International Journal of Business, Human and Social Sciences
ISSN: 2517-9411
Vol:8, No:6, 2014

Decision Tree Modeling in Emergency Logistics Planning

Yousef Abu Nahleh, Arun Kumar, Fugen Daver, Reham Al-Hindawi

Abstract**—**Despite the availability of natural disaster related time series data for last 110 years, there is no forecasting tool available to humanitarian relief organizations to determine forecasts for emergency logistics planning. This study develops a forecasting tool based on identifying probability of disaster for each country in the world by using decision tree modeling. Further, the determination of aggregate forecasts leads to efficient pre-disaster planning. Based on the research findings, the relief agencies can optimize the various resources allocation in emergency logistics planning.

Keywords**—**Decision tree modeling, Forecasting, Humanitarian relief, emergency supply chain.

I. Introduction

MANAGING supply chain network has become a vital global issue in the context of the severe effect of natural disasters and a wide variety of other reasons such as industrial plant fires, transportation delays, work stoppages, and it remains a largely unexplored area in research and practice. With increasing numbers of natural and man–made disasters, organizations are facing challenges due to limited number of available experienced logistics experts and the need for better coordination of those involved in vulnerable logistics networks. Moreover, companies running lean operations no longer have inventory or excess capacity to make up for production losses, resulting into rapid escalation of material flow problems to wide-scale network disruptions.

The dynamic nature of the global supply chain environment dictates that the companies with resilient supply chains in the future will have a sustainable competitive advantage over other firms.

Over the past three decades, the number of reported disasters has increased fourfold. Around 6.1 billion people have been affected by disasters with an estimated damage of almost 2.3 trillion dollars [1]. An adequate level of mitigation measures and a coordinated post-disaster relief logistics management may help to reduce the loss of both human lives and economic damage. Time plays a critical role in the logistic plan, and it directly affects the survival rate in affected areas. This makes the task of logistics planning and supply chain management more complex than conventional distribution problems.

The emergency supply chain differs from the normal supply chain in many ways such as huge surge of demand with a short notice, damaged roadways, chaotic behavior of victims, break-down of infrastructure and communication lines, short lead time, major uncertainties about what is actually needed and what is available at the site, large volumes of critical supplies to be transported and so on. Under these critical conditions, delivering supplies becomes an extremely difficult task for the suppliers with limited or nonexistent transportation capacity. The design of a reliable emergency supply chain network is hampered by a lack of (1) knowledge about how emergent supply chains operate and interact, (2) methods to analyze and coordinate the flows of both priority and non-priority goods, and (3) scientific methods to analyze logistics systems under extreme conditions. Furthermore, forecasting and evaluating the reliability of transportation networks are significant for path selection in emergency logistics management under earthquake and other natural disasters. The reliability of arcs and nodes of a transportation network is time-varying under disaster conditions.

In major non-natural disasters such as terrorist attacks (e.g., September 11, 2001) or natural disasters such as the Hurricane Katrina of 2005 a disaster management structure organizer will face significant problems of emergency services and evacuation. In several disasters, the disaster area requests residents to be evacuated of the area and need to be moved to safe places as fast as possible, leading to a sudden and great surge of demands for emergency services.

Humanitarian relief organizations and NGO's are mostly non-profit organizations with the idea of providing critical services to the public in order to minimize the pain and sufferings after a natural disaster. According to UN Office for Humanitarian Affairs, there is increasing human vulnerability in natural disasters, 244.7 million affected in 2011, and in complex emergencies 54 million in need of life-saving assistance in 2011. Furthermore, emergency management involves preparing for disaster before it happens, responding to disasters immediately, as well as supporting, and rebuilding societies after the natural or human-made disasters have occurred. It is essential to have comprehensive emergency plans and evaluate and improve the plans continuously.

Immediately after the disaster, there is a huge surge of demand of relief materials with a short notice and the humanitarian relief organizations often face significant problems of emergency logistics management such as

Yousef Abu Nahleh is with the School of Aerospace, Mechanical and Manufacturing Eng., RMIT University, Melbourne, VIC3000,Australia (phone: +61399256226; e-mail: s3319062@student.rmit.edu.au).

Arun Kumar is with the School of Aerospace, Mechanical and Manufacturing Eng., RMIT University, Melbourne, VIC3000, Australia (phone: +61 3 9925 4328; e-mail: a.kumar@rmit.edu.au).

FugenDaver is with the School of Aerospace, Mechanical and Manufacturing Eng., RMIT University, Melbourne, VIC3000, Australia (phone:+61 3 9925 6008; e-mail: fugen.daver@rmit.edu.au).

