Original Research Article

Facility location for prepositioning of relief items

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A B S T R A C T

The primary objective of this study was to determine the facility location for the prepositioning of relief items (PRI) for disaster relief. The present work was inspired by the importance of the prepositioning of relief items and the convolution that affects the determination of their location. Expert interviews were used to verify the factors for PRI identified through the literature review. A factor rating system (FRS) under the group decision-making (GDM) is suggested to establish the weights of the criteria. The interviews with decision makers showed the dissimilarity of decision opinions, thus confirming the significance of GDM. The results of the present study are imperative from the decision maker's perspective as managerial insights have been considered. The model is constructed based on the subjective opinion of experts and can be further validated statistically. This study can be further carried out the using of another technique, such as Fuzzy-FRS, with a greater number of factors. The results of this study will be valuable for decision makers planning of facility locations for the prepositioning of relief items. The proposed FRS approach highlights the significance of using multiple decision-makers to enhance the sense of possession of an established PRI. To the best of our knowledge, a factor rating system (FRS) under group decision-making (GDM) has not been considered concurrently for one particular problem (facility location) in humanitarian logistics. This study provides an in-depth analysis of prepositioning of relief items.

1. Background

Disasters often cause heavy damage resulting in injuries and harm to valued lives. The impact of the disaster can be lessened only by rapid and effective response. The response operation for a disaster is dependent on being adequately prepared. By ensuring the judicious accessibility of relief items the humanitarian organizations can promote their emergency response capacity and preparedness towards disasters. The best way to respond to disasters is by prepositioning of relief items at facility location. This helps save time in arrival of relief items and minimise the number of people who get hurt during the disaster.

Hence, it can be considered that prepositioning of relief items (PRI) is as an effectual and highly successful strategy which can be effectively used for the promotion of disaster preparedness. Pre disaster planning (PDP) and PRI have a momentous and gigantic role in minimising the relief item arrival time at disaster hit areas. Prepositioning of relief items is a key constituent of humanitarian supply chain and logistics

For prepositioning of relief items, we have to ask ourselves where to locate it. So, the primary objective of this study is to identify the facility location for prepositioning of relief items. The location for facilities of PRI to aid humanitarian relief distribution is a more complex problem due to the uncertainty and unpredictability of disaster occurrence. The location decision process involves qualitative as well as quantitative factors. The factor rating

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system, owing to application of methodology applied for calculating scores it is also known as scoring method and multi-factor rating system. It is a popular and easily applied subjective decision-making method under the MADM approach. According to Heragu, (1997)[1-5] FRS is used for assigning weights to the identified factors in a complex problem. This study is based on the subjective opinion of the experts. A case study on the Uttrakhand state of India has been developed. It is northern state located in the Himalayan region.

2. Literature Review

The search for requisite literature was carried online in various databases like EBSCO, Scopus and Web of Science etc. Reports which had important findings related to our search were also assessed during literature review. Organisations like World Health Organisation, the international Federation of Red Crescent and the Red cross society was also studied and relevant portion has been extracted. The keywords which were used included in the search were "Emergency shelter, Disaster, Disaster Planning, humanitarian relief, disaster planning, disaster relief, and emergency response".[6-9] The Boolean expression with Boolean operators "And" and "Or" were used for search along with aforesaid keywords. Titles of the paper which matched our requirement were assessed. The primary criterion was publication and relevance to humanitarian logistics and PRI for natural disasters.

All retrieved articles were entered for removing duplicity in the "EndNote software". The titles of the retrieved articles were assessed and irrelevant studies (which had only title related to priority location but the content was not relevant) were excluded. The abstracts of remaining articles were thoroughly read in the second stage. Full text of the selected 23 articles was read. These 23 articles were closely connected to humanitarian logistics and matched our area of PRI. Oloruntoba & Gray (2006) has emphasised on the role of planning in humanitarian supply chain. According to them planning has significant importance in HSC. Various authors like Campbell & Jones (2011) in their study have advocated for placing relief items as close to relief items as possible. According to them one of the goals of prepositioning of relief inventory is to place relief items in close proximity to such areas which are very much prone to disasters and have been classified as disaster prone areas

According to Apte (2010) many prominent factors which are closely related to supply chain should be considered by logistics manager.[10-14] Factors include determination and categorisation of distribution channels, estimation of the number of relief items for prepositioning contingency models for selection of warehouse, predication of relief item demand. Relief operations are severely affected by investments in Pre and Post disaster stages (Balcik & Beamon, 2008). Uncertainties related to transportation

capacity, demand level, time, cost, damage level, can be minimised by researchers with the help of models which are scenario based (Torabi et. al., 2018). Significant differences in Risk levels can be achieved if risk is considered explicitly and unambiguously (Akgun et. al., 2014). One of the critical challenges that need to be resolved in planning facility location is uncertainty. Because of this uncertainty predicting the accurate level of demand for supply of relief items becomes difficult. Two stage scenario based accidental planning can be used for modelling uncertainties (Alem, 2016). Inadequacy of financial resources, large number of volunteer participants, high level of staff turnover are various factors complicate various warehousing operations. Amongst various methods, mathematical model gives more flexibility than other such methods (Beamon & Kotleba, 2006).

