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Issues and Challenges in Self-Sustaining Response Supply Chains

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Monterey, California. Naval Postgraduate School

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28 September 2013

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Abstract

The most basic representation of a supply chain has three elements: supply, demand, and the flow between the two. A humanitarian response supply chain (RSC) tends to have unknown demand and at best uncertain supply with disrupted flow. A self-sustaining supply chain requires that the supply chain itself provide all resources consumed while transporting supplies, thus complicating the operations with numerous challenges and unfamiliar issues. If an RSC is self-sustaining, it will reduce some of the uncertainties in supply. However, self-sustaining response supply chains (SSRSC) generate significant additional cost. We explore the issues and challenges of SSRSC that arise in logistics networks in order to understand the costs associated with SSRSC observed in special operations and humanitarian assistance and disaster relief.

Keywords: Self-sustaining, supply chain, humanitarian assistance, and disaster relief

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Issues and Challenges in Self-Sustaining Response Supply Chains

Introduction

Disasters in recent years have offered many lessons. One lesson is the economic reality of the increasing cost of a disaster. The cost has risen dramatically, from US$16.1 billion per year in 1992–2001 to US$40 billion per year in 2002–2011 (Jones, 2013). The cost increase can be attributed to the complexity of operations in humanitarian logistics. Humanitarian logistics has been defined as "that special branch of logistics which manages response supply chain of critical supplies and services with challenges such as demand surges, uncertain supplies, critical time-windows in face of infrastructure vulnerabilities and vast scope and size of the operations" (Apte, 2009, p. 17). Practitioners (Eisner, 2007; Fenton, 2008; Nelon, 2008) and scholars (Celik et al., 2012; Holguin-Veras et al., 2009; Kovacs & Spens, 2007; Van Wassenhove, 2006) agree that preparation is a significant part of relief effort. Understanding the effect of complexity of operations on the cost is one way to improve planning.

Availability of the supplies is assumed in most supply chains. However, for response supply chains (RSCs) in disaster-struck regions, this may not necessarily be true. Sustainability and self-reliance are two of the important aspects of a response supply chain. We define a self-sustaining response supply chain (SSRSC) as a supply chain established in response to a disaster, where there are resources consumed in intermediate stages that are not locally available, and therefore must be supplied through the chain itself. It has been shown that self-sustaining supply chains increase resource requirements, manpower, and equipment, resulting in significantly higher cost (Regnier, E., Simon, J., Nussbaum, D., & Whitney, L., 2013a; Regnier, E., Simon, J. , & Nussbaum, D., 2013b).

In this report, we explore the challenges and issues in a SSRSC. We focus on operations from an economic perspective. Fundamentally, our work is based on literature survey and discussions with subject matter experts. In our exploration, therefore, we are limited by absence of actual data. We believe this could develop into the second phase of this research study. At present, we focus on conceptual and stylized scenarios. However, we have extensively studied the topics of response supply chain and analyzed costs associated with self-sustaining supply chains. We are beginning this effort of exposing the vein of research in this new area by combining the two research streams from RSC and SSSC for exposing the issues and challenges in SSRSC.

The article is organized as follows. In the section entitled Supply Chains, we offer background on different types of supply chains. Next, we review the literature for sustainable supply chains and response supply chains in order to understand the issues and challenges. After this we describe the potential problem, discuss the expected results, and finally, we offer the conclusion.

Supply Chains

We can partition supply chains into three broad categories in terms of how the supply chain manages material—traditional, sustainable, and self-sustaining. Traditional supply chains that function in traditional logistics networks have been well studied in operations management. Sustainable supply chains (SSC) have received considerable attention in this age of green consciousness and fiscal austerity and can be measured by looking at their agility, adaptability, and alignment (Lee, 2004). SSC often achieve these through "The Three R's," reduction, reuse, and recycling—the latter two "R's" tend to be performed outside of the traditional supply chain. Self-sustaining supply chains extend themselves beyond the reuse and recycling. They require that some of the resources consumed in the logistical activities of transporting supplies to their destinations be provided via the supply network itself. This makes self-sustaining supply chains even more complex; they essentially become supply chain islands, where the network must be

- nimble enough to transport, create, conserve, and consume supply;
- flexible enough to repair and reuse the waste that it produces; and
- rigid enough to fulfill the ultimate demand of the supply chain while simultaneously fulfilling its own needs during the process of delivering the good or service it promises.

