A Procurement Auctions-Based Framework for Coordinating Platforms in Humanitarian Logistics

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Abstract

This chapter focuses on an auction-based procurement framework for single coordinating platforms in humanitarian logistics. It first covers disaster relief operations, humanitarian logistics, and procurement in this context and illustrate many of the issues that make the management and coordination of procurement functions complex and challenging. Then the proposed framework along with the auction model is discussed including the unique design characteristics associated with disaster relief environment. Three-phase approach presents a complete representation of the procurement in humanitarian logistics. Results indicate that the proposed announcement options increase the fill rate. Announcement construction criteria allow coordinating platforms to use varying bundling choices.

Introduction

A disaster is defined as "an unforeseen and often sudden event that causes great damage, destruction and human suffering with at least ten people reported killed, 100 people reported affected, a declaration of a state of emergency, and a call for international assistance" (CRED 2011). Last two decades have witnessed devastating floods, earthquakes, tsunamis following an earthquakes, famines, or refugee crises all over the world. Only in 2010, close to 300,000 people were killed and more than 200 million people were affected by disasters causing $124 billion worth of economic damage (ADSR 2011). Disasters are classified based on their source (natural or man-made), speed of onset (slow or sudden), or location (dispersed or localized) (Duran et al. 2011b). Earthquakes, hurricanes, and floods are examples of sudden onset natural disasters. Famine is an example of slow onset natural disasters and a refugee crisis is an example of slow onset man-made disasters.

Although different types of disasters require different chain of relief operations, typical stages of disaster relief operations include mitigation, preparedness, response, and recovery (Altay and Green 2006). The mitigation phase is related to

infrastructure investment for minimizing the damage of disasters such as building walls to the shoreline to prevent floods. The preparedness phase aims to develop means to get ready for a disaster strike. Disaster education, pre-positioned inventories, and early warning systems are major examples. The response phase comes immediately after the onset of the disaster. This is the most challenging phase of all phases. Urgent needs of affected people should be supplied in the shortest time. The recovery phase aims to rehabilitate the affected area by reconstructing bridges and buildings, cleaning up the rubble, and helping the injured and mentally traumatized people.

Humanitarian logistics, which plays a key role in every stage of disaster relief operations, is defined as "the process of planning, implementing and controlling the efficient, cost-effective flow and storage of goods and materials, as well as related information, from point of origin to point of consumption for the purpose of meeting the end beneficiary's requirements" (Thomas and Mizushima 2005). When a state of emergency is declared and aid is appealed, resources such as relief personnel, relief goods and equipment are mobilized to the disaster location. By its definition, mobilization of resources as well as its predecessor and successor operations in a relief chain (Duran et al. 2011b) can be categorized as humanitarian logistics, which contribute to more than 80% of the total relief costs (Van Wassenhove 2006). Although local government of the disaster location is the main responsible to alleviate the suffering of its people (Thomas and Fritz 2006), non-governmental organizations (NGOs) as well as other relief aid agencies offer their help to transport the right number of relief goods on time to the right place. NGOs and relief aid agencies spend about $20 billion annually to overcome those challenges (derived from Tatham and Pettit 2010).

Due to its nature and operating environment, humanitarian logistics have different characteristics than commercial logistics. The main difference is its objective of alleviating the suffering of beneficiaries. Several other characteristics of humanitarian logistics are summarized by comparison in Table 1. Among the topics listed in Table 1, the auction framework presented in this chapter aims to address the demand-supply imbalance, procurement activities using cash donations, ad-hoc delivery network structure, and stakeholder coordination. The motivation for using auctions for procurement operations is to utilize the inventory of suppliers more efficiently in a scarce resource environment by using special parameters for humanitarian logistics addressing these topics. The proposed auction is planned to take place after the first rush (i.e., 12-72 hours) in the aftermath of a disaster.

Table 1. Comparison of commercial and humanitarian logistics (Ertem et al. 2010)

Topic	Commercial logistics	Humanitarian logistics
Main objective	Maximize profit	Save lives and help beneficiaries
Demand pattern	Fairly stable and can be predicted with forecasting techniques	Irregular with respect to quantity, time, and place. Demand is estimated within the first hours of response

Supply pattern	Mostly predictable	Cash is donated for procurement. Unsolicited donations, and in-kind donations need sorting, prioritizing to decrease bottlenecks
Flow type	Commercial products	Resources like evacuation vehicles, people, shelter, food, hygiene kits, etc.
Lead time	Mostly predetermined	Approximately zero lead time, demand is needed immediately
Delivery network structure	Established techniques to find the number and locations of warehouses, distribution centres	Ad-hoc distribution facilities or demand nodes, dynamic network structure
Inventory control	Safety stocks for certain service levels can be found easily when demand and supply pattern is given	Unpredictable demand pattern makes inventory control challenging. Pre-positioned inventories are usually insufficient
Technology and information systems	Highly developed technology is used with commercial software packages	Less technology is used, few software packages that can record and track logistics data. Data network is non-existent
Performance measurement method	Based on standard supply chain metrics	Time to respond the disaster, fill rate, percentage of demand supplied fully, meeting donor expectation
Equipment and vehicles	Ordinary trucks, vehicles, fork-lifts	Robust equipment are needed to be mounted and demounted easily
Human resources	Commercial logistics is a respected career path	High employee-turnover, based on voluntary staff, harsh physical and psychological environment
Stakeholders	Shareholders, customers, suppliers	Donors, governments, military, NGOs, beneficiaries, United Nations etc.

