Freight Transportation and Service Personnel Allocation in Humanitarian Logistics

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Abstract

Efficient transportation logistics of humanitarian supplies and service providers are a crucial success factor in preparing for the operations. The aftermath of a humanitarian crisis requires quicker responses to the affected people. The disaster response plan includes enormous transportation planning and logistics to move service personnel, and emergency freight to the affected region. Transportation models serve as critical decision-making tools to obtain the best possible resource allocation and cost optimization objectives to provide quick responses to a disaster situation. Based on an example case, the paper formulizes a multi-objective transportation model to optimize the logistics cost of moving service personnel, and emergency freights for a long distance. The result shows the proposed models provide the delivery given the capacity constraints while reducing the costs.

Keywords: Emergency freight, service personnel, transportation network, logistics

1. Introduction

Natural and man-made disasters have devastating consequences for people worldwide, particularly those living in developing countries. In 2016 alone, there were 327 disaster events, of which 191 were natural disasters, and 136 were man-made disasters [1]. Man-made disasters such as war, civilian attacks, bombs, significant fires, explosions, and transportation (such as maritime and aviation) occur unexpectedly in various regions. More than 90% of the disaster- and crisis-affected people live in developing countries that usually cannot provide sufficient help themselves [2]. Among the affected countries, Yemen, Iraq, Syria, Myanmar, Afghanistan, Somalia, and the Democratic Republic of Congo need the most humanitarian services.

Logistics operations such as procuring relief aid and transportation are essential in the humanitarian relief chain and account for around 80% of all disaster relief activities [3]. This paper presents the emergency freight and service personnel relocation model following the assumption that the humanitarian services have already started in an affected area. For the supplies and personnel allocation, a network of depots has been established, i.e., depot locations are already in place, and their distances and average travel costs are known. The demand for emergency equipment, relief item, and service personnel needed for humanitarian operations is known from experience. Humanitarian operations planning requires collaboration among service agents to allocate an appropriate number of service personnel and transportation of emergency goods to the service area faster. Selecting the transportation network, hub structure, and capacity constraints plays an important role in developing the model. The problem in consideration is a multi-objective transportation planning decision includes (i) minimizing freight transportation cost and (ii) the costs of service personnel allocation. Such optimization problems with multiple objectives can be solved by different approaches [4]. This paper focuses on the two primary objectives, transportation of emergency freight and relocation of service personnel for humanitarian services. After a brief literature review, the following section describes the transportation model. The next section is an application of a real scenario and interpretation. The computational result presents the cost optimization. A short discussion and future research recommendation conclude the paper.

2. Literature Review (12 font)

Freight transportation planning is vital for delivering emergency supplies and equipment during humanitarian operations. Research focuses on vehicle routing, network design, minimizing cost, and resource allocation. Humanitarian logistics is distinct from commercial supply chains and logistics operations because of uncertainties in the transportation network, hub location, changing facility capacity, changing demand, road hazards, limited availability of resources, and other security challenges such as service personnel safety, shelter, and hygiene as well as the efficient and timely delivery [5].

Humanitarian operations focus on faster response and minimum transportation costs. Identifying humanitarian operations such as transportation routes, storage and handling, distribution, and performance evaluation [6]. The network design includes identifying the transportation routes connected to the affected area. Analysis of the safety of the sources to destination links following a disaster is essential. Researchers studied network reliability in emergency freight transportation [7, 8]. Alumur (2012) introduced multiple modes and hubs in the traditional transportation model, considering air hubs and ground hubs along with the corresponding operation of hub links [9]. A transportation model integrating queuing model with a hub network discussed the logistics needs and hub framework in a serial queuing system [10].

The transportation model incorporated waiting times in the resource allocation framework [11]. The hub network analysis and the introduction of different service types in the logistics network. For example, greater service (i.e., faster delivery) follows direct shipment with high cost [12]. A hybrid hub and spoke network model is proposed, allowing immediate shipment among nodes instead of using a pure hub network system [13]. The primary objective of disaster management is to provide the availability of emergency support at a minimum cost. The next section describes the model.

