Conceptualising Inventory Prepositioning in the Humanitarian Sector

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Abstract: Improved responsiveness to natural and man-made disasters is critical to saving lives and alleviating the suffering caused by such disasters. Emphasis on the design of the relief chain to reduce delivery time of relief inventory improves responsiveness. This is the essence of inventory pre-positioning (IPP). IPP is yet to be clearly defined; and the main factors affecting IPP decision-making need to be further discussed in the humanitarian literature. Quantitative factors such as costs usually take precedence over qualitative factors such as collaboration, infrastructure and others that can substantially impact IPP decisions. This can lead to ineffective decision-making in humanitarian organizations. This paper provides a definition of IPP by reviewing relevant literatures; and a conceptual framework of the main factors affecting IPP decision-making specific to the humanitarian sector, developed through desk reviews and observations.

Keywords: humanitarian logistics, inventory prepositioning, collaboration

1 Introduction

Disasters destroy the very infrastructure of the country, affecting the social, financial, economic and physical structure of the society and can be triggered by natural, political and economic events (Whybark 2007). The least developed countries are very vulnerable to disasters (Kovacs and Spens 2007). The overarching aim of the humanitarian sector is to save lives, meet the basic needs of people and alleviate suffering (Van Wassenhove 2006), which is partly contingent on the speed of humanitarian response (Campbell et al 2008). Emphasis is in the humanitarian literature is often placed on response to disasters (Barbarosoglu et al 2004, Sheu 2007) however, effectiveness and efficiency of humanitarian logistics is improved with focus on preparative activities (Tomasini and Van Wassenhove 2009). Increasing the effectiveness of response is possible through positioning inventory in preparation for disasters, to reduce the procurement and transportation phase in response to disasters (Duran et al 2007). Stocks are strategically placed that when disasters occur the time between getting goods to the disaster area is greatly reduced (Duran et al 2007, Balcik and Beamon 2008). The positioning of inventory for relief purposes is termed inventory pre-positioning (IPP). IPP is also identified as improving the cost effectiveness of the relief chain (Balcik and Beamon 2008).

IPP is yet to be consistently defined in the humanitarian literature. Duran et al (2007) argue that IPP consists of facility locations, inventory management and network design decisions, while Balcik and Beamon (2008) consider that IPP consists of facility location and inventory management decisions. Factors considered in IPP decisions are incomplete. Reference is often made to quantitative factors such as inventory, transportation and other costs (Barbarosoglu et al 2004), with very little attention being paid to qualitative issues such as difficulty with customs clearance, the impact of collaboration and coordination or unrest (Duran et al 2007). Thus the aim of this paper is to describe IPP which is done in two parts. First a definition of IPP encompassing key IPP decisions is presented, which lends to the second part, the development of a conceptual framework of the factors that affect these IPP decisions. Given the far reaching implications of collaboration on IPP special emphasis is placed on this as impacting the IPP decision. A desk review of the business and humanitarian literature forms the basis of the definition and decisions of IPP while the desk review of the humanitarian literature forms the basis of the framework of factors that affect IPP. The structure of the paper is such that section two provides a definition and description of IPP along with the key IPP decisions that need to be taken. Sections three discusses that factors that affect the IPP decisions as identified in section two. Section four concludes the article and discusses opportunities for further research.

2 Defining IPP in the Humanitarian Sector

There are three decisions commonly treated in studies related to IPP. These include facility location, identifying the most suitable place for inventory in the relief network; inventory management concerned with inventory policy decisions; and transportation decisions to transport inventory to where it is needed. These decisions are very often treated independently in the humanitarian literature (Jia et al 2007, Kapucu et al 2007, Barbarosoglu et al 2004). However, Balcik and Beamon (2008) and Duran et al (2007) in integrating facility location and inventory policy decisions showed improvements in the responsiveness of the relief supply chain, with a reduction in some associated costs. However, facility location, inventory management and transportation decisions all need to be integrated for the relief network to be truly effective and efficient, as transportation decisions at the strategic level directly affects facility location, facility capacity, and inventory policy decisions (Crainic et al 1997). Additionally, Balcik and Beamon (2008) and Duran et al (2007) did not consider factors deemed to be significant to any network design exercise such as operating costs (Chopra and Meindl 2004) and factors significant to the humanitarian sector such as the effect of customs regulations, road damage, collaboration and coordination in their model. We contend that these factors need to be considered in the design of effective and efficient relief networks. Below we present a working definition of IPP before briefly discussing the decisions that need to be integrated to realise improvements in disaster relief network. IPP is defined as:

'The strategic positioning of inventory in the relief network in preparation for disasters, through the integration of facility location, inventory management and

transportation decisions, while taking into account the key factors affecting it, to improve the response and efficiency of the relief network.'

In *facility location* decisions (Table 1) the business literature considers the number, location, size and capacity of each facility in the network (Simchi-Levi et al 2008). These basic facility location decisions which are also applicable to the humanitarian sector need to be taken simultaneously. For example, the number of facilities impacts the spatial arrangement of facilities in the network, such that the greater the number of facilities the closer the facilities will be located. This in turn impacts on the capacity requirement of each facility, such that the greater the number of facilities the smaller the capacity of each facility. The location of each facility impacts on the distribution centre to be allocated to each facility.

Table 1: Facility location decisions

Decision	Description	Source
Number of facilities	The number of facilities in the network	Simchi-Levi et al 2008
Facility points	The location of each of the facilities	Jayaraman 1998
Capacity of facility	The available capacity of the facility	Chopra & Meindl 2004
Allocation	Allocating demand to facility locations	Chopra & Meindl 2004

In the business literature *inventory management decisions* (Table 2) include decisions on the type of inventory and inventory policy decisions (Zipkin 2000). The disaster for which the organisation is being prepared influences the choice of and the amount of inventory to be stored at each facility and the inventory policy. For instance, preparing for a cholera outbreak will require different inventory than preparing for and earthquake or storm which in turn impacts on inventory policy decisions.

Table 2: Inventory Management Decisions

Decision	Description	Source
Inventory types	Related to customer order decoupling point, and what inventory to store at each facility.	Hoekstra, S. and Romme 1992
Inventory policy	The target inventory levels; minimum and maximum inventory levels; stock replenishment policy; order quantity; safety stock levels; review policy; out of stock policy; shelf life policy	Zipkin 2000

Transportation decisions (Table 3) address transportation policy decisions of mode, route planning, scheduling and resource repositioning decisions (Crainic et al 1997).

Table 3: Transportation Decisions

Decision	Description	Source
Transportation policy	The number of vehicles, route planning, transportation mode, vehicle scheduling, resource repositioning	Crainic et al 1997, Melo et al 2009

The facility location, inventory management and transportation decisions discussed in this section are not unfamiliar to the decisions that need to be made in the business sector. In fact, this is the lens through which we view the relevant decisions in the humanitarian sector. The added value is in relating these decisions to the humanitarian sector to establish a definition of IPP and to further analyse the factors that affect IPP, the topic of discussion in the following section.

3 Framework of Factors affecting Inventory Pre-positioning

The decisions that need to be made in IPP as presented in section two form the basis on which we develop the framework of factors that affect IPP decisions. Many factors can affect the design of a network (Schmidt and Wilhelm 2000), however, not many authors present a comprehensive framework taking into consideration quantitative as well as qualitative factors in their network design decisions (Schmidt and Wilhelm 2000, Candas and Kutanoglu 2001). This necessitates the development of a framework of factors specific to the humanitarian sector to facilitate sound IPP decision-making. Please refer to Figure 1 below for this framework.

Balcik and Beamon (2008) argue that the lack of financial resources inhibits organisations in pursuing the option of IPP and thus impacts on the *number of facilities* an organisation can have in its network. This also implies that logistics and facility costs can affect the number of facilities to be in the relief network, as financial resources are required to cover these costs. With demand forecasting, the more uncertain demand is, the greater the need to pool resources. This tends to reduce the number of facilities to be located in the relief network (Whybark 2007).