Procurement in humanitarian logistics, which is the scope of this chapter, can be defined as acquiring the possession of relief goods or equipment by the humanitarian organizations by making monetary payments to the suppliers. Procurement is one of the first and perhaps the most overlooked step in the disaster relief operations. Procurement is necessary to have the required goods readily available for the successor relief operations including inventory pre-positioning, vehicle routing and assignment, transportation scheduling, and resource allocation. In some studies (Gong 2003; Coulter et al. 2007), procurement is seen as a means to help the recovery of the affected country. Estimates show that 65% of the total disaster relief budget is dedicated to procurement of relief supplies and equipment (Schulz 2009, p97), which makes procurement the step of humanitarian logistics where majority of donor funding is spent. Organization of funding mechanisms, donor expectations, diversity of stakeholders, unpredictability of disasters and resource scarcity/oversupply are some factors (Balcik et al. 2010) that contribute to the complexity of the procurement operations in disaster relief. This complexity poses tough “what type, how much, when, from where, and how” questions for humanitarian organizations procuring relief goods.

In this chapter we propose a procurement method for humanitarian logistics that is based on auctions. The purpose of this auction-based approach is to address and promote the coordination among humanitarian organizations and suppliers during response and recovery operations after the first rush of the disaster onset. The auction model is developed to handle unique characteristics and restrictions of disaster relief environments using a single round sealed-bid auction. The next section overviews the procurement operations in humanitarian logistics to give some perspectives on timing of the procurement as well as supplier location. Then the proposed auction-based procurement framework is introduced with its operating mechanisms in Section 3. Considered system parameters that are unique for humanitarian logistics and models along with formulations that handle those parameters in the decision system are also discussed in Section 3. Section 4 gives the results of the study.

Procurement Operations in Humanitarian Logistics

Procurement methods in humanitarian logistics can be classified in two dimensions: (1) location of suppliers, and (2) time of procurement. Figure 1 illustrates these two dimensions with respect to disaster relief operations. Whether locally or globally supplied, procurement before the disaster onset addresses the mitigation and preparedness phases whereas procurement after the disaster onset addresses the response and recovery phases. Since the relief environment changes significantly with the disaster onset, the procurement methods change significantly, too. Moreover, operational procedures, contract types, resource availability, quality, and price of the relief goods change depending on the location of suppliers.

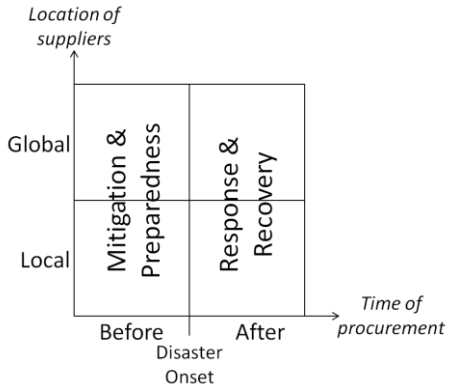

Figure 1. Classification of procurement methods in humanitarian logistics

Procurement before the disaster onset

Procurement before the disaster onset is necessary for prepositioning relief supplies in strategic locations near disaster-prone areas. The beneficiaries are supplied from pre-positioned inventory during the initial days after the disaster; therefore, having those supplies ready to dispatch is of critical importance. Nevertheless, only a small percentage of the total relief supply is sourced from the pre-positioned inventory (Balcik and Beamon 2008). Pre-positioning is a strategic decision which requires thorough analysis of relief operations. When humanitarian organizations decide to pre-position inventory, some issues such as the number of warehouse(s) and their locations as well as the types and the amount relief supplies to stock (Duran et al. 2011b) should be considered which requires extensive investigation and management effort.

Procurement before the disaster onset from global suppliers has quality and availability advantages over other procurement methods. Before the disaster onset, humanitarian organizations have enough time to search through various suppliers, compare their quality and availability. Once purchased and stocked in the warehouse, relief goods should be tracked for their quantity, expiration dates, and location in the warehouse, which -often- is only possible by using proper information technology tools. However, pre-positioned inventory is a costly investment for humanitarian organizations. Safeguarding the relief goods, preserving their condition and transportation have considerable operational costs that add up to the total pre-positioning cost.