3. Method

The Transportation Problem deals with determining the minimum-cost plan for transporting commodity and service personnel from several sources to several destinations. The following mathematical model presents the freight TUES and service personnel reallocation. A network representation of the model setup is shown in Figure 1.

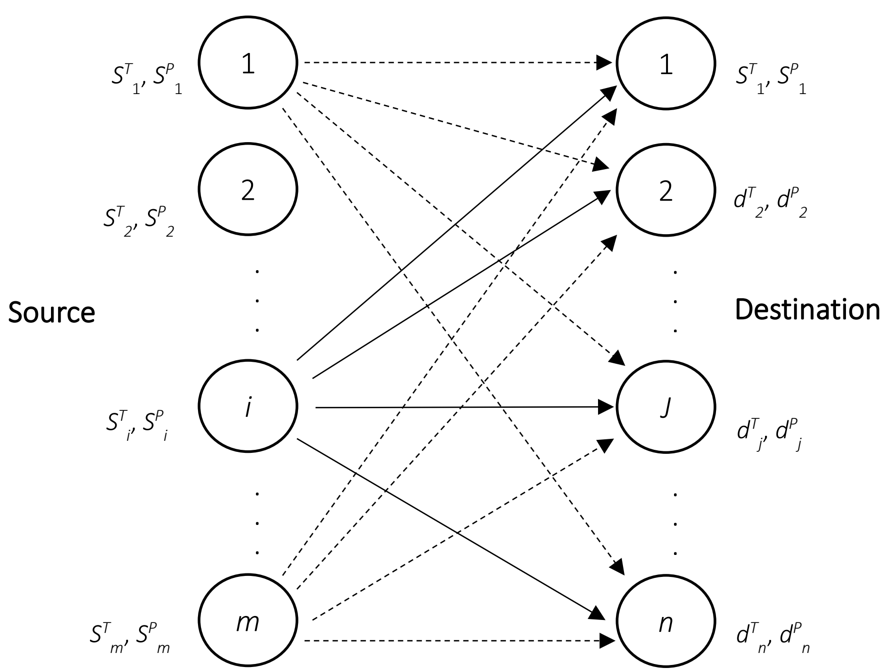

Figure 1. Transportation network model

Assume there are *m* sources or origins and *n* destinations. At source S_i there are *i* location the commodity exists, and S_i^T for freight TUEs (twenty-foot equivalent unit) and S_i^P is the service personnel, respectively at location i. Demand at the j-th destination is denoted by d_j. Demand at destination j *are* d_j^T and d_j^P represent demand of TUEs and the service personnel, respectively at location *j*. The cost of transporting one unit of the commodity from the *i*-th source to the *j*-th destination is denoted c_{ij}. The notations, X_{ij}^T *and* X_{ij}^P represent what quantity will be transported from source *i* to the destination *j*. The problem is to determine the optimum X_{ij} that will minimize the overall transportation cost. The nodes of the network represent amounts of the relief item at the sources, intermediatory depots, and destination points. Every arc represents a material flow in the model.

At the *i*-th source, the transportation quantity for Tues, *T* and service personnel, *P* are equivalent to source quantity.

$$\sum_{j=1}^{n}(X_{ij}^T + X_{ij}^P) = (S_i^T + S_i^P) \qquad 1 \le i \le m$$

As the *j*-th destination, the demand quantity for Tues, T and Personnel, P is equivalent to the transportation quantity:

$$\sum_{i=1}^{m}(X_{ij}^T + X_{ij}^P) = (d_j^T + d_j^P) \qquad 1 \le i \le n$$

According to continuity condition, if demand equals supply, then the equation (and model) is *balanced*:

$$\sum_{i=1}^{m}(S_i^T + S_i^P) = \sum_{i=1}^{m}\sum_{j=1}^{n}(X_{ij}^T + X_{ij}^P) = \sum_{j=1}^{n}\sum_{i=1}^{m}(X_{ij}^T + X_{ij}^P) = \sum_{i=1}^{m}(d_j^T + d_j^P)$$

Given the transportation network flow, the objective function minimizing total costs is given below.