In addition to the management of material, one important aspect of supply chains is the environment in which they operate. At one end of the spectrum are traditional supply chains with less variable fluctuations in demand; on the other end are 'response' supply chains in which supply, demand, customers, and network configurations continuously change due to unpredictability. A supply chain in its most basic form encompasses three elements: supply, demand, and flow, with flow being the intermediary between the other two components. Typically, a traditional supply chain supplies a pre-established, standardized product to customers to meet a relatively constant and forecasted demand through structured resources and continuous flow. In contrast, at any given time, a humanitarian response supply chain supplies a wide range of products and services fulfilling spurts of demand while sharing the flow and capacity with other relief items (Apte, 2009). Traditional supply chain models may fail when they are stressed due to unknowns and uncertainties. Supply chains stressed in this way—extreme supply chains—need special attention from the researchers.

Sustainable, self-sustaining, and response supply chains are becoming more relevant to the Department of Defense (DoD) as we proceed through the 21st century. A major reason for this is the the era of fiscal austerity that the United States has entered after the 2008 financial crisis. The U.S. DoD budget is tighter, so it must be able to maintain the same capabilities as in the past while using fewer resources. Thus sustainability and self-sustainment become increasingly important for the DoD. Strategic changes also drive the growing importance of response supply chains; as people move to more disaster-prone areas of the world, the U.S. military will continue to play a major role in being the first responders in humanitarian assistance and disaster relief (HADR). Also, the face of conflict has tacked towards more irregular enemies vice large armed forces, thus requiring smaller, independent teams that coexist with each other over long periods of time.

Virtually every supply chain, regardless of whether it is self-sustaining or not, shares common characteristics such as supply, inventory, distribution networks, flows, lead-times, information systems, customers, demands, and key performance indicators. In this research, we study the similarities and differences of SSRSCs with SSSCs to expose the challenges in SSRSC in terms of operations. We believe studying operations is the first step to understand the burden of cost in such supply chains (Regnier et al., 2013a; 2013b).

When a self-sustaining supply chain is initiated, it is endowed with a certain set of goods. These goods are used to sustain the SSSC itself during the transport, and these may also be the same types of items that it is attempting to deliver to its customers. When a self-sustaining supply chain begins, it has a limited amount of space to carry all of the goods being delivered and consumed during the delivery. Therefore, the choice of goods to carry is critical in that the SSSC cannot restock during the delivery process. The carriers must be efficient, innovative, and sustainable in their use of goods—they must have the tools to not only reach their destination, but also to have the provisions that the customer desires. If it runs out of goods, not only does the customer not receive goods, but also the supply chain itself could perish, resulting in, at best, unfulfilled demand and at worst, loss of life. Thus, efficient reuse is critical, as space is at a premium. Furthermore, the logistics network in an SSSC could be unstable and variable over time. These self-sustaining supply chains, especially within the context of HADR and DoD special operations, provide for a unique research opportunity that has not been thoroughly studied (see Figure 1).

For example, consider the supply chain of providing fuel. Transportation of this single commodity requires fuel to be consumed by vehicles that transport it.

There exist numerous challenges in this network if it is to be self-sustaining. It has also been researched and proved that such SSSCs can incur significantly higher costs than traditional networks (Regnier et al., 2013a; 2013b).

In this project, we study such challenges in response supply chains, where multiple goods are conveyed and consumed through the same network—a network that is rife with uncertainty.