This type of procurement and prepositioning is practiced both by some large humanitarian organizations and military forces of all countries. Examples for large humanitarian organizations can be given as United Nations Humanitarian Response Depot (UNHRD) of World Food Programme (WFP), World Vision International (WVI), and CARE. For example UNHRD network consists of five global depots in Italy, Ghana, United Arab Emirates, Malaysia, and Panama (UNHRD 2011). WVI also manages four global warehouses in the USA, Italy, Germany, and Dubai. Similarly, CARE International has three global warehouses in Dubai, Panama, and Cambodia (Duran et al. 2011a). Additionally, Pettit and Beresford (2005) analyse the current military practices in disaster relief operations using the UK military forces case and Ghanmi (2010) presents Canadian military forces hub location problem.

Procurement before the disaster onset from local suppliers is rarely applied, because the “locality” of the disaster is unknown before the disaster onset. Hence, there is no distinction between local or global suppliers before the disaster onset. One alternative definition for disaster locality can be the locality of the global warehouse of large humanitarian organizations. In this definition, procurement from the local suppliers near the global warehouse is considered. Using local suppliers before the disaster onset can be helpful for long-term economic development of the host country. Other advantages of using local suppliers are low transportation costs and fast delivery. On the other hand, quality may not be as

expected or the capacity of local suppliers may not be enough for high volume demand (Balcik and Beamon 2008).

Procurement after the disaster onset

Procurement after the disaster onset is necessary because disasters are unpredictable in nature (Balcik et al. 2010). The location, timing, and severity of a disaster are unknown to the decision makers before the disaster. Inventory can be pre-positioned only when these aspects are estimated to an acceptable degree. Therefore, no matter how good the estimates are, there will be procurement after the disaster. Unlike the procurement before the disaster onset, more tactical and operational decisions have to be made by the humanitarian organizations. For example gifts-in-kind need to be sorted, prioritized, and stored (Duran et al. 2011a). There is often a demand mismatch and operational problems in practice for gifts-in-kind (Tomasini and Van Wassenhove 2004; Thomas and Fritz 2006; Murray 2005). Also, funding for the disaster is proliferated after the disaster onset (Tatham and Pettit 2010) which requires dynamic spending strategies for the available funds. If there existed more funding in the mitigation and preparedness phases, not only the overall cost of a relief operation would be less, but also there would be fewer high-cost, agile procurement activity (Jahre and Heigh 2008). Therefore, the funding structure necessitates the procurement after the disaster onset.

Procurement after the disaster onset from global suppliers is mostly practiced by large humanitarian organizations. They usually send their personnel to the disaster area after the onset and assess the needs of the people. Depending on the type and severity of the disaster, they then decide whether to procure locally or globally. Since infrastructure is usually destroyed after the disaster, local suppliers may not always be easily accessible. Moreover, local supplier capacity might not sufficient for sudden demand amplification. Large humanitarian organizations usually distribute kits (e.g., medical, hygiene, family, and kitchen) as a form of aid. These packaged kits might not be in the product spectrum of local suppliers; hence, they would have to produce such kits from scratch on demand. Therefore, large humanitarian organizations usually procure relief goods from global suppliers, but use the local transportation and ad-hoc warehousing services.

Another variant of procurement after the disaster onset is procuring from already contracted global suppliers. In this approach, large humanitarian organizations establish Long Term Agreements (LTAs) with global suppliers to supply certain amount of relief goods on demand. LTAs create a common platform for attributes between global suppliers and humanitarian organizations for quality, price, packaging and labelling, lead time, and capacity. The suppliers to establish LTAs with can be determined using a multi-attribute auction mechanism. It is an efficient approach for humanitarian organizations, because they do not have to make the payment in advance and stock the relief goods (UNHRD 2011). One caveat of this approach for global suppliers is that they have to stock certain amount

of inventory on their premises for a possible disaster, which is actually transferring the inventory management cost to the supplier. The terms for LTAs should be defined clearly in order to protect both sides.

Procurement after the disaster onset from local suppliers is the most convenient method of supplying the immediate needs of beneficiaries, if only local suppliers have sufficient inventory in good condition. Procuring from local suppliers is encouraged especially in the recovery phase of disaster relief to support local economy and contribution of local people (Gong 2003; Coulter et al. 2007). The two most important criteria in deciding among local suppliers are price and timely delivery (Shahadat 2003). Reliability of the supplier and ability to offer quality products are also required by humanitarian organizations exercising procurement in developing countries (Shahadat 2003).