$$Min\ Z = \sum_{j=1}^{n}\sum_{i=1}^{m}\left(C_{ij}^T . X_{ij}^T + C_{ij}^P . X_{ij}^P\right) \qquad (1)$$

The costs indicate the cost for transporting Tues and service people between the supply source and distribution hubs. Each of these services, there are different debarkations used such as air bases for service personnel, and seaports for cargo. The same ports of embarkation is used both service personnel flight and cargo transportation with constraint capacity limitations. In the case where demand and supply are not equal, the solution is to add a dummy source or dummy destination to compliment the difference. The transportation model subjects to the following constraints:

$$\sum_{j=1}^{n} X_{ij}^T = S_i^T \qquad \sum_{j=1}^{n} X_{ij}^P = S_i^P \qquad i = 1, \dots, m \qquad (2)$$

$$\sum_{i=1}^{m} X_{ij}^T = d_i^P \qquad \sum_{i=1}^{m} X_{ij}^P = d_i^P \qquad j = 1, \dots, n \qquad (3)$$

$$X_{ij}^T \ge 0 \qquad X_{ij}^P \ge 0$$

The objective is to minimize transportation cost *Z* (Eq. 1), satisfying constraints (Eq. 2) and (Eq. 3). Total supply should be less than or equal to the available supply (Eq. 2). Sum of shipments to a destination should be less than or equal to the demand (Eq. 3). The constraints of the model are mostly continuity conditions, as the model is based on a network flow formulation.

4. Application (Case Study)

To evaluate the model's scope, we considered a case study of rebuilding the war-torn regions of Iraq. The transportation model is to find the optimal strategy for transporting quantity, i.e., TUEs of emergency humanitarian supplies, construction equipment, and reallocation of service personnel. While we took some of the information from security deployment data, the case study could be more precisely real due to the security and classified nature of the information. All the assumptions are based on one of the author's professional experiences while working in the region. The decision-maker directed the move of the emergency supplies, construction equipment, and service personnel. This movement includes freight cargo and service personnel from four embarkation ports to the destinations through intermediary hubs to restore facilities and rebuild civil infrastructure. For service personnel movements, there were two primary air hubs: Al Asad, Iraq, in Western al Anbar Province, and Ali al Salem in Kuwait. We only use military airlifts (flights) from these bases to deliver the service personnel to the destination, although they use commercial flights from Germany, Kuwait, and other Middle Eastern airports. For cargo movement, all cargo had to be marshaled, accounted for, cleaned, and pre-cleared before transport via established ground lines of communication (GLOCs) to one of three ports of debarkation: Aqaba, Jordan via the Northern GLOC; Kuwait Naval Base (which included area Kuwaiti ports) via the main Southern GLOC; and Umm Qasr, Iraq, via an alternate Southern GLOC.

For simplicity of this presentation, all cargo is transported via sealift, although many high-value or perishable items (i.e., medical supplies) are airlifted. The airbases of debarkation are for service personnel relocation, and seaports of debarkation for cargo. The ports of embarkation receive both cargo and service personnel. Capacity limitations constrain each intermediary hub. Hypothetical constraints are assigned so as not to include potentially classified and sensitive capacity information. In Figure 2, the map below depicts the location of each transportation node in the rebuilding region in Iraq.

Figure 2. Intermediary transportation hubs in Iraq

In Iraq, an estimated 6.7 million people in Iraq, including 3.3 million children (under age 18) and 3.3 million women and girls, continue to need some form of humanitarian assistance and protection (14]. There are international humanitarian efforts to support rebuilding the infrastructure of Iraq since the Iraq War in 2003. International projects involved and implemented efforts to repair and upgrade Iraqi water and sewage treatment plants, electricity production, hospitals, schools, housing, and transportation systems. However, it is challenging for reconstruction actors to find safety, security, and legitimate partnership in the region

