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A case study on flood relief service supply chain in Kerala

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Abstract
During August 2018, the state of Kerala witnessed the worst flood in the history as a result of unusually high rainfall. According to the Kerala Government records, over a million people were evacuated and accommodated in 3,274 relief camps across the 14 districts. In order to sustain the lives of the affected people, urgent relief services were to be provided timely and accurately. Even though the resources were supplied to different relief camps, they were either excess or deficit on several occasions. For effective operation of these supply chain activities actual demand of each camp should be calculated considering various factors and transportation should be carried out in lower risk routes. By studying the conditions existed during the flood period, indicators affecting the demand of a camp was studied. The transportation network condition was also studied for selecting the right routes for supplying. In this paper a criteria for calculating the exact demand of relief camps is presented and a transportation matrix with the risk and time as criteria is formulated. A model is also proposed by studying the selected camp sites and the selected resource points. The result of the study proposes an efficient and timely relief supply service model for urgent disaster incidents.

Keywords: disaster relief; relief service supply; demand estimation; risk factor; supply chain

1. Introduction

At the present, the number of people getting affected by climate-related disasters are increasing drastically. Whenever a disaster occurs, it questions our response system. The government is often criticized for the mismanagement and lack of preparation towards the disaster. Recent studies have demonstrated the increasing contribution of supply logistics in the field of disaster relief management.

Recently Kerala state have been heavily struck by massive floods, which was considered to be the disaster of the century. Due to unexpected heavy rainfall the first start of the flood took place during the end of July. A severe series of continuous rainfall was experienced during the month of August 2018. This has resulted into a massive flood. The number of casualties were high and the damage caused was severe. During the emergencies people often face problems regarding the transportation of basic necessities to the people in need. When looking onto the situation after a flood scenario, it is clear that the proper distribution of the basic necessities were not made. This calls for an effective supply chain. In many places the resources were in excess, whereas other places lacked resources. Other issues faced was the improper transportation channel and the improper time management which eventually resulted in the increase in risk. Disaster relief management has greater relation with the supply chain management. The transportation of the basic utilities and relief during a disaster scenario has to be done quickly and efficiently. A proper and efficient supply chain management in disaster relief eventually results in maximizing the survival rate of the casualties and minimizing the risk. This study focuses on formulating an effective supply of resources by considering the demand of inhabitants and the risk involved in transporting the materials.

2. Literature review

Wapee Manopiniwes and *et al*. proposed a model which minimizes the sum of total cost of relief operations corresponding to the cost of warehouse, shipping cost and holding cost of relief items [1]. The model was created based on the case study of Thai floods.

Guojun Ji and Caihong Zhu proposed three evaluating indicators associated with disaster affected areas [2]. The first indicator represents the ratio of dead relative to the total population in a given affected area. The second one denotes the building damaged condition such as if it is completely damaged or damage level is low in the affected area for a given time. The third denotes the distance which include traffic conditions, environmental and geographical locations associated with given affected area in a given interval of time.

D. Clay Whybark discussed about the major issues involved during the distribution phase. The author claimed that preparation of the distribution system is concerned with timeliness. The warehouse activities have different considerations during disaster circumstances. The push pull technique involved in the management of disaster relief inventory is also discussed. This technique requires moving control to the decentralized managers and having proper communication to get the information.

Gwo-Hshiung Tzeng and *et al.*, proposed a fuzzy multi objective programming to create an emergency relief distribution model. This model was prepared based on a major earthquake occurred at Taichung in 1991. This model takes the quickest route from supply point to demand point by using Trans CAD software. The three main objectives of the model is to minimize total cost and total travel time and to maximize satisfaction [4].

3. Model formulation

Through this study an attempt was made to construct a relief service distribution model for disaster situations. One of the major reasons for the inefficient supply of materials to the various camps is the imprecise information about the demand of the material at that camp. Identifying the exact demand of relief camps, locating the availability of the resources and assessing the transportation facilities are the major tasks involved in disaster relief supply chain.

The basic amenities like food, water, cloths and other materials should be provided timely and efficiently to the camps for the survival of the camp inhabitants. The type and amount of each commodity per day per survivor is suggested after considering the earlier studies in Table 3.1 [5].

Table 3.1: List of required items for survivors

Item	Quantity per day per survivor
Water (drinking)	4 litres
Water (non-potable)	10 litres
Meals	3 meals
Basic Medical Kit	1 pack
Cot/ Sleeping Mat	1
Blanket	1
Baby Supplies	1 box
Clothing	1 bag

3.1 Assumptions

The model is to determine the relief supply demand and assessing the risk of transporting it from supply storage centres to corresponding relief camps.

