 32% address the preparedness stage.

The humanitarian supply chain must provide supplies to beneficiaries in each of these phases and these activities require logistics support. It is important to consider humanitarian logistics as operating in each of the phases in the Disaster Management Cycle (Howden, 2009). Thomas (2003) also indicates that logistics actually serves as a bridge between disaster preparedness and response. The logistic activities differ in volume, variety of supplies and urgency. Table 3 shows the variety of activities in each of these four stages and the characteristics of humanitarian logistics throughout the Disaster Management Cycle.

| | Logistics & Supply Chain IS related papers in disaster operational management |
|---|---|
| *Number of articles* | 22 |
| *Article Type* | |
| Journal | 17 |
| Conference proceedings | 5 |
| Others | 0 |
| *Research Methodology* | |
| Mathematical Programming | 8 |
| Stochastic Programming | 5 |
| Expert Systems/Intelligent Systems | 2 |
| Probability and Statistics/logistic regression analysis | 2 |
| Soft OR | 5 |
| *Disaster Cycle Phases* | |
| Mitigation | 0 |
| Preparedness | 7 |
| Response | 14 |
| Recovery | 1 |
| *Research Contribution* | |
| Theory | 3 |
| Model | 11 |
| Application | 4 |
| Practical | 4 |
| *Disaster Type* | |
| Flood | 1 |
| Earthquake/Tsunami | 6 |
| Hurricanes/Cyclones | 2 |
| Humanitarian | 3 |
| All disasters | 8 |

**Table 2. Characteristics of Articles in Logistics & Supply Chain Information Systems in Disaster Operational Management**

### Information Technology in Humanitarian Logistics

According to Howden (2009), Humanitarian Logistics Information System (HLIS) must be able to operate across the entire disaster management cycle. They must be scalable to manage the large number of suppliers during the response phase, as well as the high diversity of supplies across the recovery and mitigation phases and manage the flow of information from the preparation phase to the response phase. In the preparation phase, HLIS should be used to record what emergency response supplies are available at the onset of the disaster. Logisticians must be trained to use these information systems and simulations should be run in preparation of their use in disaster responses. In the response phase, HLIS can eliminate the need for duplicate data entry and offer more timely and accurate information (Lee & Zbinden, 2003). During transition to the recovery phase, HLIS will enable organizations to know what supplies have been distributed and what supplies are remaining. This will allow them to utilize surplus supplies in recovery activities and to better plan for the next disaster response. In the recovery phase, we can offer a suitable environment to develop and test new HLIS that can then be applied to disaster response activities.

| Phases | Activity | Period | Logistics Volume | Supplies Required | Urgency | Procurement of Supplies |
|---|---|---|---|---|---|---|
| Mitigation | - Zoning and land use management to prevent occupation of high hazard areas<br>- Barrier construction to deflect disaster forces<br>- Active preventive measures to control developing situations<br>- Building codes to improve disaster resistance of structures<br>- Tax incentives or disincentives<br>- Controls on rebuilding after events<br>- Risk analysis to measure the potential for extreme hazards<br>- Insurance to reduce the financial impact of disasters | Long Term-Continuous | Low | Varied supplies | Low | Local |
| Preparedness | - Recruiting personnel for the emergency services and for community volunteer groups<br>- Emergency planning<br>- Development of mutual aid agreements and memorandums of understanding<br>- Training for both response personnel and concerned citizens<br>- Threat based public education<br>- Budgeting for and acquiring vehicles and equipment<br>- Maintaining emergency supplies<br>- Construction of an emergency operations center<br>- Development of communications systems<br>- Conducting disaster exercises to train personnel and test capabilities | Long Term-Continuous | Low | Specific standard supplies prepositioned for disaster response | Low | Local |
| Response | - Activating the emergency operations plan<br>- Activating the emergency operations center<br>- Evacuation of threatened populations<br>- Opening of shelters and provision of mass care<br>- Emergency rescue and medical care<br>- Fire fighting<br>- Urban search and rescue<br>- Emergency infrastructure protection and recovery of lifeline services<br>- Fatality management | Days-Months | High | Specific standard supplies: food, medical supplies, water and sanitation equipment, shelter, household kits, etc. | High: Lead times for supplies can make the difference between life and death. | International |
| Recovery | - Disaster debris cleanup<br>- Financial assistance to individuals and governments<br>- Rebuilding of roads and bridges and key facilities<br>- Sustained mass care for displaced human and animal populations<br>- Reburial of displaced human remains<br>- Full restoration of lifeline services<br>- Mental health and pastoral care | Days-Months | Medium | Varied supplies depending on the context of the disaster: reconstruction material, livelihoods equipment | Medium: here maybe government and donor pressure to complete recovery activities | Local-International |