Figure 3 presents transportation supply network for humanitarian relief freight

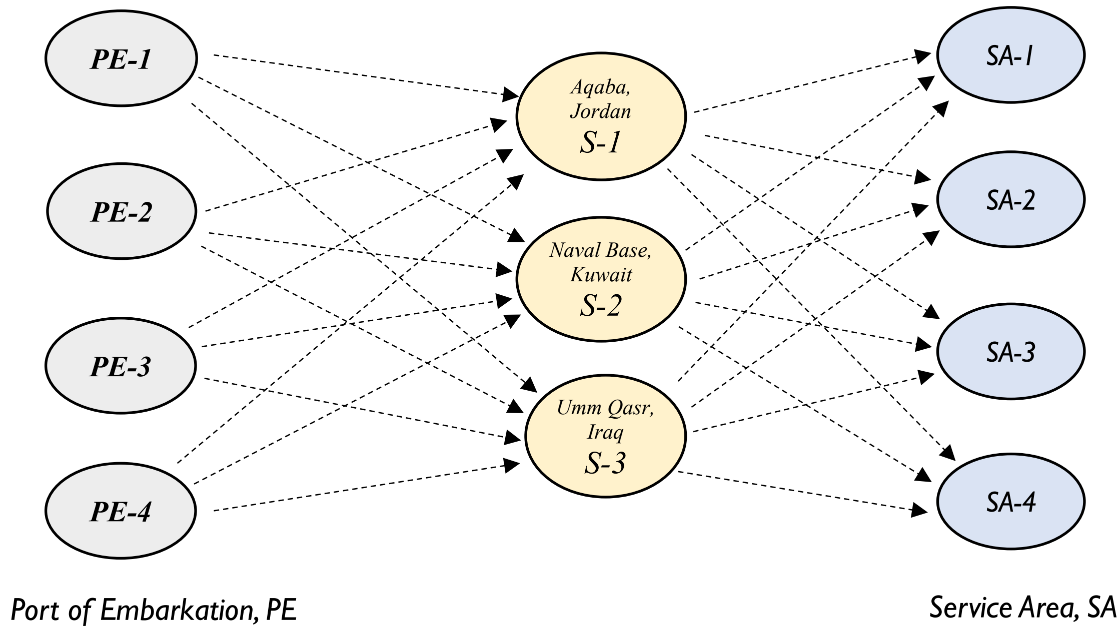

Figure 3. humanitarian relief freight transportation supply network

Following is the emergency service personnel supply network shown in Figure 4.