Several factors affect where to locate the facility, referred to here as *facility points*. According to Whybark (2007) determining facility points in the humanitarian sector can be influenced by logistics costs and the political environment. High transportation, warehousing and other overhead costs may make locating facilities in certain areas unattractive, whereas low facility costs tends to increase the attractiveness of certain locations. Some organisations choose certain facility points as they are rent free, sometimes to the neglect of additional transportation costs. Opportunities for collaboration and coordination amongst relief organisations counteracts high logistics costs (Balcik et al 2010) making it attractive for organisations to position inventory in close proximity to each other. Political factors such as conflicts, deteriorating security and piracy (Ashagabley 2006) can make certain areas unattractive as facility points due to the risk of imminent danger and theft. Forecasting demand affects the location of relief inventory, not solely because of the need to know where to locate inventory (Chang et al 2007), but also for the removal or rotation of supplies if disasters do not occur (Whybark 2007). Infrastructure includes easy access to major roads, other transportation infrastructure and ports (Jia et al 2009). Poor infrastructure signals difficulty in transportation and accessibility to the facility, reducing the attraction to that facility point. Macro-economic factors, such as high taxes at boarder crossing in Africa (Camm et al 1997) and high tariff barriers to products from Asia to Africa (Broadman 2007) can dissuade organisations from locating in such areas.

Available funds and logistics costs are limiting factors in the design of the relief network (Balcik and Beamon 2008) and thus can impact the *capacity of the facility*, as the organisation may not be able to afford a large facility. The ability to forecast demand allows for the synchronisation of supply and demand. The inability to achieve this synchronisation may necessitate having a larger facility as the organisation is unsure of inventory requirements and thus will keep more inventory in stock. Physical characteristics of inventory impact the capacity of the facility such that bulky products require larger facilities.

Collaboration and coordination amongst relief organisations is important to the *allocation* decision to avoid overlaps or gaps in response to disasters. The quality of infrastructure also affects allocation such that poor transport infrastructure between a facility and distribution centre may impact on the transportation mode. If the road access is poor then an organisation may opt to use air transport, a more costly, unattractive option for a high volume distribution centre, thus resulting in the facility being allocated to a different facility. The ability to forecast demand allows organisations to determine which facilities will be able to satisfy the need of each distribution centre.

The *inventory type* refers to whether the make to stock order is centrally or locally located, which is contingent on the strategy of the organisation. An organisation may decide to store generic, inexpensive inventory in its local facilities, placing the customer order decoupling point (CODP) closer to the beneficiary and it may decide to store more expensive inventory in a central facility, placing the CODP further upstream the relief supply chain.

For *inventory policy* decisions, demand forecasting and financial resources have been briefly addressed in the literature. Lodree and Taskin (2008) showed in their study of inventory policy for an imminent hurricane, that the inability to forecast demand directly impacts inventory policy as it is difficult to estimate inventory requirements due to the disaster. Balcik and Beamon (2008) showed that a larger pre-disaster budget allowed for the storage of more relief inventory, which improved the responsiveness of the relief supply chain. Greater supply lead times may encourage facilities to opt for ordering smaller batches of inventory at more frequent intervals to have more inventory in the pipeline or at the facility, thus affecting the inventory policy. Product characteristics such as the shelf life affect how long a product can be stored and the policy for disposal if it becomes obsolete.

Transportation policy is affected by the availability and quality of ports, roads, other major thoroughfares (Kapucu et al 2007), and bureaucratic customs procedures (Ashagbley 2006) as these impact on the transportation mode of choice, thus also impacting routing and scheduling decisions. Collaboration and coordination amongst organisations in sharing distribution resources also impacts the transportation policy as organisations pool resources (Balcik 2010). Available financial resources impact the decision to outsource distribution and also vehicular fleet composition. Duran et al (2007) showed that a lack of financial resources caused CARE to use third party logistics providers for goods distribution. The availability of vehicles in the fleet impacts resource positioning and vehicle scheduling decisions. The uncertainty of demand creates problems in scheduling, routing and the use or resources as the need for inventory is unknown (Chang et al 2007). Conflicts, piracy and general safety (Ashagabley 2006) impacts the mode of transportation and route planning, as

organisaions may not use routes that are deemed unsafe. The physical characteristics of inventory affect the mode of transportation, for example it may be more effective to ship rather than air freight bulky products.