Reham Al-Hindawi is with the Industrial Eng., Hashemite University, Zarqa, Jordan (phone: +962 (5) 3903333; e-mail: Alhindawi_r@yahoo.com).

transporting large amounts of many different commodities including food, clothing, medicine, medical supplies, machinery, and personnel from several origins to several destinations inside the disaster area. The transportation of supplies and relief personnel must be done quickly and efficiently to maximize the survival rate of the affected population and minimize the cost of such operations. The demands in the relief chain occur in irregular amounts and at irregular intervals and occur suddenly, such that the locations are often completely unknown until the demand occurs.

In large-scale disasters such as earthquakes or hurricanes and biological attacks, facilities cannot satisfy the demand in the disaster area by the simple point that if the region is damaged, then the facilities placed near the disaster area will be damaged as well. For instance, in the 2008 earthquake in Sichuan region of China, Wenchuan, destroyed an area about 66 km long and 20 km wide, was called as "very terrible" [2]. Majority of local health facilities had been damaged and their personnel killed or injured. After the earthquake in Haiti (January 2010), we saw from the media that almost all help came only from international organizations due to the total damage of local facilities. This study develops a forecasting tool to assess the logistic and supply needs, and the population's needs as a consequence of a disaster, as well as the available local capacity and complementary requirements to meet those needs. It is important to determine not only the needs of the affected population, but also the needs of the relief organizations that perform the relief tasks. A disaster scenario is usually a dynamic and changing situation, thus the tool must help not only to identify the current situation, but also to anticipate future needs

II. Literature Review

One of the earliest studies for logistics management in relief operations was addressed by [3], for the increasing refugee population in Somalia. Subsequently, [4] addressed the need of logistics management in relief operations for the 1985 Mexico City earthquake. Some specific features of the emergency logistics problem were studied in the routing literature by [5], [6]; however, the general logistics problem involving relief supplies distribution characteristics received far less attention. Further, [7], [8] addressed the mathematical formulations for commodities transportation in emergency. [9] extended the commodity logistics model to integrate the wounded evacuation and emergency medical centre location problems, and the logistics operations are illustrated by a concrete application on earthquake scenario. Further, [10] present a meta-heuristic of Ant Colony Optimization (ACO) for solving the logistics problem arising in disaster relief activities. The logistics planning involves dispatching commodities to distribution centers in the affected areas and evacuating the wounded people to medical centers. Furthermore, [11] proposed a model to determine the number and location of distribution centers to be used in relief operations.

Humanitarian logistics, also called relief supply chain management, have gained attention due to an increasing number of natural and man-made disasters and the recognition of the central role of logistics in responding to these [12]. The needs are expected to increase another five-fold over the next fifty years' [13]. However, the literature in the area of humanitarian logistics is largely focused on handbooks and general procedures [14]. [15] have reviewed the literature on disaster operations management, resulting in only 109 academic articles published in operations management related journals, indicating needs for more research on the subject. The analytical techniques used in the field of operations research and management include mainly simulation, optimization and statistics. They concluded that most of the disaster management research was related to social sciences and humanities literature. [16], and [17] discuss the need for speed and better coordination between those involved in the humanitarian logistics network. Logistics in humanitarian aid operations are highly dynamic, innovative and characterized by complexity of operational conditions and often politically volatile climate, high level of uncertainties in terms of demand and supplies, pressure of time and high staff turnover [18], [19]. Some studies such as [20], [21], [13], [19], and [22], emphasized that some supply chain concepts share similarities to emergency logistics and therefore can be successfully adapted in emergency response logistics. Reference [23] discussed the food security and humanitarian assistance among displaced Iraqi populations in Jordan and Syria. In a recent study, [24] highlighted pre-storm emergency supplies inventory planning. More research is needed to develop new models or new variants of old ones, especially in preparedness, response and recovery stages of the disaster management.

Although the literature in logistics management is extensive, the particular problem on the reliability of supply chains in emergency logistics planning has received little attention. Reference [25] studied the supply chain system reliability based on Markov process for normal business supply chains. Huang evaluated the reliability of railway emergency supply chain in China. Reference [26] proposed the GO methodology to analyze the transportation network reliability for emergency logistics; [27] recently studied the supply chain reliability in emergency situations in China. However, none of these studies provide an in-depth analysis of reliability of supply chains under natural disasters and vulnerability. Moreover, to my best knowledge, there is no research dealing with these two aspects of humanitarian and commercial logistics in an integrated manner which is the subject of this study, though such plan can significantly enhance the system-wide operational efficiency.