Procurement coordinating platforms

Some humanitarian organizations act as coordinating platforms for disaster relief procurement. For instance, UNHRD, Regional Logistics Units (RLUs) of the International Federation of Red Cross and Red Crescent Societies (IFRC) (Gatignon et al. 2010), and European Commission's European Community Humanitarian Office (ECHO)'s Humanitarian Procurement Centers (HPCs) function as coordinating platforms for different humanitarian organizations. Although UNHRD and RLUs can perform procurement on behalf of their partners, procurement is not among their primary functions. On the other hand, HPCs were primarily established to facilitate procurement operations of humanitarian organizations. Hence, some information on how HPCs work will be given in the following.

European Community Humanitarian Office (ECHO) distributed €1.115 million in 2010 providing humanitarian assistance to about 151 million people (ECHO Annual Report 2011). ECHO initiated Humanitarian Procurement Centres (HPCs) which are defined as "not for profit organizations specialized in the technical and commercial management of supplies and services necessary for the implementation of humanitarian actions. They can provide Technical Assistance in procurement to Contracting Authorities or supply pre-established stocks, purchasing or logistics capacity (HPC Annex IV 2009)." Humanitarian organizations should be qualified by an assessment procedure to become HPCs for services like stockholding, procurement and consultancy.

ECHO partners conduct procurement by three procedures when using EU funding: (1) open procedure, (2) negotiated procedure, and (3) negotiated procedure with a single tender. Under the first procedure, all involved suppliers may offer a tender after the publication of a contract notice. Under the second procedure, only invited suppliers may offer a tender based on the qualifications (i.e., expertise, certifications, product quality, lead-time, etc.) on a contract notice. Third procedure is for several special circumstances including employing an HPC and for contracts less than €60,000. Hence, employing an HPC facilitates the procurement operation

for ECHO partners for contracts exceeding this threshold. Other advantages for ECHO partners include reduced costs, use of HPC's procurement expertise and broad supplier base, quality assurance, transparency in procurement activities, substitutability of relief goods, and cost savings regarding transportation (Schulz 2009).

A procurement auctions-based framework

One way to obtain the needs of beneficiaries is procurement auctions. An auction is a mechanism which provides procedures to establish resource allocation based on bids submitted by participants (McAfee and McMillan 1987). Two parties are defined for a specific auction: auctioneer and bidder. In selling auctions (i.e., forward auctions), there is one seller and multiple buyers. In procurement auctions (i.e., reverse auctions), there is one buyer and multiple sellers. Generally, procurement auction-based models include two main phases: (1) the bid construction phase and (2) the winner determination phase (de Vries and Vohra 2003, 2004). In the bid construction phase, the bidders evaluate the auction and construct a bid price considering a number of objectives and constraints. When the auctioneer has all the bid prices, the winning bid is determined by utilizing a winner determination algorithm (Bichler and Kalagnanam 2002; Kalagnanam and Parkes 2004; Ledyard et al. 2002).

Procurement auctions have been used successfully in commercial logistics (Rothkopf and Whinston 2007; Elmaghraby and Keskinocak 2006); however, procurement auction platforms in commercial logistics cannot be easily applied in humanitarian logistics during the aftermath of a disaster. Nevertheless, Trestrail et al. (2009) is one of the few studies that analyze the procurement process from the bidders' perspective and illustrate the remote procurement of the world's largest donor of food aid (i.e., United States Department of Agriculture (USDA)). Bagchi et al. (2011) proposes an optimal auction mechanism for USDA to deter gaming of suppliers and enhance bid preparation process by combining carrier and supplier bids. On the other hand, Falasca and Zobel (2011) present a two-stage stochastic procurement model from the perspective of humanitarian organizations (i.e., auctioneer's perspective). Here, we propose an auction-based procurement framework for humanitarian logistics that utilizes a single coordinating platform with an assumption that the suppliers are acting on humanitarian grounds based on their corporate social responsibility and are trying their best to supply the requirements. The type of auction utilized here is a single round sealed-bid auction. Such a platform with the proposed framework could also be used as a coordination point to overcome the lack of coordination among organizations (Oloruntoba and Gray 2006; Kovacs and Spens 2009; Balcik et al. 2010).

In the proposed auction-based procurement framework, the coordinating platform (CP) is the auctioneer and the suppliers of relief goods are the bidders. This framework is developed to be used during response and recovery operations after the first rush (i.e., 12-72 hours) of the disaster onset. The main idea for using auctions in disaster relief procurement is to utilize the inventory of available suppliers more efficiently by introducing special parameters (i.e., priority of items, announcement options, ease of logistics) for humanitarian logistics. The framework aims to satisfy the requirements of beneficiaries with a higher fulfilment using these parameters. The framework consists of three phases: (1) announcement construction, (2) bid construction and submission, and (3) bid evaluation. Figure 2 depicts these phases, which correspond to the *appeals management*, the *suppliers' bid quotation*, and the *supplier selection* activities in humanitarian logistics, respectively.