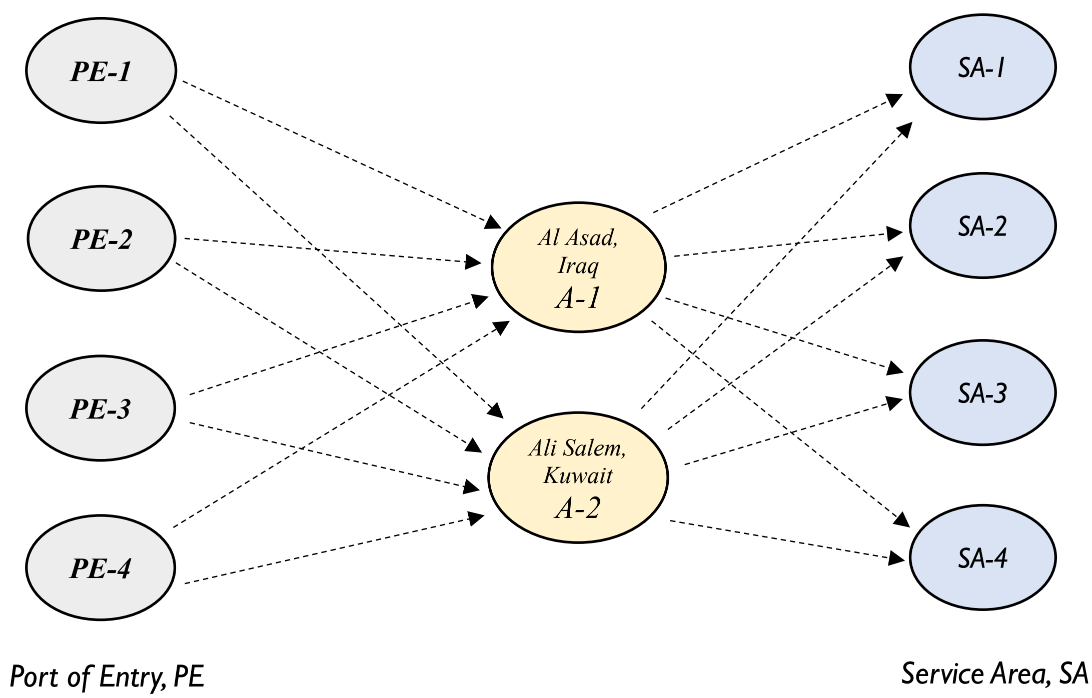

Figure 4. Humanitarian service personnel transportation network

5. Results and Discussion

The objective function (1) yields the minimum transportation cost. Table 1 and Table 2 include the TUEs data and capacity constraints at the port of embarkation, intermediary hubs, and destination.

Table 1. Relief freight and support personnel transport data

PER PASSENGER AND PER TEU TRANSPORTATION COSTS									
	Regional Debarkation Hubs		Ports of Debarkation			Ports of Embarkation (*PE*) Sea/Airports			
	SUPPLY CAPACITY		SUPPLY CAPACITY			DEMAND CAPACITY			
TEUS	Al Asad, Iraq (*A*1)	Ali al Salem, Kuwait (*A*2)	Aqaba, Jordan (*S*1)	Naval Base, Kuwait (*S*2)	Umm Qasr, Iraq (*S*3)	*PE*-1	*PE*-2	*PE*-3	*PE*-4
Service Area, SA-1	2000	1900	140	80	110	80	100	210	85
Service Area, SA-2	2000	1900	140	80	110	80	100	210	85
Service Area, SA-3	2000	1900	140	80	110	80	100	210	85
Service Area, SA-4	2000	1900	140	80	110	80	100	210	85
Personnel	*A*1	*A*2	*S*1	*S*2	*S*3	*PE*-1	*PE*-2	*PE*-3	*PE*-4
Service Area, SA-1	210	180	0	0	0	0	0	0	0
Service Area, SA-2	210	180	0	0	0	0	0	0	0
Service Area, SA-3	210	180	0	0	0	0	0	0	0
Service Area, SA-4	210	180	0	0	0	0	0	0	0

Table 2. Capacity constraints at the supply source and regional depots

Debarkation Hub		*SA*-1, TEUS	*SA*-1, Personnel	SA-2, TEUS	*SA*-2, Personnel	SA-3, TEUS	*SA*-3, Personnel	SA-4, TEUS	*SA*-4, Personnel
Al Asad Cap (*A*1)	=	4	1000	2	200	1	100	8	200
Ali al Salem Cap. (*A*2)	=	4	1500	2	400	1	150	8	300
Aqaba Cap (S1)	=	700	0	300	0	100	0	50	0
KNB Cap (S2)	=	1500	0	400	0	200	0	200	0
Umm Qasr Cap. (*S*3)	=	400	0	100	0	30	0	30	0
Port of Embarkation (PE)									
PE-1	<=	1000	2000	250	500	200	220	80	400
PE-2	<=	500	200	100	50	75	25	40	50
PE-3	<=	500	1000	200	300	75	115	60	200
PE-4	<=	1000	200	250	70	225	35	75	25

The model setup provides a solution for routing and capacity of transporting humanitarian fleet such that expected total transportation costs is minimized. Similar to real world transportation network, the model is dependent on cost and capacity constraint.

After the model setup, the solution is analyzed by the Excel spreadsheet. An array of formulas is established that cycles through each combination of costs in the network and subjects the iterations to the quantity constraints listed above. Table 3 presents a screenshot example of this array – set for each transport services.