Reference [28] mentioned five reasons why the research in this area is very important. The first reason, [29] emphasized that the current method is not enough and that something has to be done to improve the emergency supply chain. Second, the cost in terms of both economic impact and human suffering is still growing. Third, there are many different organizations donating money and resource for the humanitarian / disaster relief event, so we have to find the best way to spend this money [30]. The fourth reason, how emergency supply chain systems can be organized to deal with uncertainty. Finally, by studying emergency supply chain we can deal with outcome rather than cost such as time because the time is very important in relief process specially the first 72 hours.

III. Methodology

A. Decision Tree Modeling

Decision trees are usually used to provision decision-making in an uncertain situation. For instance, in finding the probability of disaster happening for each country and the approximate number of victims before the disaster happens or when it happens so the government and the relief organization can predict the number of victims. This information can be gathered to respond faster to the situation. Decision trees sort this type of analysis reasonably easy to apply.

A decision tree has three kinds of nodes: (a) decision (b) chance, and (c) leaf. The branches creating from a decision node exemplify options existing; those originating from an unplanned node characterize uncontrollable occasions. At every chance node, every division is assigned a restricted probability like the probability of the occurrence represented by the branch, conditioned upon the information existing at the node. Leaf nodes exemplify the probable endpoints, i.e. the consequences of the decisions and chance results connected with the path from the start of the tree.

IV. Results and Discussion

The disaster data for each country has been collected from the Centre for Research on the Epidemiology of Disasters (CRED)'s EM-DAT worldwide database for natural disasters. This has been sponsored by the United States Agency for International Development's Office of Foreign Disaster Assistance (USAID/OFDA). It contains data from year 1900 to 2011. CRED has compiled the data from numerous sources including UN agencies, NGOs, insurance companies and research institutes [31]. Systematic collection and analysis of these data provides invaluable information to governments and relief agencies in charge of relief and recovery activities. EM-DAT provides an objective basis for vulnerability assessment and rational decision making in disaster situations. In addition to providing information on the human impact of disasters, such as the number of people killed, injured or affected, EM-DAT provides disaster-related economic damage estimates and disaster-specific international aid contributions.

If you could somehow define exactly what would occur as a result of selecting each choice in a decision, making decisions would be easy. In calculating the relief materials quantity decisions, where there are significant uncertain variables which make the approximate number of victims very hard to predict. The objective of choosing the optimal solution, the top set of selections at the decision nodes—can be reached by applying a "roll-up" method to the decision tree. Beginning with the leaf nodes and continuing recursively to the root, each node is tagged by the value of the condition it exemplifies. Every chance node is labeled with the probable value of its replacements, and every decision node is labeled with the value of the optimal that has the biggest rate. Consider the next instance to describe the "roll-up" idea.

Suppose a disaster happens in one country in the world, in this situation the lead time will be approximately zero. So the government and the relief organization should take the decision "What is the approximate number of victims?" very fast. By using the proposed Decision tree Model, which is builded on the disaster historical data, they can find an approximate number of people to start relief operation, after that they can modify it to the actual data according to the current situation. Table I shows a sample of the Decision tree Model with the all available data.

If the probability of disaster occur for specific country wanted for example "Ethiopia" and the type of disaster is flood. The probability of disaster will be multiplication of all the probabilities.

$$P(\text{Ethiopia}, Flood) = P(Flood) \times P(disaster\ happen\ in\ \text{Ethiopia}) \times P(Region) \times P(Continet) \times P(Disaster\ happen\ or\ not)$$

$$P(\text{Ethiopia}, Flood) = 0.036 \times 0.1261 \times 0.4082 \times 0.1558 \times 0.7323$$

$$P(\text{Ethiopia}, Flood) = 0.7450 \times 0.1170 \times 0.4082 \times 0.1558 \times 0.7323$$

$$P(\text{Ethiopia}, Flood) = 0.004$$

V. Conclusion

In disaster response actions, the survival rate among affected people depends on the effectiveness of search and rescue operations and this requires, in turn, a good pre-disaster planning. Despite availability of annual natural disaster related data from 1900 to 2011, there is no forecasting tool available to humanitarian relief organizations to forecast the aggregate number of people affected, economic losses, number of natural disasters, and the number of people killed. Using the historical data, the probabilities of disaster occurrence have been found for each country in the world and for each kind of disaster. These probabilities have been used to build the Decision tree models which will use as a forecasting tool to predict the probability of disaster and all the variables. Furthermore, Decision trees are usually used to provision decision-making in an uncertain situation. These forecasts are used by the various international and national humanitarian organizations in emergency logistics planning. This leads to better coordination of search and rescue activities and efficient evacuation of injured people. Furthermore, overall health conditions of everyone in the affected area depend on the timely availability of commodities such as food shelter and medicine.