The study (Davis et. al., 2013) depicted that "model integrates hurricane path intensity to determine how best to preposition supplies in recognized single commodity supply network where one or more of the nodes is in a high-risk path for a particular event". This situation arises either when an already existing network has now been reject for providing service to community or when decisions related to strategic prepositioning have been made. Major part of activities related to preparedness of emergency supplies relates with prepositioning of emergency supplies. Prepositioning helps in reducing response time and thus improves delivery time for providing relief to disaster hit areas.[15-18]

Galindo & Batta, (2013) in their studies have expressed that its desirable that emergency supplies be positioned near demand points(DPs). This results in a single staged network having regional ware houses, providing most optimal and efficient response and which is fully capable of meeting relief demands. Networks in which relief goods are first passed through regional warehouse are known as two staged network. Two staged networks are generally costlier than a centralized network. According to study conducted by Charles et. al. (2017) adding the second stage local warehouses at country level for decentralizing cannot be justified. The following study article provides an exhaustive review and examination of various analytical methodologies developed for humanitarian inventory management. The past studies on relief inventory management which are very well established and have very well addressed the basic inventory questions like how much to store, when to store, where to store etc. But within commercial supply chain setting, the direct application of prevailing models and policies to manage inventories related to humanitarian supply chain can't be pragmatically applied (Balcik et. al., 2017). The outcomes of this study focuses on how to optimally use up-front investment to attain the largest possible response-time advantage. The study also illustrates how to support the execution of a steady

network expansion strategy. The model so developed uses historical data to estimate the magnitude of potential demand, demand frequency, location of relief supply (Duran et. al., 2011). [19–24]

John et. al (2012) in their study have closely examined large number of publications which have diverse effect on the supply chain involving humanitarian approach. John et. al. (2012) in order to create an enhanced and thoughtful understanding of the concepts of HSCM have examined publications from the allied field of SCM). Madu & Kuei (2015) have coined the atmosphere and nature of disaster relief as complex, ever changing, systematic yet chaotic and organization involved in relief operations involve an efficient and assorted specialist which work in project mode. The study analyses the disaster relief cycle from LSS and CIMO logic perspectives.

According to Mochizuki et. al., (2015), a model consisting of multiple humanitarian crises, two member organisation and one service provider was developed for evaluating four primary sourcing options. The four sourcing operations involve:

1. Own storage
2. UN storage for own items,
3. Stock-swap,
4. White stock uses under two budgeting regimes of fixed and flexible constraints

According to Carroll et. al, (2009) capacity and capability for dealing successfully and efficiently with "unpredictability", lies predominantly within the context of HLSCM itself. According to them this could be argued solely. From the lean and agile concepts for short term will offer competence and efficiencies in designing the structures and relevant system for HLSCM.

Caunhye et. al., (2012) have reviewed various optimization models which have been used in emergency logistics. Various activities which have been used in these models are fragmented into two pre and post disaster operation. The pre disaster operations mainly involve, evacuation from the area which can be affected by disaster, facility location and pre-positioning of stock. Post-disaster Operations mainly involve effective distribution of relief items and transportation of casualties for medical aid. Suitable modelling of the individuals' conduct is necessary for optimization of the location of capacitated circulation centres from which an individual person can choose (Gutjahr & Nolz, 2016). Opit & Nakade, (2015) have proposed a novel model for stock prepositioning. The proposed model, within a particular time period, can simultaneously generate maximum amount of relief distributed against the demand generated from a single disaster area along with generating the maximum proportion of relief demand covered in distribution centres. [25–28]

Out of extensive coverage of literature on humanitarian logistics, factors affecting prepositioning of relief inventories have not been referred in most of the studies. Less number of studies has discussed prepositioning as an important factor for relief inventory management. Amongst important examples of factors are scenario planning for uncertain situation, essential and accurate number of relief items needed for prepositioning, warehousing characteristics, locations and sites for storing relief items etc. The present study has identified as well as addressed these gaps with an aim to investigate the possible causes affecting PRI for naturally occurring disasters.