**Table 3. Activities of Disaster Cycle Phases and Humanitarian Logistics throughout the Disaster Management Cycle**
(Adapted from *How Information Systems Can Improve Humanitarian Logistics* by Howden,2009)

Blecken and Hellingrath (2008) have reviewed and assessed five SCM tools for humanitarian operations (SUMA, LSS, Helios, LogistiX, Sahana). They report that these tools have been developed under differing priorities and objectives. Some of the tools in their study fulfill several of the requirements and functionalities but none of the tools is able to completely satisfy all requirements. Specifically, stock organization, final distribution issues, route planning and scheduling, and resources planning are not addressed by any of these tools.

Vehicle routing problems and emergency relief material distribution under urgent situations have been investigated by Balcik et al. (2008). Yi et al (2007) proposed an Ant Colony Optimization (ACO) for solving complex logistics support and evacuation coordination problems. A mathematical model for helicopter mission planning during disaster relief operations was developed by Barbarosoglu et al.(2002). Tzeng et al.(2007) constructed a relief-distribution model using the fuzzy multi-objective programming method for designing relief delivery systems in a real case. Chiu & Zheng (2007) proposed a cell transmission model (CTM)-based linear-programming model solution for simultaneous mobilization destination, traffic assignment, and departure schedule for multi-priority groups (SMDTS-MPG) for real-time emergency response in disasters. Two mathematical models for path selection in emergency logistics management are also presented by Yuan and Wang (2009). Zografos et al.(2008) integrated mathematical models addressing hazardous materials logistical and emergency response decisions in their DSS for hazardous materials transportation risk management. This system provides a user friendly GIS based environment for routing and scheduling the distribution of hazardous materials and supporting decisions related to the emergency response location and routing, and the specification of the evacuation routes of an impacted area.

| Classification Domain | Disaster Cycle Phases / Reference |
|---|---|
| Intelligence System/ Multi-agent System | **Preparedness** : Benini et al.(2009), Sheremetov et al.(2004)<br>**Response** : Balcik et al. (2008), Barborosoglu (2002), Chang et al.(2007) , Lau et al.(2008) |
| Real-time response system/Web based/ Web services | **Response** : Sheu and Jiuh-Biing (2010), Yi and Hong (2007), Tomaszewski B.M. et al. (2006) |
| GIS/Satellite images/Remote sensing | **Preparedness**: Yeletaysi et al.(2008), |
| Modeling /Statistical Modeling/Visualization | **Preparedness**: Lodree et al.(2009), Mete et al.(2009), Taskin et al.(2009), Yi and Hong (2007)<br>**Response**: Mete et al.(2009), Sheu and Jiuh-Biing (2010), Yuan and Dingwei (2009), Zografos et al.(2002), Zografos et al.(2008), Tzeng et al.(2007), Yi et al.(2007)<br>**Recovery**: Lodree et al.(2009) |

**Table 4 Articles List by IT Domain and Disaster Cycle Phases**

A scenario planning approach for flood emergency logistics preparation under uncertainty was proposed by Chang et al. (2007) which can integrate with a decision-making tool for flood emergency logistics. Lodree et al. (2009) proposed a model and solution method for the disaster relief inventory control problem. They present a mathematical formulation of the problem followed by a solution approach and then present a numerical example and simulation to illustrate how the methodology can be implemented in practice. Mete et al. (2009) also presented an original model for the dynamic location allocation problem with control of customer service level and safety stock optimization. The multi-period inventory control problem is formulated as a stochastic programming model by Taskin et al. (2009). This model allows the inventory manager to determine an appropriate stock level at the beginning of the hurricane season.