The assumptions taken are as follows.

1. The quantity of resources available at the supply points is greater than the demand of the relief camps. In practical cases the total demand of a particular relief camp need not be met with the resources available at that particular resource centre.
2. The transportation costs are not considered for evaluating the transportation matrix. Importance for human survival is given more importance in a disaster scenario than the cost involved in relief services. The transportation network during a flood or similar disaster scenario is greatly influenced by the risk involved in the relief supply transportation.
3. Different condition of the roads demands different types of vehicles and other transportation facilities and in this model it is assumed that the suitable transportation mode for the corresponding disaster scenario is available.

3.2 Demand calculation

The demand of relief items for each camp depends on the number of inhabitants in the respective camp. Even though the amount of materials required is proportional to the number of people, a fraction of the demand may be met by the local resources and need not to be supplied from resource supplying locations. For accounting for the supply of materials the rate of survivors who left and added to the camp between two successive supplies should also be considered.

The commodities to be supplied can be classified into two based on the frequency of supply.

Category 1: Materials like meals and drinking water comes under this category. Most of them are consumable products and should be supplied to a person more than once.

Category 2: Commodities like sleeping mats, and cloths that can be reused and need to be supplied once for an individual are included in this category.

The demand calculation equation formulated for the above two category of commodities can be written in terms of the following notations:

D_t^i = demand of the item at camp i for t^{th} number of supply

c = demand of the particular relief item per person

x_t = Number of people in the camp during t^{th} supply

k_j = net number of people registered or left the camp in an hour

m = number of hours between t^{th} and $t-1^{th}$ supply

L = the total amount of material contributed to the camp during the time interval m

For Category 1, the demand calculation equation is as follows:

$$D_t^i = c\left(x_{t-1} + \sum_{j=1}^{m} k_j\right) - L \tag{1}$$

For Category 2,

$$D_t^i = \begin{cases} cx_t - L\,, & for\ t = 1 \\ \left(\sum_{j=1}^{m} k_j\, c\right) - L\,, & for\ t > 1 \end{cases} \tag{2}$$

The starting stage of a relief camp *i* is represented by *t* = 0.

□ $x_{t=0} = 0$

3.3 Risk factor estimation

The two major factors influencing the timely and efficient supply of relief items are,

1. The condition of roads connecting the relief camp and resource centre.
2. The distance between the resource supply centre and the relief camps.

Instead of cost, a risk factor is introduced for formulating the transportation matrix for prioritizing the relief camps. The risk factor estimation equation formulated based on the previous data and expert advice is represented with the following notations:

R_{ij} = Risk factor of transporting items from camp *i* to relief camp *j*

r_{ij} = factor indicating the condition of roads from supply centre i to relief camp j

s_{ij} = factor corresponding to distance between supply point i and relief camp j

S_{ij} = distance between supply and demand points

S_{max} = Maximum of the distance set S_{ij}

$$R_{ij} = 0.6r_{ij} + 0.4s_{ij} \quad (3)$$

$$r_{ij} = \begin{cases} 0 \leq r_{ij} < 0.25 \text{ , for low damage} \\ 0.25 < r_{ij} < 0.5 \text{ , for medium damage} \\ 0.5 < r_{ij} < 0.75 \text{ , for high damage} \\ 0.75 < r_{ij} < 1 \text{ , for very high damage} \end{cases} \quad (4)$$

$$s_{ij} = \frac{S_{ij}}{S_{max}} \quad (5)$$

The demand of the particular relief camp is calculated using the demand estimation equations. The routes from the resource supplying centres and relief camps is assessed using the risk factor estimation equations and the transportation matrices can be solved using suitable methods.

4. Application on Kerala flood situation

In this section the applicability of the mathematical model is demonstrated by conducting a case study on the recent flood situation happened in Kerala. Two resource centres and five relief camps located at Ernakulam district was selected for study. The following relief materials were selected for study:

- Category 1 : Drinking water (*m = 6 hr, c = 1 ltr*), Meals (*m = 6 hr, c = 1 meal)*
- Category 2 : Clothing (*m = 6 hr, c = 1 bag)*, Sleeping Mats (*m = 6 hr, c = 1)*

Using the collected data the demand for the five selected camps for the second supply (*t = 2*) where calculated using equation (1).