The output of literature review was verified with expert review with different experts including policymakers, bureaucrats, academicians and NGOs, were used. The interaction of researchers with beneficiaries of HSCM was already available to make a meaningful contribution out of experts interviews. 20 experts were used for interview. Out of 20 experts 5 were from academia, academic experts were carefully selected for knowledge related to disaster and humanitarian supply chain management. 5 experts were from humanitarian organizations or NGOs who have practical experience to deal with real conditions of disaster. 10 experts were from disaster response force who have practical experience of rescue and relief operations. The detailed profile of experts is given in Table 1. These experts were aware with all the hitches of the disaster management in their respective field related to disaster. Hence, the diversified group of experienced experts gave their valuable insights to select the factors of prepositioning of relief items.

Table 1: Detailed profile of the experts

Organization	No. of Respondent	Designation	Experience
State Disaster Management Authority (SDMA), Uttrakhand, India	2	Government Executive	12 years
National Disaster Response Force (NDRF), India	4	Commandant	12 years
State Disaster Response Force (SDRF), Uttrakhand, India	4	SAR Team Commander (Inspector)	10 years
National & International Non-Government Organization (NGOs)	5	Secretary, Members	15 years
Academicians	5	Professor	15 years

The review of selected literature provided 6 factors of prepositioning of relief items. These identified factors were agreed upon by the experts. The detailed discussion with the experts added 3 more different barriers like local economy, trained workforce and past disaster profile. With the expert discussions, these factors found more significant

for the appropriate planning for prepositioning of relief items. So finally, with the help of literature review and expert interviews, total 9 most influencing factors were identified which are significant in the successful planning for prepositioning of relief items. During discussion with experts, it was realized that different factors have different significance in order to plan prepositioning of relief items.

2.1. Identified factors for prepositioning of relief items

Humanitarian logistics, PRI and relief operations at pre disaster, during and post disaster stages face variety of challenges. The prominent challenges faced during relief operations which severely affect the operations comprise of exaggerated interference of governments and citizens, both at pre and post disaster stages, complications in timely arrival at disaster areas, damages to transportation networks, difficulties in supplying relief items to the victims of the disaster, problems related to safety of relief inventories, lack of professionally trained staff, inadequate level of staff turnover, changes in logistics capacities, unclear and indistinct request for relief items, limited access to reliable information about damages, victims, demands and availability of resources. Moreover, PRI can be affected by many other factors which are significant and highly affect relief operations. Yet, no comprehensive study has been conducted on these factors. Studies which have been carried out in the area of humanitarian logistics have addressed only a few aspects of these factors.

2.2. Warehouse site selection

Warehouses are one of the key components of the prepositioning of relief items that assists with rapid response to disasters (Farahani & Rezapour, 2011). Bozkurt, (2011) have termed warehouses as strategic location used for storing relief items. Prepositioning and warehousing of relief inventories should be done at the best possible sites (Apte, 2010).

Warehouses are places for long-term prepositioning of relief items. Warehouse site selection is a strategic decision to closeness with the disaster hit area (Beamon & Kotleba, 2006). However, the short distance between a warehouse and a disaster location carries with it a danger of damage to the warehouse.

2.3. Procurement facilities

The availability of procurement of relief items at the same site is also a very important factor to prepositioning of relief items. Humanitarian organizations have ease to storing and maintaining good qualities relief items with the local procuring facilities (Bagchi et al.,2011).

2.4. Uncertainty predictability

Prediction about the occurrence of disaster with the time and magnitude is another important factor for the prepositioning of relief items (Torabi et al., 2018). Preparations for relief and rescue operations will completely depend on the precise forecast of impending disasters and their effects there of (Alem et al., 2016; Campbell & Jones, 2011).

2.5. Local economy

For planning the prepositioning of relief items, another important factor is needed to be considered the local economy. The pre-positioning of relief items requires a significant amount of resources, and can only be completed with support from local economies.

2.6. Trained workforce

Before prepositioning of relief items, training human resources is another important factor. First, there is need to acquire a trained workforce. So that, workers will be able to effectively place and maintain relief items at the correct location.

2.7. Past disaster profile

For planning the prepositioning of relief items, another important factor is needed to be considered the past disaster profile of that area. To effectively manage the relief items, it is important to understand the past disaster profile of that area.

2.8. Demand estimation

The first thing in PRI planning is determining what relief items to bring and who will need them, where they will have needed (Tatham et. al, 2017). The most challenging factor here is ambiguity (Maghfiroh & Hanaoka, 2017), which makes the process of estimating demands uncertain. When disasters strike, the demand for relief items is huge. However, these demands can accurately be predicted based on data obtained from past disasters (Balcik & Beamon, 2008).