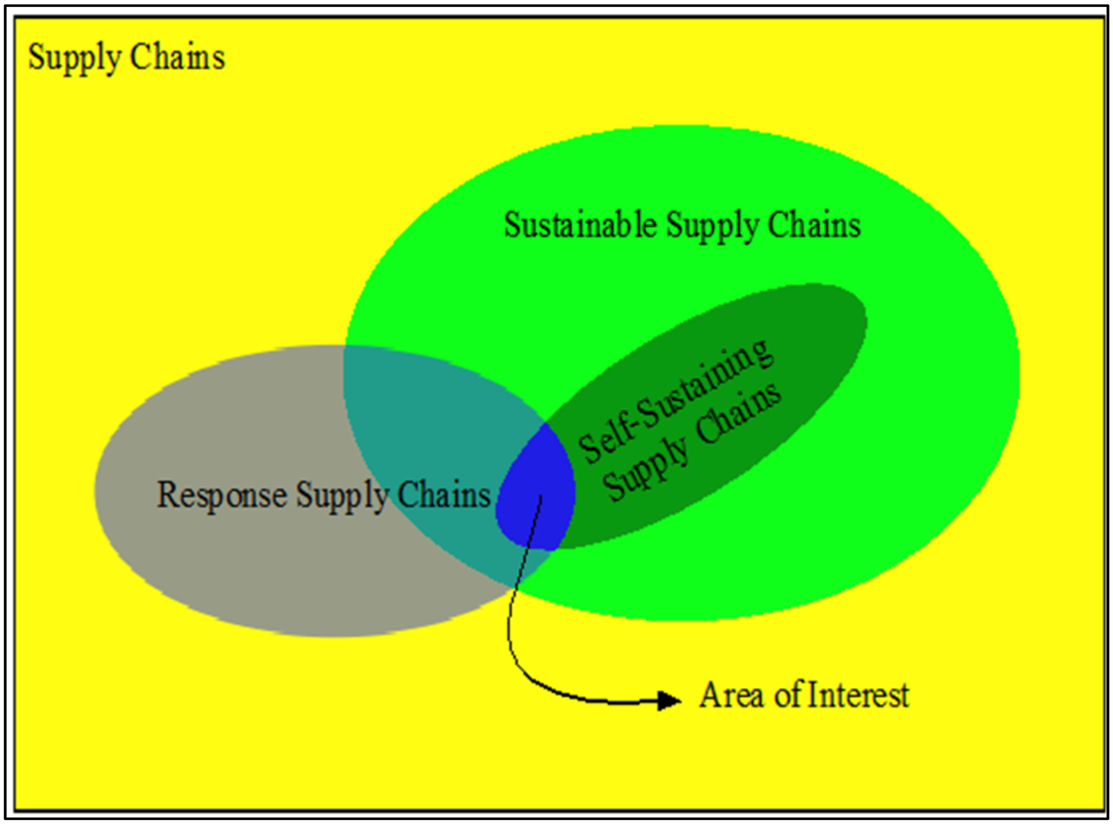

Figure 1. Positioning Self-Sustaining Response Supply Chains

Uncertainty in response supply chains is typified by "unknown unknowns," to quote Donald Rumsfeld. When disaster strikes, authorities do not know who is hurt, the severity of the damage, what portions of the network remain or are degraded, how the supply chain will develop in the future, where demand will materialize, where supply will materialize—to name a few unknowns. The only *knowns* are the goals to save lives and to reduce suffering. Saving lives involves delivering the goods that are needed to sustain life—the same goods, such as water, fuel, medical supplies, equipment, and information, that self-sustaining supply chains use and deliver during their life cycles. In such instances, the transportation capabilities needed to deliver goods, save lives, and reduce suffering must be reliable. The uncertainties are brought on due to the process of providing relief in a disaster with variable speed of onset and scope of affected region that in turn makes SSRSC more complex. Understanding the complexities, we believe, will lead to better planning for HADR and in turn facilitate effective (in terms of reaching most of the affected population) and efficient (in terms of time and money) relief operations in case of disaster. There has been evidence that the degree to which a disaster can affect depends on the planning (Natarajarathinam, Capar, & Narayanan, 2009). For all these reasons, we plan to explore these complexities in SSRSC, thus allowing the DoD to identify the burden of cost.

Literature Review

Our focus in this article is self-sustaining response supply chain. Supply chains in general have received considerable attention as significant cost drivers in any operation, whether business, humanitarian, or otherwise (Chopra & Meindl, 2013; Jacobs & Chase, 2013). Usually the focus is on demand uncertainties (Lee, 2002) and logistics optimization of a fixed and known network (Chopra, 2003; Robeson & Copacino, 1994). Often, this optimization is a delicate balance between having maximum flexibility while being able to deal with significant disruptions in the supply network (Lim, Bassamboo, Chopra, & Daskin, 2008).