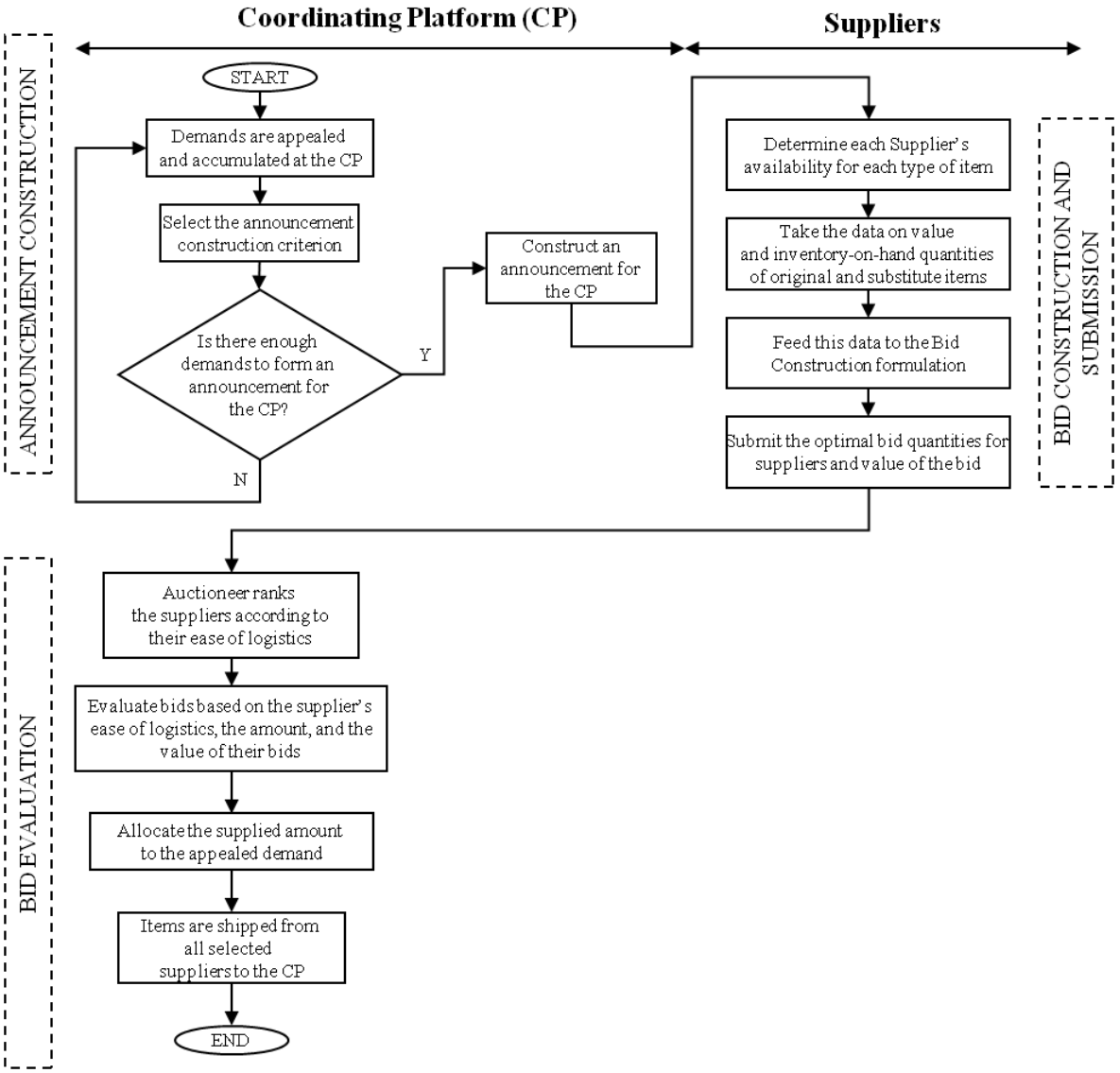

Figure 2. Procurement auction framework for humanitarian logistics

In Figure 2, the announcement construction and bid evaluation phases are managed by the CP, and the bid construction phase is managed by the suppliers. The CP collects the appeals from humanitarian organizations. CPs can be exemplified by Humanitarian Procurement Centers (HPCs) of ECHO. These humanitarian organizations can be exemplified by ECHO partners. ECHO case is used to describe the framework in this chapter, but the model can be applied to other similar entities. The CP accumulates demands from humanitarian organizations and releases

announcements based upon predefined criteria. Once an announcement is released, the suppliers evaluate their on-hand inventory quantities and product values. Here, product value is considered to be a function of its sales price, condition, and age. Suppliers then decide on product quantity and mix in their bids. Using a general multidimensional knapsack problem (MDKP), bid quantities and associated item values are maximized by the CP while primarily selecting the suppliers that have easy access to the disaster location since the need of the beneficiaries should be satisfied as soon as possible in a disrupted transportation network.