2.9. Transportation infrastructure

When planning for prepositioning of relief items, humanitarian organizations have to evaluate the transportation infrastructure of an area. To effectively deliver relief items to an area impacted by disaster, it is important to understand the area's transportation infrastructure (Galindo & Batta, 2013).

2.10. Communication infrastructure

One important factor to consider when planning the prepositioning of relief items is communication

infrastructures. It is needed to get information about disaster hit areas and needs of victims to supply appropriate relief (Apte, 2010).

3. Materials and Methods

Various authors have used a variety of analytical methods for selecting suitable sites to locate facilities for providing relief items to the disaster hit sites. Heragu, (1997) have termed factor rating system (FRS) as an uncomplicated, popular and easily applicable subjective decision-making method. The FRS is an effective technique of multi-attribute decision-making approach. FRS is an efficient yet simple method using preferences made by experts (decision makers) which can effectively satisfy the chaotic and turbulent nature of disaster management. The Factors rating method is a widely used approach to facility location. The flow diagram (Figure 1) depicts the various steps used in factor rating method.
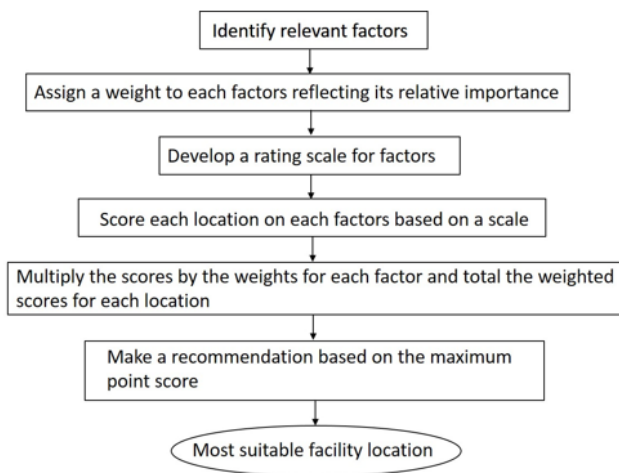

Fig. 1: Steps used in factor rating method

4. Case of Uttrakhand

The Uttrakhand state of India is located in the Himalayan region. Natural hazards in Uttrakhand are pronounced due to its tectonic activity, lithological, structural and ecological settings, topography and changing landscapes owing to various natural and anthropogenic activities. Natural hazards like earthquakes, landslides, cloud bursts, flash floods, floods, lightning, forest fires etc are frequent in Uttrakhand causing loss of life and property from time to time. Many times natural hazards turn into disaster in the different district of Uttrakhand. So it is necessary to locate the facility of PRI to aid humanitarian relief distribution.

5. Results and Analysis

The facility location process involves many factors. These identified relevant factors for facility location of PRI assigned weights out of 10 to each factors reflecting its relative importance and percentage of weights. From which past disaster profile, transportation infrastructure, demand estimation, uncertainty predictability, communication infrastructures, warehouse site selection are most significant factors. Procurement facilities, trained workforce and local economy are the least significant factors.

Based on these weights, the 13 alternative districts of Uttrakhand state of India were awarded score between 50 to 100 points shown in Table 3. Table also shows weighted scores calculated by multiply district score and factor weight. From these weighted scores, experts as a decision maker decided to threshold score to be 65 for locating facilities.

Therefore, seven districts with score more than 65 are recommended for facility location namely, Haridwar, Dehradun, Chamoli, Pithoragarh, Nainital, Rudraprayag and Uttarkashi out of 13 districts of Uttrakhand state of India. Figure shows the spatial location of the seven selected facility location for PRI in Uttrakhand state of India.
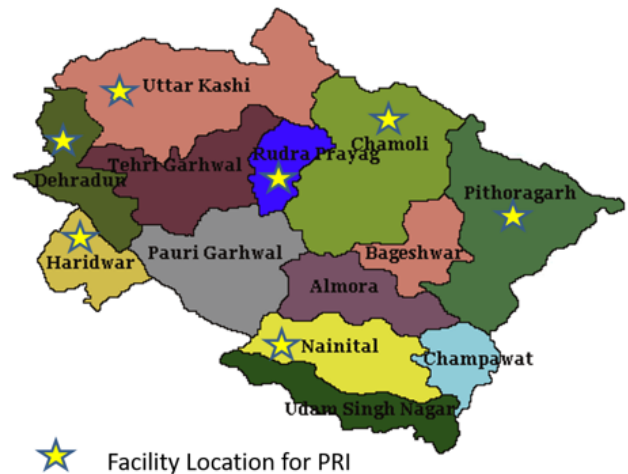

Fig. 2: Proposedfacility location for PRI in Uttarakhand state of India.