Decisions	Factors affecting the decision
Number of facilities	• Logistics and facility costs • Availability of financial resources • Potential to accurately forecast demand
Facility points	• Potential for collaboration and coordination • Political environment (safety and security) • Quality of infrastructure • Logistics and facility costs • Impact of macro-economic factors • Potential to accurately forecast demand
Capacity of facility	• Logistics and facility costs • Availability of financial resources • Potential to accurately forecast demand • Supply lead time • Product characteristics
Allocation	• Potential for collaboration and coordination • Quality of infrastructure • Logistics and facility costs • Potential to accurately forecast demand
Inventory type	• Strategic
Inventory policy	• Availability of financial resources • Potential to accurately forecast demand • Supply lead time • Product characteristics
Transportation policy	• Quality of infrastructure • Potential for collaboration and coordination • Political environment (safety and security) • Logistics and facility costs • Availability of financial resources • Potential to accurately forecast demand • Physical characteristics

Fig. 1: Conceptual Framework of factors affecting IPP decisions

This discussion has identified various factors that affect decisions relevant to IPP. Some factors have shown to have a greater range of influence than others, influencing more decisions than other factors. We also envisage that some factors are able to influence a range of factors which in turn affects a range of decisions. One such factor is the potential for collaboration and coordination, which has the potential to impact factors such as logistics and facility costs, financial resources, the impact of macro-economic factors, supply lead time, the quality of infrastructure as well as the safety and security of personnel and inventory. Relief organisations that collaborate can do so in the context of warehousing, transportation and inventory. According to Balcik et al (2010) organisations that collaborate can share transportation resources leading to reduced transportation cost; and procure jointly, facilitating a reduction in the cost

of inventory with the purchase of larger quantities. They further argue that collaborating on long-haul shipments allows for reductions in freight costs and time savings in handling customs procedures. Shared warehousing also has the potential to improve inventory turnover. In the context of the factors that affect IPP decisions it is evident that collaboration among relief organisations reduces the negative effect of the majority of the factors that affect IPP. These include reducing logistics and facility costs, while simultaneously reducing the need for financial resources and reducing supply lead times as a result of the collaborative power of the various organisations working together. Collaboration and coordination also extends to pooled warehousing in locations that are probably less likely to be affected by poor infrastructure, safety and security issues, high taxes or problems at border crossings as experienced in some areas in Africa.

4 Conclusion

The overarching objective of the paper was to give form to inventory pre-positioning in the humanitarian literature through providing a definition of IPP and identifying and discussing the factors that affect these decisions in the humanitarian sector. In section two we formulated this definition and identified that these decisions must be considered in an integrated manner to increase the effectiveness and efficiency of the relief supply chain. The factors that affect these decisions were identified and discussed in section three, emphasizing the potential to collaborate as impacting on many of the other factors which affect IPP decisions. The culmination of the paper is the framework of decisions in IPP and the factors that affect IPP, which can be directly applied in the process of making IPP decisions.

Avenues of further research include the empirical validation of the definition of IPP through the validation of the decisions that need to be taken in IPP; the validation of the factors identified as affecting IPP decisions, through the use of case studies and expert interviews. The research can then be extended to investigate the relationships that exist amongst the various factors affecting IPP, paying particular attention to the impact of potential to collaborate on the other factors as previously discussed. Additionally, now that this paper has positioned the view point of the definition of IPP and the factors that affect it elements of the framework once further validated can be used to develop solution approaches appropriate to deal with these factors.

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