Sustainable supply chains have received considerable attention in this age of green conciseness and fiscal austerity. Supply chain management often achieves these through reduction, reuse, and recycling—the latter two “R’s” are often performed outside of the traditional supply chain. Furthermore, sustainability has been gaining traction in popular literature (McDonough & Braungart, 2010) as well as in academic literature (Dey, LaGuardia, & Srinivasan, 2011; McKinnon, Browne, & Whiteing, 2012; Seliger, 2007; Wang & Gupta, 2011). Early on, Kleindorfer, Singhal, and Van Wassenhove (2005) helped focus the operations community on the “Triple Bottom Line”—profit, people, and planet. They argued that sustainability is not only a social need but also provides financial benefits to a firm.

Sustainability is often achieved through a closed-loop supply chain (Guide & Van Wassenhove, 2009) where goods are refurbished or remanufactured after their virgin uses. This results in the goods being more sustainable since less new material is required. Focus has turned toward the closed loop and sustainability in supply chain management as environmental legislation and the social consciousness has punctuated the need to include the environment in analysis and make the most out of existing material (Ferguson & Souza, 2010; McKinnon et al., 2010). Companies have begun to realize that profits and sustainability go hand in hand; Walmart has been particularly instrumental in bringing sustainability into the mainstream of supply chain management (Plambeck & Denend, 2010).

The post-Cold War environment changed the global power-structure, which has resulted in increased demand of resources such as energy and water

(Pickering, 2013). On the other hand, due to the missions of DoD, it requires these resources. Sustainability facilitates the DoD plan for maintaining such resources. The Office of Federal Procurement Policy defined sustainable acquisition as "acquiring goods and services in order to create and maintain conditions under which humans and nature can exist in productive harmony, and that permits fulfilling the social, economic, and other requirements of present and future generations of Americans." (Pickering, 2013) However, sustainable acquisition does not necessarily influence supply chains that are self-sustaining.

Self-sustaining supply chains extend themselves beyond the reuse and recycling. A major challenge in self-sustaining supply chains is that the resources consumed while transporting supplies to their destinations need to be provided via the network itself. (Dubbs, 2011; Hathorn, 2013, and Regnier, Simon, Nussbaum, & Whitney, 2013) have identified the multiplicative effects on cost in such situations.

Response supply chains are those supply chains that are developed during a disaster or a crisis. A disaster has been defined by many government and non-government organizations. The International Federations of Red Cross (IFRC) classified an event as a disaster if that event is "... a sudden, calamitous event that seriously disrupts the functioning of a community or society and causes human, material, and economic or environmental losses that exceed the community's or society's ability to cope using its own resources." (IFRC), A disaster may lead to a crisis as history tells us. For instance, the 2011 Japan earthquake resulted in a tsunami and then in explosion of nuclear facilities, resulting in a colossal crisis.

According to Merriam-Webster, crisis is defined as "an unstable or crucial time or state of affairs in which a decisive change is impending; especially: one with the distinct possibility of a highly undesirable outcome" ("Crisis," n.d.). We also define response supply chains as supply chains where crisis exists with a high probability. Although, crisis in a supply chain is unpredictable, it may not be unexpected (Coombs, 1999).

Response supply chains (especially in humanitarian assistance and disaster relief) can be classed as extreme supply chains. Apte (2009) explored the factors at play in response supply chains. Disaster relief has been identified as an important and complementary area of study to sustainable supply chains (Guide & Van Wassenhove, 2003).

Scholars have given different names to extreme supply chains. However, the issues and challenges are similar. Whybark, Melnyk, Day, and Davis (2010) discussed the new realities and management challenges for the disaster relief supply chains that function under extreme conditions. Such supply chains in austere environments need planning and research for better management. Though the commercial supply chain managers will probably get frustrated in these situations, there are lessons to be learned from the private sector (Van Wassenhove, 2006).

Dash et al. (2013) described the main characteristics of a disaster response chain by pointing out specific issues faced by the managers. They indicated two major challenges. First, response supply chains must be set up quickly with available resources such as information and manpower. Second, the operational apparatus of the supply chain needs to be effective due to economic concerns.