TABLE I
SAMPLE OF THE DECISION TREE MODEL

P (Disaster)	Continent	P(Hit by natural disasters)	Region	P(Hit by natural disasters)	Country	P (Hit by natural disasters)	Type of disaster	Average of no_ killed	Average of No. of Victims	Average of total-damages ('000 US$)	Average # natural disasters	P(Hit by natural disasters)
73.23 %	Africa	15.58%	Eastern Africa	40.82%	Burundi	6.19%	Earthquake	3	120	0	1	3.70%
							Epidemic	82	104887	0	7	25.90%
							Flood	2	5122	0	13	48.10%
							Storm	4	8228	0	6	22.20%
					Comoros	1.83%	Epidemic	7	749	0	2	25.00%
							Flood	2	2500	0	1	12.50%
							Storm	0	300	0	1	12.50%
							Volcano	0	71050	0	4	50.00%
					Djibouti	1.61%	Epidemic	19	886	0	3	42.90%
							Flood	65	80000	706.3	3	42.90%
							Storm	0	775	0	1	14.30%
					Eritrea	0.92%	Flood	0	3507	0	2	50.00%
							Insect infestation	0	0	0	1	25.00%
							Storm	3	15675	5165	1	25.00%
					Ethiopia	11.70%	Drought	0	12600000	0	1	2.00%
							Epidemic	90	2879	0	6	11.80%
							Flood	48	40857	423.7	38	74.50%
							Insect infestation	0	0	0	1	2.00%
							Mass movement dry	13	0	0	1	2.00%
							Mass movement wet	13	97	0	2	3.90%
							Volcano	5	2000	0	1	2.00%
							Wildfire	0	5	0	1	2.00%
					Kenya	12.61%	Drought	0	2700000	0	1	1.80%
							Earthquake	1	0	50000	2	3.60%
							Epidemic	117	401337	0	17	30.90%
							Flood	20	48656	398	31	56.40%
							Mass movement wet	14	7	0	4	7.30%
					Madagascar	8.72%	Epidemic	121	3055	0	1	2.60%
							Flood	10	27197	30000	5	13.20%
							Insect infestation	0	0	3500	1	2.60%
							Storm	50	178318	20141.3	31	81.60%

REFERENCES

[1] A. Kumar, Y. L. A. Latif, and F. Daver "Developing forecasting tool for humanitarian relief organizations in emergency logistics planning," *World Academy of Science, Engineering and Technology Journal*, pp. 1687-1693November 2012.

[2] M. D. Petersen, A. D. Frankel, S. C. Harmsen, C. S. Mueller, K. M. Haller, R. L. Wheeler, *et al.*, "Documentation for the 2008 Update of the United States National Seismic Hazard Maps: U.S. Geological Survey," *USGS* 2008.

[3] D. Kemball-Cook and R. Stephenson, "Lessons in logistics from Somalia," *Disasters*, vol. 8, pp. 57-66, Mar 1984.

[4] S. A. Ardekani and A. G. Hobeika, "Logistics Problems in the Aftermath of the 1985 Mexico City Earthquake," *Transportation Quarterly,* vol. 42, pp. 107-124, 1988.

[5] B.-T. Aharon, C. Byung Do, M. Supreet Reddy, and Y. Tao, "Robust optimization for emergency logistics planning: Risk mitigation in humanitarian relief supply chains," *Transportation research part B: methodological,* vol. 45, pp. 1177-1189, 2011.

[6] P. Tatham and G. Kovács, "The application of “swift trust” to humanitarian logistics," *International Journal of Production Economics,* vol. 126, pp. 35-45, 7// 2010.

[7] M.-S. Chang, C.-F. Hsueh, and S.-R. Chen, "Real-time vehicle routing problem with time windows and simultaneous delivery/pickup demands," *Journal of the Eastern Asia Society for Transportation Studies,* vol. 5, pp. 2273-2286, 2003.

[8] L. Özdamar, E. Ekinci, and B. Küçükyazici, "Emergency Logistics Planning in Natural Disasters," *Annals of Operations Research,* vol. 129, pp. 217-245, 2004/07/01 2004.