Lau et al. (2008) modeled a supply chain as a multi-agent system where agents are subject to an adjustable autonomy. They proposed a centralized fuzzy framework for sensing and translating environmental changes to the changes in autonomy levels and objectives of the agents. Sheremetov et al. (2004) defined a generic multi-agent architecture of a CMS (Contingency Management System). A multi-layer computer architecture supporting the conceptual model is also described in their paper.

Tomaszewski et al. (2006) developed the Geocollaborative Web Portal (GWP), an asynchronous, open source geospatial information framework designed to support international group interaction and knowledge management in the context of humanitarian relief logistics. Yeletaysi et al. (2008) also focused on a framework for integrating GIS and systems simulation as an analysis tool. They demonstrated a two-step analysis framework where a GIS model is combined with a systems simulation tool to perform a supply chain interruption analysis. Falasca et al. (2008) proposed a simulation-based framework that incorporated concepts of resilience into the process of supply chain design. Their framework incorporates strategic considerations (i.e., network design decisions) to quantify coordinated supply chain resilience and to support decision making in terms of the development of measurable, more effective supply chain configurations.

With regards to emergency response models, Wei et al.(2009) developed an emergency response model through systematic analysis. They summarized key measures concerning effective operation of emergency logistics system and handling emergency incidents.

This overview indicates that most of the HLIS related papers concentrate on using mathematic modeling including stochastic programming to optimize logistics systems. There are also a few papers related to multi-agent technology as summarized in Table 4.

### Humanitarian Supply Chain Problems

Logistics and supply chains play a critical role in humanitarian aid especially in disaster management. However recent events have shown that problems occur with regard to supply chain structure, distribution network configuration, inventory control, disaster assessment, cooperation and coordination, procurement uncertainties and limitations and performance measurement (Beamon, 2004).

Russell (2005) also described several problems in relief efforts: *Unsolicited and unsuitable goods*— the goods need to be culturally and technologically appropriate. *Infrastructure* — most of the infrastructure in the disaster area was damaged and caused inaccessible infrastructure, and the lack of infrastructure needed for large-scale assistance led to bottlenecks, delays, and congestion at entry points to the disaster area. Also communication problems and poor information technology infrastructure caused very limited visibility into incoming shipments. *Political pressure* — in some cases, tsunami aid became politicized adding unpredictable constraints to the relief logistics. *Lacking the necessary logistics skill* — in the ideal situation, after a disaster, work must be done to determine the nature of the disaster, the extent of the damage, the initial needs of the victims, the secondary threats to the population, the local response capacity, the need for international assistance, and the means for delivering any needed assistance. In practice, organizations often send teams with personnel lacking the necessary logistics skills to perform such assessments. *Competing supply chains*— during the relief operation all aid agencies need many of the same items concomitantly. As each agency sets up its own supply chain and starts procuring necessary supplies, the multiple relief chains can compete against each other. *Financial supply chains* — before relief can begin to flow, the financial supply chain must be put into place. This is a difficult process in the beginning and takes time.

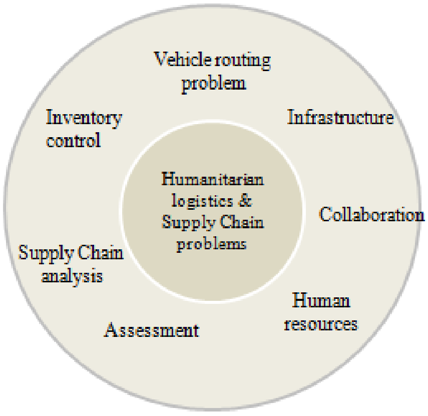


**Figure. 1 An Overview of Humanitarian Logistics and Supply Chain Problems**

Figure 1 shows an overview of Humanitarian logistics & supply chain challenges. The uncertainty in number, location, warehouse presence and distribution centers and also the uncertain demand raises issues such as how much inventory to hold and how much to reorder causing vehicle routing and inventory control problems. Destruction of basic and supporting infrastructure causes difficulty in setting up and supporting supply chains. If there are insufficient transport services or limited warehouse capacities, bottlenecks problems can also arise in the supply chain.