Table 3. Results of humanitarian relief freight and support personnel transportation cost

CALCULATED QUANTITES (Cost Optimized Transportation Route Matrices)										
	Air Base Embarkation Hubs		Sea Ports of Embarkation			Ports of Embarkation (PE)				Total Transportation
Transportation (TEUs)	Al Asad, Iraq (*A*1)	Ali al Salem, Kuwait (*A*2)	Aqaba, Jordan (*S*1)	Kuwait Naval Base (*S*2)	Umm Qasr, Iraq (*S*3)	*PE*-1	*PE*-2	*PE*-3	*PE*-4	$Cost
Service Area-1	4	4	700	1,500	400	1,000	500	108	1,000	$515,280
Service Area-2	2	2	300	396	100	250	100	200	250	$185,730
Service Area-3	1	1	100	200	30	200	-	-	132	$64,420
Service Area-4	8	8	50	159	30	80	40	60	75	$83,595
Total	15	15	1,150	2,255	560	1,530	640	368	1,457	$849,025
(Personnel)										
Service Area-1	1,000	1,500	-	-	-	2,000	200	100	200	$480,000
Service Area-2	200	200	-	-	-	140	50	140	70	$78,000
Service Area-3	100	150	-	-	-	108	25	83	35	$48,000
Service Area-4	200	300	-	-	-	231	50	194	25	$96,000
Total	1,500	2,150	-	-	-	2,479	325	516	330	$702,000
									Total =	**$1,551,025**

The MS Excel Solver is used to find the optimized value of transportation costs given the capacity constraint. The transporting quantities of all TUEs and service personnel from four ports are summarized in the above matrix and then multiplied by the corresponding transportation costs to obtain the total cost of relocating support staff and emergency freight. The aforementioned is the best combination of relief TUEs and support personnel transport and expenses.

6. Conclusion

Generally, in disaster management, the transportation of emergency freight and service personnel reallocation planning needs to be improved. Transportation models serve as critical decision-making tools for quick responses and bringing necessary supplies to a disaster region. This paper's transportation model has two primary operations objectives: transportation of humanitarian relief and supporting staff. The minimization of the transportation cost model identified the optimal quantity of TUEs and humanitarian support personnel to reallocate in the disaster area, given the capacity constraints at the supply source and intermediary hubs. The process includes four supply sources (ports of embarkations), intermediary debarkation hubs, and four regions as the destination. Among the intermediary hubs were two airports for support personnel and high-value cargo and three seaports of debarkation for TUE's supplies. The main reason to apply the transshipment model is that it may be cheaper to ship through intermediate or transient nodes before reaching the destination. The model is primarily to support the rebuilding of war-devastated regions. However, the model is easily adjustable to any humanitarian mission and disaster support operations.

Further research could, e.g., include intermodal transportation considering the cost structure of the different modes. Another possible extension could be the requirements of capacity uncertainty in developing the distribution model for disaster situations and developing a more comprehensive humanitarian activity that incorporates several more tasks and delays.

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Biography

Wallace A. Burns, Jr. is a Professor of Transportation and Logistics Management at the W. E. Boston School of Business, American Military University, and a retired US Naval supply officer. Professor Burns holds multiple professional certifications, including Project Management Professional (PMP), Certified in Logistics, Transportation, and Distribution (CLTD), Certified Information Systems Security Professional (CISSP), Certified Defense Financial Manager (CDFM), and Lean Six Sigma Black Belt (LSSBB). He earned his doctorate in Interdisciplinary Leadership from Creighton University, holds master's degrees in Industrial Engineering Technology from the University of Southern Mississippi and Management from Houston Baptist University, and earned a bachelor's degree in Economics from the University of Mississippi.

Mohammad Rahman is an Associate Professor in the school of Engineering Science and Technology at the Central Connecticut State University. His research and teaching focus on supply chain strategy & logistics, decision making under uncertainty, and the six-sigma quality process. His articles appeared in academic journals, including the European Journal of Operations Research, the Journal of the Operational Research Society, and published book chapters. He presented papers at national and international conferences and regularly serves as a journal reviewer. Rahman served as PI and Co-PI in research projects sponsored by The American Association of University Professors (AAUP), US Department of Transportation (USDOT), and Mississippi Department of Education (MDE). He participated in the Pan-American Advanced Studies Institutes Program Award (PASI-NSF), NASA Academy of Aerospace Quality Workshop award. He serves as an executive member of Industrial Engineering & Operations Management (IEOM) and member of other professional forums.