6. Conclusion

The location for facilities of PRI to aid humanitarian relief distribution is a multifaceted problem. Primary factor is the uncertainty in occurrence along with the unpredictability of magnitude of disaster occurrence. The decision-making in determining a suitable location requires availability of reliable and unbiased qualitative as well as quantitative factors to choose from. Availability of effective and efficient transportation facilities during

Table 2: Relevant factors PRI fornatural disasters

Relevant factors PRI for Natural Disasters			
Factors	Notation	Total Points	Weightage factors (%)
Warehouse site selection	A	6	0.12
Procurement Facilities	B	3	0.06
Uncertainty Predictability	C	7	0.14
Local economy	D	1	0.02
Trained workforce	E	2	0.04
Past disaster profile	F	10	0.2
Demand Estimation	G	8	0.16
Transportation infrastructures	H	7	0.14
Communication infrastructures	I	6	0.12
	Total	50	1

Table 3: Decision matrix forfacility location

Decision Matrix for Facility Location									
Objectives	A		C	D	E	F	G	H	I	Total Points
Location of Facility	0.12	0.06	0.14	0.02	0.04	0.2	0.16	0.14	0.12	
Haridwar (F1)	80	90	85	90	80	50	50	65	90	69.8
Tehri (F2)	60	60	70	70	60	65	60	55	70	63.1
Dehradun (F3)	90	90	90	95	90	70	60	90	95	81.9
Chamoli (F4)	55	70	70	60	60	90	80	80	60	73.4
Almora (F5)	60	75	60	70	70	60	70	60	65	63.7
Pithoragarh (F6)	55	65	60	60	60	90	80	80	60	71.7
Nainital (F7)	70	80	70	90	70	70	75	70	80	73
Bageshwar(F8)	55	55	70	60	60	80	60	60	55	63.9
Champawat(F9)	60	65	70	55	60	60	55	50	65	60
U S Nagar(F10)	80	80	75	80	80	50	50	50	70	63.1
Pauri (F11)	60	65	70	70	80	50	55	50	65	59.1
Rudraprayag (F12)	55	60	50	60	60	95	80	65	55	68.3
Uttarkashi (F13)	55	50	55	50	60	95	80	60	50	66.9

disaster, requisite infrastructure for efficient and condition resistant communication system and procurement facilities concerning alternative location selection are some of the sensitive factors which cannot be ignored by decisions makers. Furthermore, the process could become highly judgmental if a wide variety of qualitative factors are present. In such cases, the selection process may lack consistency and flexibility. The FRS methodology has been employed successfully to provide consistent evaluation (weighting) of location alternatives.

This study presents the best location related to facilities of PRI to facilitate distribution channels to be engaged in humanitarian relief. We also proposed an FRS under the GDM condition to take account of the decision opinions of multiple decision makers. One of the most significant factor that need to be considered in planning facility location is past disaster profile of disaster site. As it helps to predicting the accurate location of facility for storing of relief items. The result of this study is the location for facilities of PRI should be nearby to potential disaster areas.

Finally, a sense of ownership might be developed by the involvement of multiple decision makers or managers early in the process of location selection. The sense of ownership finds wide significance in maximizing the optimal utilization of facilities (established) at the same time it enables coordination of highest degree. The multi-expert method, which has been used by the authors in the present study for determining the weight of objectives engages the much asserted coordination among the decision makers by combining a collective outcome which is representative in nature from a decision maker's judgments.

A case study on location for the state of Uttrakhand has been developed and proposed in the present study. Uttrakhand being a disaster prone state requires a

well-structured strategy for providing relief inventory through facility location during natural disasters. Present study proposes seven districts which scored more than 65 points during study have been recommended for developing facility location. The districts Haridwar, Dehradun, Chamoli, Pithoragarh, Nainital, Rudraprayag and Uttarkashi are proposed for developing facility location for relief inventories in the Uttrakhand state of India. Districts scoring less than 65 were ignored as the importance of identified factors were found less significant than districts with score 65 and above. The policy makers should focus on developing these centres as primary location for providing relief inventory in case of disasters. As no study is perfect, this study also suffers with some limitations. One of the key limitations of this study is that it is entirely based on the subjective opinion of the experts. Opinion tends to be biased. Statistically validation has not been conducted in this study. This study can be further carried by the use of another technique like Fuzzy-FRS with more number of factors.

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None.

9. Conflict of Interest

None.

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