Collaboration problems can arise when there is no central command. Duplication efforts from government and other NGOs may also occur, especially when they operate at the same time in the same disaster area. This can also lead to competition for and clogging of the basic resources. Due to lack of effective tracking and tracing systems, it is difficult to predict response times and difficult to determine whether the supplies are enough to meet the demand. The humanitarian logistics aid sector can be regarded as very traditional in that it still regards logistics as a necessary expense. According to Kovács & Spens (2007), there is a shortage of logistics experts. The supply chain processes are largely manual and there is inadequate assessment and planning and limited collaboration and coordination. It also lacks operational knowledge and has insufficient investments in technology and communication as well as a lack of knowledge of the latest methods and techniques.

### Supply Chain Operations Reference Model

The Supply Chain Operations Reference Model (SCOR model) is a business process reference model. The SCC (Supply Chain Council) established the SCOR model for evaluating and comparing supply chain activities and performance. It provides a framework that links business process, metrics, best practices and technology into a unified structure to support communication among supply chain partners and to improve the effectiveness of supply chains.
Table 5 shows that most information technologies used in the reviewed papers are focused on performance reliability of the supply chain in delivering and the speed responsiveness at which a supply chain provides products .There are only a few papers that focus on supply chain agility and supply chain asset management.

| Process | Supply Reliability | Supply Chain Responsiveness | Supply Chain Agility | Supply Chain Cost | Supply Chain Asset management |
|---|---|---|---|---|---|
| **Plan** | Benini et al.(2009) ,Lodree et al.(2009), Sheu and Jiuh-Biing (2010),[12],[18] | Yi and Hong (2007), Tomaszewski B.M. et al. (2006), Yi et al.(2007), | Yeletaysi et al.(2008) | Yi and Hong (2007) | Benini et al.(2009), Lodree et al.(2009) |
| **Source** | Mete et al.(2009), Taskin et al.(2009) | | | Taskin et al.(2009) | |
| **Make** | - | - | - | - | - |
| **Deliver** | Mete et al.(2009), Sheremetov et al.(2004) | Balcik et al. (2008), Barborosoglu (2002), Chang et al.(2007), Lau et al.(2008), Sheu and Jiuh-Biing (2010), Yi and Hong (2007), Yuan and Dingwei (2009), Zografos et al.(2002), Zografos et al.(2008), Tzeng et al.(2007), Yi et al.(2007), | | Balcik et al. (2008), Sheu and Jiuh-Biing (2010), Tzeng et al.(2007) | |
| **Return** | - | - | - | - | - |

**Table 5. Articles List by SCOR Metrics and Processes**

## FUTURE RESEARCH DIRECTIONS

To identify potential research directions in the logistics of disaster operations, Altay & Green (2006) suggested that the following areas and research questions should be given priority: *Multi-agency research* — the multi-functional nature and political hierarchy in emergency response organizations are well suited for hierarchical planning and multi-attribute, multi-objective approaches as various groups have different priorities. So what are the optimal organizational and network structures that would facilitate communications and coordination in the resolution of disasters? *Methods* — how to determine decision rules on what method to use to address a specific class of disaster problems. Can new techniques be developed to take advantage of the inherent structure of disaster problems? *Technology* — what are the underlying assumptions and building blocks of logistical problems immediately before, during and after disasters? *DOM (Disaster Operational Management) stages* — the area that lacks DOM research is recovery planning so there are some key questions that can be included, for example, what are operational problems of damage assessment and cleanup? What are the key characteristics of food and monetary aid collection, allocation and distribution problems? Can we modify existing distribution and tracking models? *Business continuity* — why do businesses fail in the aftermath of a disaster? What is the rate of failure? What distinguishes survivors from failing businesses? *Infrastructure design* — how can we incorporate survivability as an objective in the design and maintenance of infrastructures without disturbing routine operations but improving operations under disaster conditions. *Management engineering* — could existing vehicle routing, location and allocation models for emergency services be improved and adapted to disaster situations and mass emergencies? Could comprehensive models be developed to coordinate mitigation and preparedness planning with responses? What are the fundamental differences between disaster response operations and everyday emergency responses?