The articles reviewed for this research offered a spectrum of issues and challenges for a response supply or for the sustainable supply chain. But in our search, we did not find any that dealt with the issues and challenges of a self-sustaining response supply chain. We believe that this study is one of the first attempts to uncover fundamentals of SSRSC.

The Potential Problem

Our problem posits a potential supply network with three types of nodes: source nodes, coordinating (warehousing) nodes, and demand nodes. The supply network has supplies that are sourced from outside the affected region, transported through coordination or warehouse nodes, and delivered to the demand centers in the affected region. Such an environment can be encountered in many disaster situations and combat operations.

For example, in spite of sufficient supplies to realize their missions and perform operations as planned, during Operation Iraqi Freedom's (OIF) major combat operations through the fall of Baghdad, on-hand inventory was lower than planned for all commodities except fuel (Peltz et al., 2005). Peltz et al. (2005) found that inventories for commodities such as food and water gradually improved but spare parts experienced distribution problems.

Many response supply chains in the face of disaster, such as in the case of Hurricane Sandy in the northeastern United States, suffer similar shortages in supplies and lack of on-hand, pre-positioned inventory, resulting in delivery issues and starving affected population.

The source nodes supply items such as water, food, or fuel. Examples of the suppliers can be found in the private, military, and public sectors. The franchises of Nutriset in several countries produce and supply Plumpy'Nut to malnourished children in the Horn of Africa through UNICEF (Swaminathan, 2009). During Operation Iraqi Freedom, though the distribution of food and water gradually improved, the spare parts production shortage continued due to high demand on account of the faster pace of the combat operations (Peltz et al., 2005).

The coordination nodes are places where the provisions or emergency supplies can be warehoused or transferred to be sent to the affected regions. Coordination operations are similar to how the military maintains and operates inventory practices ashore or at sea for future events of a conflict or disaster. A recent example is the process of relief operations during the 2010 earthquake in Japan by the U.S. Navy.

The demand nodes are in the affected region where the critical supplies reach the final destination. For example, in the aftermath of Hurricane Sandy, the National Guard provided 2.1 million Meals, Ready to Eat (MREs) and over one million bottles of water (Gibbs & Holloway, 2013) to the affected population, and these were sourced from outside of the affected areas.

The unanticipated high demand for spare parts in Operation Iraqi Freedom (OIF) showed the inefficiency of the traditional supply chain. The war reserves did not contain certain critical items and had inadequate inventory of other items, making success extremely difficult in combat operations. In addition, war reserve stocks were planned for five months of combat operations. This was much shorter than the lead-times for many parts. Lack of funding and support resulted in long production lead-times for many items. Moreover, the inadequate national supply with forward positioned war reserve and theater supply preparation led to excessive transportation cost.

In such a situation (i.e., OIF), a self-sustaining response supply chain might have eased the shortage, long lead-times, and high-cost issues. Having said this, the SSRSC is also not without challenges. In the next section, we discuss some of the challenges these SSRSCs face.

Challenges

The type of disaster plays an inevitable role in the self-sustaining supply chain established in response to that disaster. If the disaster is manmade, such as war, the supply chains are managed by military organizations through the pre-established protocol. In case of a natural disaster, the attributes such as speed of onset and the scope of the affected area have an effect on the complexity of humanitarian operations as illustrated in Figure 2 (Apte, 2009), thus influencing the response supply chain.

The disasters that are localized offer some focus for the relief operations such as the 2010 Haiti earthquake, but the dispersed disasters such as the 2004 Indian Ocean tsunami or 2009 H1N1 pandemic stretch the humanitarian organizations' relief operations. We do not necessarily differentiate between the above mentioned disasters on the basis of the vastness of the affected area but by the number of administrative entities within the entire affected area (Apte & Yoho, 2011).

The disasters that occur with some notice provide lead-time for humanitarian responders to organize effective and possibly efficient relief operations. The strategic prepositioning such as infrastructure development, capacity planning of resources, and asset location can be developed for a slow-onset disaster, whereas for sudden-onset disaster, such planning has to be done long before a disaster strikes. In some cases, it may not be done at all. In such cases, response may cost considerably more, since the United Nations Human Development Program (2007) and the World Meteorological Organization (2009) have estimated that every dollar invested in preparing for a disaster saves seven dollars in disaster response.