Procurement auction parameters

Here, we explore the design parameters of the auction-based procurement framework that address the unique characteristics of the humanitarian logistics. These unique characteristics include irregular and unpredictable demand and supply pattern, flows for specific resources such as kits and shelter, dynamic delivery network structure, limited use of technology and information systems, and a multifaceted stakeholder environment.

In humanitarian logistics, satisfying the immediate demand with available supply is challenging, because demand in humanitarian logistics is highly irregular and unpredictable with respect to quantity, time, and place. To address this irregularity, *priority of items* parameter is included in the framework. Priority of items is determined by the humanitarian organizations based on the phase of the disaster relief (*time*) and the severity of the disaster location (*place*). The *quantity* dimension is included by accumulating the appeals and releasing an announcement based on a criterion (announcement construction phase in Figure 2). Prioritization of the appeals list is necessary in humanitarian logistics because individual items might have varying urgency. Moreover, since disaster relief atmosphere is known for resource scarcity, not all the items in the appeals list can be satisfied within a certain amount of time. Therefore, priority of items concept is used in this framework. Three levels are used to specify urgent-immediate (first level), the low-priority (second level), and the non-priority items (third level) (Van Wassenhove and Tomasini 2003; Davidson 2006; Chiu and Zheng 2007).

Two types of supply sources are available in humanitarian logistics: cash donations and gifts-in-kind donations. Both supply sources are unpredictable and tend to proliferate after the disaster onset. Gifts-in-kind donations cause extra burden on relief personnel and cash donations require procurement of the appealed amount from the suppliers. However, the local suppliers might become unavailable after the disaster onset and utilization of all available resources is necessary. *Announcement options* are used to address this kind of supply pattern. Here, appeals are publicized with two announcement options: (1) substitution and (2) partial fulfilment. These options are binary parameters and decided by the CP in order to utilize the available supplier inventory efficiently. Substitution option enables suppliers to bid on the item using substitutes even if they do not have the neces-

sary original amount (bid construction phase in Figure 2). Here, we consider that when substitution is allowed, a similar line item can be replaced with the original appealed item. Substitution option can also be used for gifts-in-kind to address the problem of unsolicited donation (i.e., a similar unsolicited line item can be offered instead of the solicited item). The partial fulfilment option gives suppliers the opportunity to bid partially even if they do not have the full required amount. This option relaxes the demand constraint for better utilization of supplier inventories in a scarce resource environment. In typical procurement platforms, partial bidding is not usually allowed. Partial bids are then bundled by the CP to acquire the full appealed amount (bid evaluation phase in Figure 2). The announcement options proposed here may supplement complex auction types such as multi-item auctions (for substitution) and multi-unit auctions (for partial fulfilment).

Regarding the flow type, instead of commercial products in commercial logistics, the framework focuses on relief products such as shelter, food, hygiene, and medical kits. Since a procurement platform is analyzed, we concentrate on mostly consumables and do not address the equipment availability or scheduling of these resources. Priority of items is included to address the characteristics of relief products.

In a disaster relief environment relief goods, equipment, and personnel need to flow in almost zero lead-time from the origin to the consumption using ad-hoc distribution facilities and network structure. This dynamic delivery network structure is addressed by the *ease of logistics* concept. Ease of logistics is determined by the CP based on the information received from the suppliers around the disaster location. The ease of logistics concept embraces infrastructural and geographical accessibility of the supplier to the destination where items are required. Three levels as an integer from the [1, 3] interval represents the ease of logistics. In the bid evaluation phase, CP prefers the suppliers with higher ease of logistics (i.e., quantity and value is weighted by the ease of logistics parameter in the objective function). Lead time differences of suppliers are assumed to be handled by the ease of logistics concept.

Auction Model

Procurement auctions considered in this model have one auctioneer (i.e., buyer) and multiple bidders (i.e., sellers). The CP is the auctioneer in this model and the suppliers of relief goods are the bidders. Individual demands on the appeals list are collected and accumulated until a threshold is met. The demand up to that threshold are bundled and announced together. It is considered that different disaster relief environment would require different type of demand bundling. Therefore, five different threshold criteria are proposed:

a) A threshold amount for any item type in the accumulated requirements. (Quantity)
b) A certain time period t to elapse since the last announcement. (Time)

c) A total value ($V_T = \sum_j^m R_j \cdot Q_j$) for an announcement with m items; where, R_j is the reserve value of original item j and Q_j is the original amount required for item j. (Value)
d) A threshold priority count for the urgent priority items. (Count Priority)
e) The weighted priority (WP) of the accumulated requirements falls into an interval. Interval is defined as ($lp \leq WP < up$) where, lp is the limit for lower priority and up is the limit for upper priority. WP is computed by: ($WP = \sum_j^m p_j Q_j / \sum_j^m Q_j$) where p_j is the priority of item j. (Weight Priority)