The Humanitarian Service Science and Engineering (HSS&E) community focuses on capacity building, measurement and standards. Their research agenda was proposed with the goal of better understanding, designing, deploying and sustaining the value of a shared, open GIS-based information infrastructure, user-centered information systems for coordination and service management, shared and continually optimized logistics systems, internationally accepted standards and monitoring methods (Haselkorn, 2008).

## CONCLUSION AND DISCUSSION

Humanitarian logistics differ in several ways from business logistics and therefore requires its own system designs and theories. Research into humanitarian logistics has increased in response to the increasing number of disaster incidents. The use of IT to support humanitarian logistics is a promising field. While several studies have appeared on humanitarian logistics information systems, a systematic overview of the field is lacking.

This study has presented such an overview based on a systematic review of the literature. Several different classification methods were applied to assess the literature. Only a small fraction of the body of literature on humanitarian operations deals with humanitarian logistics information systems. The preparedness and response phase receive most attention, while mitigation and recovery are hardly addressed at all. Most studies apply mathematical modeling and operations research techniques to address logistics issues. Only a small portion of research deals with intelligent IT. Among the SCOR metrics, supply chain agility receives very little attention.

Research in information technology in disaster relief logistics should emphasize more on (1) IT capacity building, measurement and standards, (2) Management engineering — vehicle routing, location and allocation models improving for disaster situations and mass emergencies, (3) using information technology support for multi-attribute, multi-objective approaches to optimize organizational and network structures.

We also found that there are still many problems in humanitarian logistics in terms of reliability, responsiveness and agility. We believe that making better use of information technology in humanitarian logistics can improve the effectiveness and efficiency of complex logistics support and evacuation coordination problems in terms of reliability, responsiveness and agility. There are still several areas to improve in the use of information technology for humanitarian supply chain agility, making agility more attainable. There are many new information technologies and innovations in various layers of the IT architecture to be explored, such as, the integration of technologies and standards (Web services, XML), business process design and management tools, mobile technologies, RFID, wireless sensors and Web 2.0.

## REFERENCES

1. Altay, N., & Green Iii, W. G. (2006). OR/MS research in disaster operations management. *European Journal of Operational Research*, 175(1): 475-493.
2. Balcik, B., Beamon, B., & Smilowitz, K. (2008). Last Mile Distribution in Humanitarian Relief. Journal of Intelligent Transportation Systems, 12, 51-63.
3. Barbarosoglu, G. (2002). An interactive approach for hierarchical analysis of helicopter logistics in disaster relief operations. European Journal of Operational Research, 140, 118-133.
4. Beamon, B.M. (2004). Humanitarian relief chains: issues and challenges, 34th International Conference on Computers and Industrial engineering San Francisco, CA, USA, November, 14-16
5. Blecken, A. F., & Hellingrath, B. (2008, May 2008). Supply Chain Management Software for Humanitarian Operations : Review and Assessment of Current Tools. Paper presented at the 5th International ISCRAM conference, Washington, DC, USA.
6. Cassidy, W. (2003).A logistics lifeline, Traffic World, October 27 (2003) 1.
7. Chang, M., Tseng, Y., & Chen, J. (2007). A scenario planning approach for the flood emergency logistics preparation problem under uncertainty. Transportation Research Part E: Logistics and Transportation Review, 43, 737-754.
8. Chiu, Y.-C., & Zheng, H. (2007). Real-time mobilization decisions for multi-priority emergency response resources and evacuation groups: Model formulation and solution. Transportation Research Part E: Logistics and Transportation Review, 43(6), 710-736.
9. Falasca, M., Zobel, C. W., & Cook, D. (2008). A Decision Support Framework to Assess Supply Chain Resilience. Paper presented at the 5th International ISCRAM Conference, May 2008, Washington, DC, USA,.