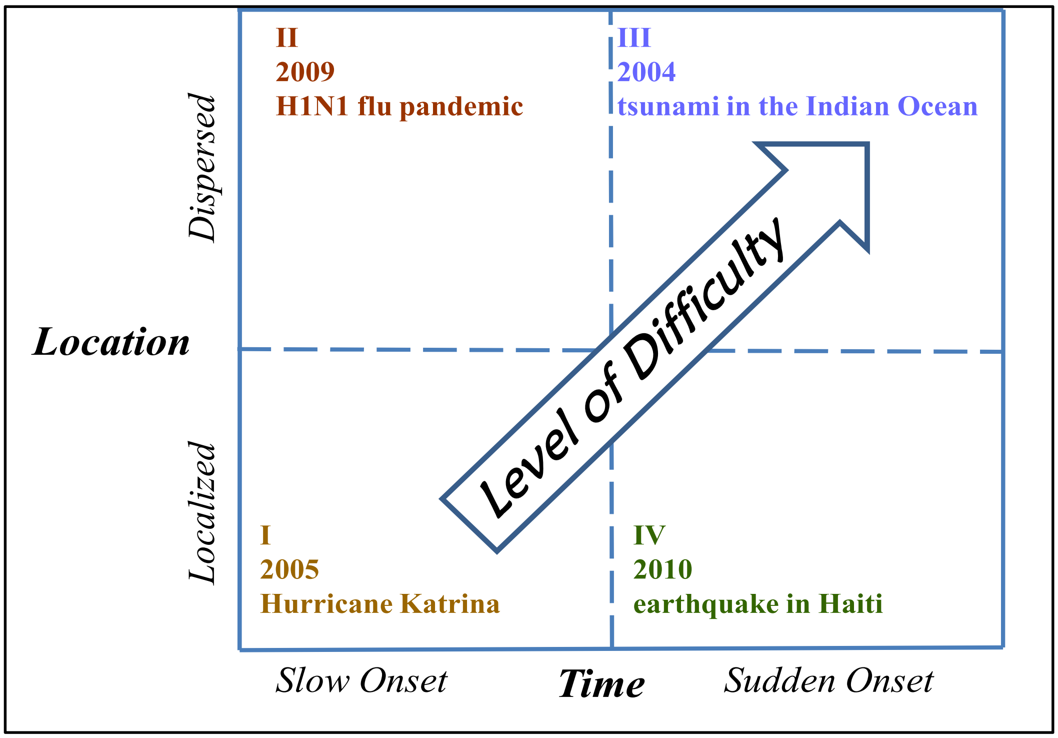

Figure 2. Classification of Disasters
(Apte & Yoho, 2010)

A common and natural indicator of complex operations, especially in the response phase can plausibly be cost. In this research, we propose that the cost of these operations is influenced by the issue of sustainment and is driven by the major challenges of speed and dispersion. In a self-sustaining supply chain, the amount of resources that must be delivered at the beginning of the supply chain is significantly larger than the amount delivered to the ultimate consumer at the end of the supply chain. Due to this "multiplier effect," it has been shown that self-sustaining supply chains increase resources and manpower, resulting in significantly higher cost (Regnier et al., 2013a; 2013b). Figure 3 illustrates our model for qualitative effects on the dimension of complexity of a SSRSC based on its cost.