Each criterion aims at different auction design parameters, which then leads to different number of bundled auctions. Limiting the quantity of items in an auction provides more auctions with smaller amounts that can be used in earlier stages of response and recovery operations. In addition, if the limit is increased, then the system can take advantage of economies of scale and lower the procurement costs, which can be utilized in later stages (i.e. sustainment) of disaster relief operations. In the second criterion, the CP keeps track of demand times and releases all accumulated demands after a certain period. This criterion considers procurements for time-sensitive items (i.e., items with expiration dates). Also, this criterion can also be utilized when a time sensitive decision has to be made. The announcement can be released when a predetermined total value of items is reached in the third criterion. The reserve price (R_j) used in the third criterion can be considered as the previous purchase price or the current market price of a good. Monetary decisions are included in the model with the third criterion. These decisions may become important during sustainment stage after the disaster. The count and the weighted priority criteria (the fourth and the fifth criteria) enable the CP to handle different priorities for different items by bundling them. If there is "enough" urgent demand for items exists in an announcement, it can be announced without waiting any longer to fulfil the immediate requirement.

When an announcement is constructed and announced based on a criterion of CP's choice, it comes with allowed substitution (S_j) or partial fulfilment (P_j) options for demanded items. Here, S_j and P_j are binary parameters where 1 represents allowing the option and 0 represents otherwise. Suppliers then decide whether to use substitute items or not (if allowed) while satisfying the requirements in the bid construction phase. An integer programming formulation is developed to represent the bid construction phase of the model:

Objective Function: $Min \sum_j^m (X_j V_j + Y_j W_j)$

With subject to:

$X_j + S_j Y_j \geq Q_j - \mathrm{M}\, z_j$ $\forall j$ (1)
$Y_j \leq \mathrm{M} S_j$ $\forall j$ (2)
$X_j \leq I_j$ $\forall j$ (3)
$Y_j \leq H_j$ $\forall j$ (4)
$X_j \geq P_j I_j - \mathrm{M}(1 - z_j)$ $\forall j$ (5)
$Y_j \geq S_j P_j H_j - \mathrm{M}(1 - z_j)$ $\forall j$ (6)

$X_j \geq 0$ and integer $\forall j$ (7)
$Y_j \geq 0$ and integer $\forall j$ (8)

The decision variables in this formulation are original (X_j) and substitute (Y_j) item quantities bid by the supplier for the item types (index j) in the bundle. The objective function minimizes the sum-product of item values (V_j, W_j) and bid quantities to use the low-valued items as early as possible in the auction. The value of a relief item is considered to be a function of its sales price, condition, and age. Suppliers are assumed to know the item values in their inventory and are ready to provide the quantity that is allocated by the auctioneer at the same value as they offered for the whole quantity.

A binary inventory availability parameter (z_j) is used to assess the suppliers' inventory on hand. It is calculated by summing the original (I_j) and the substitute (H_j) item counts. This inventory availability parameter is used in the formulation (constraints 5 and 6) to request whatever the suppliers have even if they don't have the required announcement amount (Q_j), where M is a sufficiently large integer. In the formulation, two constraints (1 and 2) handle the demand fulfilment requirements. Two constraints (3 and 4) forbid the supplier from bidding more than the on-hand inventory. The decision variables are positive integers.

In commercial logistics, winner determination is the phase that has been studied the most. In humanitarian logistics, suppliers might be differentiated with additional parameters. For instance, a bidder that is closer to the disaster area but offers substitute items could be more favourable than a distant bidder that offers original items. After the bidders construct their bids, the CP satisfies the requirements by only original items, only substitute items, or a mix of those depending on the bids received. Here, a modified version of the general multidimensional knapsack problem (MDKP) (Akcay et al. 2007) is used.

Objective Function: $Max \sum_i^n \sum_j^m \alpha_i (A_{ij} V_{ij} + B_{ij} W_{ij})$

With subject to:

$\sum_i^n (A_{ij} + B_{ij}) \leq Q_j$ $\forall j$ (9)
$A_{ij} \leq C_{ij}$ $\forall i, j$ (10)
$B_{ij} \leq D_{ij}$ $\forall i, j$ (11)
$A_{ij} \geq 0$ and integer $\forall i, j$ (12)
$B_{ij} \geq 0$ and integer $\forall i, j$ (13)

The decision variables are the original (A_{ij}) and substitute (B_{ij}) item quantities supplied from each bidder (index i) for the CP. The objective function maximizes the sum-product of item values (V_{ij} , W_{ij}) and bid quantities (C_{ij}, D_{ij}) to receive the newest and the most valuable items possible. Ease of logistics parameter (α_i) is used in the objective function to favour the suppliers that are more conveniently located. In the IP formulation, a knapsack constraint (9) makes sure that we have enough bid for the required amount (Q_j). Allocating at most the bid quantities to the suppliers are handled by two constrains, one for original items (10), one for substitutes (11). Decision variables are positive integers.