10. Haselkorn, M. (2008).Toward a Research Program in Humanitarian Service Science and Engineering. In Proceedings of the 5th International ISCRAM Conference, Washington D.C., USA

11. Howden, M. (2009, May 2009). How Humanitarian Logistics Information Systems Can Improve Humanitarian Supply Chains: A View from the Field. Paper presented at the 6th International ISCRAM Conference, Gothenberg, Sweden.

12. IFRC. (2009). World Disasters Report. Focus on Early Warning, Early Action. Geneva, Switzerland: International Federation of Red Cross and Red Crescent Societies.

13. Kovács, G., & Spens, K. M. (2007). Humanitarian logistics in disaster relief operations. International Journal of Physical Distribution & Logistics Management, 37(2), 99-114.

14. Lau, H., Agussurja, L., & Thangarajoo, R. (2008). Real-time supply chain control via multi-agent adjustable autonomy. Computers & Operations Research, 35, 3452-3464.

15. Lee, H. W., & Zbinden, M. (2003). Marrying logistics and technology for effective relief. Forced Migration Review, 18, 34-35.

16. Lodreejr, E., & Taskin, S. (2009). Supply chain planning for hurricane response with wind speed information updates. Computers & Operations Research, 36, 2-15.

17. Long, D. (1997). Logistics for disaster relief: engineering on the run. IIE Solutions 29(6): 26-29.

18. Mete, H. O., & Zabinsky, Z. B. (2009). Stochastic optimization of medical supply location and distribution in disaster management. International Journal of Production Economics, 1-9.

19. Russell, T. E. (2005). The Humanitarian Relief Supply Chain: Analysis of the 2004 South East Asia Earthquake and Tsunami. Massachusetts Institute of Technology.

20. Sheremetov, L. (2004). Intelligent multi-agent support for the contingency management system. Expert Systems with Applications, 26, 57-71.

21. Taskin, S., & {Lodree Jr.}, E. J. (2009). Inventory decisions for emergency supplies based on hurricane count predictions. International Journal of Production Economics, 1-10.

22. Thomas, A. S., & Kopczak, L. R. (2005). From Logistics to Suppy Chain Management : The path forward in the humanitarian sector: Fritz Institute.

23. Tomaszewski, B. M., MacEachren, A. M., Pezanowski, S., Liu, X., & Turton, I. (2006). Supporting humanitarian relief logistics operations through online geocollaborative knowledge management. Paper presented at the Proceedings of the 2006 international conference on Digital government research, San Diego, California.

24. Trunick, P. A. (2005). Delivering relief to tsunami victims: logisticstoday.

25. Tzeng, G.-H., Cheng, H.-J., & Huang, T. D. (2007). Multi-objective optimal planning for designing relief delivery systems. Transportation Research Part E: Logistics and Transportation Review, 43, 673-686.

26. Webster, J and Watson, RT (2002) Analyzing the Past to Prepare for the Future: Writing a Literature Review. MIS Quarterly 26 (2), 13-23.

27. Wei, C., & Jing, L. (2008, 12-15 Oct. 2008). Operational analysis on emergency logistics system and emergency response model. Paper presented at the Service Operations and Logistics, and Informatics, 2008. IEEE/SOLI 2008. IEEE International Conference on.

28. Yeletaysi, S., Fiedrich, F., & Harrald, J. R. (2008). A Framework for integrating GIS and Systems Simulation to analyze Operational Continuity of the Petroleum Supply Chain. Paper presented at the 5th International ISCRAM Conference, Washington, DC, USA.

29. Yi, W., & Kumar, a. (2007). Ant colony optimization for disaster relief operations. Transportation Research Part E: Logistics and Transportation Review, 43, 660-672.

30. Yuan, Y., & Wang, D. (2009). Path selection model and algorithm for emergency logistics management. Computers & Industrial Engineering, 56, 1081-1094.

31. Zografos, K., & Androutsopoulos, K. (2008). A decision support system for integrated hazardous materials routing and emergency response decisions. Transportation Research Part C: Emerging Technologies, 16, 684-703.