[9] W. Yi and L. Özdamar, "A dynamic logistics coordination model for evacuation and support in disaster response activities," *European Journal of Operational Research,* vol. 179, pp. 1177-1193, 6/16/ 2007.

[10] W. Yi and A. Kumar, "Ant colony optimization for disaster relief operations," *Transportation Research Part E: Logistics and Transportation Review,* vol. 43, pp. 660-672, 11// 2007.

[11] B. Balcik and B. M. Beamon, "{Facility location in humanitarian relief}," *International Journal of Logistics Research and Applications,* vol. 11, pp. 101-121, // 2008.

[12] M. Jahre, "Researcher project: HUMLOG-NET – Humanitarian Logistics Networks," *Norway,* 2008.

[13] A. S. Thomas and L. R. Kopczak, "From logistics to supply chain management: The path forward in the humanitarian sector," *Fritz Institute,* 2005.

[14] B. M. Beamon and S. A. Kotleba, "Inventory modelling for complex emergencies in humanitarian relief operations," *International Journal of Logistics: Research and Applications,* vol. 9, pp. 1-18, // 2006.

[15] N. Altay and W. G. Green III, "OR/MS research in disaster operations management," *European Journal of Operational Research* vol. 175 pp. 475-493, 2006.

[16] G. Kovacs and K. M. Spens, "Humanitarian logistics in disaster relief operations. In Jahre, Marianne (ed.): Logistics in the New Valley," *CD-ROM Proceedings of the 18th Annual Conference for Nordic Researchers in Logistics, NOFOMA , Oslo, Norway,* 2006.
[17] A. Thomas, "Why logistics? ," *Forced Migration Review,* vol. 18, p. 4, 2003.
[18] R. Oloruntoba and R. Gray, *Suppl Chain Manage.,* vol. 11, p. 115, 2006.
[19] L. N. V. Wassenhove, "Humanitarian aid logistics: supply chain management in high gear†," *Journal of the Operational Research Society,* vol. 57, pp. 475-489, 2005.
[20] B. M. Beamon, "Humanitarian relief chains: issues and challenges," in *Proceedings of the 34th International Conference on Computers and Industrial Engineering*, 2004, pp. 77-82.
[21] A. S. Thomas, "Humanitarian Logistics: Enabling Disaster Response," *Fritz Institute,* 2007.
[22] Y. Ye and N. Liu, "A Bayesian Group-Information-Updated sequential approach for humanitarian logistics planning in natural disasters," *Institution of Logistics and Decision Optimization, School of Management, Zhejiang University, China,* 2011.
[23] S. Doocy, A. Sirois, J. Anderson, M. Tileva, E. Biermann, J. D. Storey, *et al.*, "Food security and humanitarian assistance among displaced Iraqi populations in Jordan and Syria," *Soc Sci Med,* vol. 72, pp. 273-82, Jan 2011.
[24] E. J. Lodree and Jr, "Pre-storm emergency supplies inventory planning," *Journal of Humanitarian Logistics and Supply Chain Management,* vol. 1, pp. 50-77, 2011.
[25] J. Zhang, N. Mou, and M. He, "Research of the Supply Chain System Reliability Based on the Markov Process," in *Logistics*, ed, 2008, pp. 1276-1281.
[26] J.-m. Cai and X.-m. Li, "The possibility go methodology; analysis of transportation network reliability for emergency logistics under earthquake disasters," in *Emergency Management and Management Sciences (ICEMMS), 2011 2nd IEEE International Conference on*, 2011, pp. 274-277.
[27] Y. M. Zhang, "Reliability analysis of the emergency logistics supply chain," *Applied Mechanics and Materials,* vol. 170-173, pp. 101-105, 2012.
[28] J. M. Day, S. A. Melnyk, P. D. Larson, E. W. Davis, and D. C. Whybark, "Humanitarian and Disaster Relief Supply Chains: A Matter of Life and Death," *Journal of Supply Chain Management,* vol. 48, pp. 21-36, 2012.
[29] G. Kovács and K. Spens, "Identifying challenges in humanitarian logistics," *International Journal of Physical Distribution & Logistics Management,* vol. 39, pp. 506-528, 2009.
[30] J. Knight and R. Piltz, "Federal Disaster Budgeting:Are We Weather Ready?," *Climate Science Watch,* August 5 2011.
[31] D. Guha-Sapir, F. Vos, R. Below, and S. Ponserre, "Annual Disaster Statistical Review 2011, The numbers and trends, CRED, IRSS," *Universite Catholique de Louvain, Brussels, Belgium,* 2011.