Results

The proposed framework with its formulations in three phases is tested using numerous sets of synthetic data and the system behaviour under different conditions is studied using simulation techniques. The linear programming formulations were solved using CPLEX 10.1™. Different disaster types with different requirements are taken into account. Suppliers with varying inventory on hand quantities and values are used. The ease of logistics parameter is also altered among the suppliers. In the system, the CP needs to determine the announcement construction criteria and the thresholds after the disaster based on the disaster type and characteristics of the relief mission.

In the bid construction phase, suppliers make bid decisions based on substitution and partial fulfilment options determined by the CP as well as their on-hand inventories. In different experiments, it is observed that substitution and partial fulfilment options provide bidders with fewer inventories on hand to give substitute types instead of original types and to partially bid in auctions. It is also illustrated by the experiments that the addition of these options allows less powerful suppliers to bid in procurement auctions. It is also observed that the suppliers make better use of the substitution when it is the single announcement option. The effect of substitution reduces, when the partial fulfilment option is permitted together with substitution.

Partial fulfilment option too enables better usage of supplier inventories. If partial fulfilment is not allowed, powerful suppliers are more likely to be awarded an auction than the less powerful ones. Allocation shares of bidders change, when these announcement options are allowed.

The performance of the procurement auction framework is measured by the fill rate, which is defined by dividing the supplied amount to the required amount. In the bid evaluation phase, experimental results state that using only a partial fulfilment option results in slightly better fill rates than using only a substitution option. The maximum fill rate is reached when substitution and partial fulfilment options are utilized together.

Suppliers are better evaluated with the ease of logistics parameter, which gives importance to the suppliers that have easy access to the disaster location. On the other hand, the ease-of-logistics parameter does not change the fill rate, but the allocation shares of bidders fluctuate significantly because of the ease of logistics parameter.

Conclusion

Humanitarian logistics is related to control, planning, and management of complex operations in the aftermath of a disaster where relief items are needed both immediately and in the long term. To supply the demand of beneficiaries efficient-

ly, the use of procurement auction-based methods has a prospect to increase. Coordinating platforms (CPs) require effective auction models designed specifically for procurement for humanitarian logistics. This chapter gives an overview of procurement operations in humanitarian logistics and presents a unique procurement auction-based framework for coordinating platforms.

The coordination in a multi-faceted stakeholder environment of disaster relief operations is more difficult than the coordination in commercial logistics. Especially, diverse stakeholder spectrum poses extra challenges on coordination efforts during a disaster relief operation. A single-coordinating platform would help address the coordination issues that are caused by the lack of professionalization due to the mostly voluntary nature of relief operations. Also, more tracking and tracing technology could be used and more operational data could be recorded to help after-the-fact performance analysis. Procurement operations could be used as a means to facilitate coordination among NGOs, suppliers, governments, military, and the United Nations.

Several system level auction parameters specifically designed for humanitarian logistics are presented. Announcement creation is tied to five different methods that could be used in different disaster specific settings. For example, announcements can be created with a lower-interval-level weighted priority criterion during the initial days after a disaster. This will result in having more frequent announcements with higher priority items. Then, in the sustainment phase, the criterion can be changed to the total value for budgetary motives.

Two announcement options are presented, substitution and partial fulfilment. The use of substitution is beneficial both for suppliers and the CP. By this way, the inventory on hand at the suppliers is better utilized. In addition, allowing substitution provides more diverse sets of suppliers, which benefits the CP. Suppliers are allowed to bid less than the announced quantity, which provides suppliers the opportunity to quick inventory turnaround. Options in announcements nearly double the fill rate which is critical in disaster relief performance. In disaster relief operations, substitutions and partial fulfilment options should be permitted to get the highest fill rate. Moreover, the announcement options proposed here may supplement complex auction types such as multi-item auctions (for substitution) and multi-unit auctions (for partial fulfilment).

The value of the items plays a balanced role in the framework, since the bid-construction phase aims to discover the minimum valued original and substitute item type combination, but the bid evaluation phase aims to discover the maximum valued original and substitute item type combination. The use of item value helps suppliers to make use of the old items more effectively in the bid-construction phase and helps the CP to get better-conditioned items in the bid evaluation phase.

Varying quality of original relief supplies from different bidders and substitute items from the same bidder might be a limitation of the proposed framework. To alleviate this limitation, coordinating platforms should explicitly declare the product quality specifications during the announcement phase.

As a future study, the framework should be tested using the data from real disaster relief operations. We believe that the current structure of the ECHO-Humanitarian Procurement Centres (HPCs) allows the introduction of such framework. Moreover, 3PL services such as transportation scheduling, vehicle routing, and warehousing could be included in the supplier selection process using a reverse auction process. Procurement thresholds of HPCs could also be studied in the future and optimized to select the best procurement procedure.

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