Table 4.1: Number of inhabitants of selected relief camps at *t=1* and number of people added or left the camp during supply at *t=1* and *t=2*

CAMP	SH	RU	RLV	EKA	KUR
x_1	2180	1980	4794	2085	7500
$\sum_{j=1}^{m} k_j$	810	744	1800	780	2460

Table 4.2: Calculated values of demand of selected relief camps

CAMP	Commodities				
		Water	Meals	Clothing	Sleeping mats
SH	$c\left(x_{t-1} + \sum_{j=1}^{m} k_j\right)$	2990	2990	810	810
	L	2093	2000	567	490
	D	897	990	243	320
RU	$c\left(x_{t-1} + \sum_{j=1}^{m} k_j\right)$	2724	2724	744	744
	L	2450	2150	670	560
	D	274	574	74	184
RLV	$c\left(x_{t-1} + \sum_{j=1}^{m} k_j\right)$	6594	6594	1800	1800
	L	4950	3950	1080	990
	D	1644	2644	720	810
EKA	$c\left(x_{t-1} + \sum_{j=1}^{m} k_j\right)$	2865	2865	780	780
	L	1700	1400	430	350
	D	1165	1465	390	390
KUR	$c\left(x_{t-1} + \sum_{j=1}^{m} k_j\right)$	9960	9960	2460	2460
	L	6000	2980	860	620
	D	3960	6980	1600	1840

The corresponding parameters for calculating the risk factor is shown in Table 4.3, Table 4.4, and Table 4.5 and the estimated risk factor of transporting commodities between the selected resource supply centres and relief camps is tabulated in Table 4.6.

Table 4.3: Road condition factor (r_{ij})

	SH	RLV	RU	EKA	KUR
BMC	0.35	0.4	0.1	0.4	0.8
RSC	0.2	0.25	0.2	0.2	0.9

Table 4.4: Distance from relief camps to resource centres (S_{ij}) in km

	SH	RLV	RU	EKA	KUR
BMC	15	12.3	7.7	21	24
RSC	4.5	9	18	14	35

Table 4.5: Calculated distance factor (s_{ij})

	SH	RLV	RU	EKA	KUR
BMC	0.43	0.35	0.22	0.6	0.69
RSC	0.13	0.26	0.51	0.4	1

Table 4.6: Calculated risk factor (R_{ij})

	SH	RLV	RU	EKA	KUR
BMC	0.38	0.38	0.15	0.48	0.76
RSC	0.17	0.25	0.32	0.28	0.94

Accordingly, the satisfactory transportation matrices for the selected relief commodities were calculated using MODI method and the results are shown in Table 4.7, 4.8, 4.9 and 4.10. The optimal results show that the commodities for the different relief camps are assigned suitably.

Table 4.7: Transportation matrix for drinking water (in ltr)

CC	Supply	RC	SH	RU	RLV	EKA	KUR
		Demand	897	274	1644	1165	3960
BMC	4600		897		1644	1165	
RSC	4600			274			3960

Table 4.8: Transportation matrix for meals (in packets)

CC	Supply	RC	SH	RU	RLV	EKA	KUR
		Demand	990	574	2644	1465	6980
BMC	8000		990	574	2644	1465	1980
RSC	5000						5000

Table 4.9: Transportation matrix for clothing (in bag)

CC	Supply	RC	SH	RU	RLV	EKA	KUR
		Demand	243	74	720	350	1600
BMC	2000		243	74	720	350	600
RSC	1000						1000

Table 4.10: Transportation matrix for sleeping mat

CC	Supply	RC	SH	RU	RLV	EKA	KUR
		Demand	320	184	810	390	1840
BMC	2500		320		810	390	
RSC	2100			184			1840

5. Conclusions

An efficient relief service logistics is required in a disaster situation in order to sustain the survival of the affected people. The relief services should be provided in the right quantity at the right time for the right people.

In this paper, firstly, a demand calculation method was introduced and discussed. Then a criterion for estimating the risk factor involved in transporting commodities from resource centres to relief camps is explained. The proposed model was then applied to the flood situation happened in Kerala during August 2018.

The proposed model uses risk factor as a criteria for solving the transportation matrix rather than cost. In practical cases the availability of updated and exact data required for solving the model is a problem.

5.1 Future scope

The assumptions made in the model have suitable importance in real life scenario. In future the model can be developed by considering the cost involved in relief supply chain activities. The model can also be improved if the transportation modes are considered for the formulation of the model.

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7. References

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