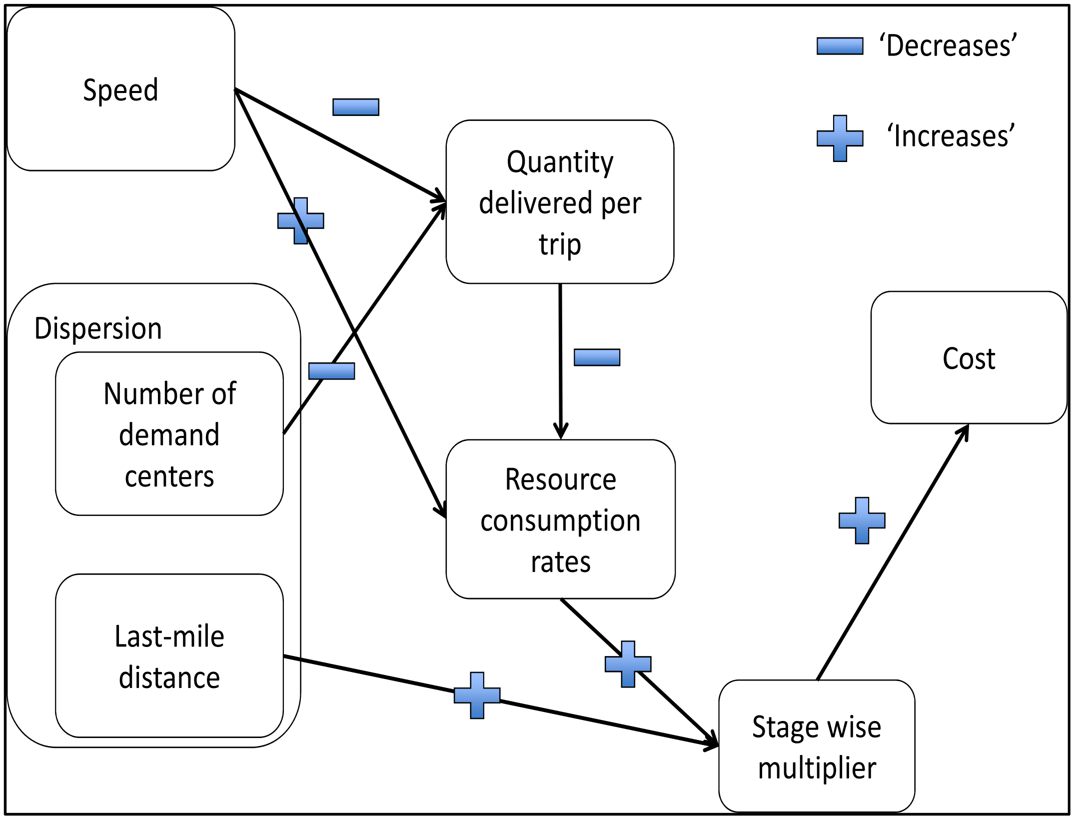

Figure 3. Qualitative Effects of Speed and Dispersion in SSRSC
Note. Adapted from Apte, Khawam, Regnier, & Simon, 2013

Dispersion

From the perspective of a response supply chain for a localized disaster, when the infrastructure exists, demand may be treated as consolidated within a region—affected people can access relief supplies at a larger, centralized demand center. Large and scattered demand in the affected region in case of a dispersed disaster may increase the need for coordination and collaboration among the relief organizations. This may result in a higher level of complexity of operations. The dispersion leads to more demand points at the end of longer supply chains, resulting in substantial increases in the cost of operations.

Speed

In case of a slow-onset disaster, there may be some lead-time in setting up and even beginning operations for the supply chain. A response supply chain could benefit from economies of scale leading to larger convoys and larger lot sizes. In case of a sudden-onset disaster, on the other hand, due to the urgency of the demand, there may be more suppliers involved, and the uncertainty of demand may force smaller loads to be deployed in vehicles with lesser capacity. This results in a larger multiplier on one or more stages of the supply chain, which in turn leads to increased costs for the supply chain to deliver a given quantity of goods.

Sustainment

The issue of the response supply chain being self-sustaining means that the resources consumed by the relief operations must be provided through the supply chain. Generally, response supply chains become self-sustaining only in austere regions, where disaster or conflict has made resources locally unavailable. One such resource is fuel. Researchers (Dubbs, 2011; Hathorn, 2013, and Regnier, Simon, Nussbaum, & Whitney, 2013) have identified the multiplier effect for fuel. Their study focused on situations where the fuel requirement due to self-sustainment is significantly larger. Dubbs (2011) estimated that in Helmand Province in Afghanistan, from Camp Leatherneck to a forward operating base that was remote, the supply chain consumed 72% of the fuel that was delivered. Hathorn (2013) estimated that a supply route from San Diego to the Spratly Islands under threat may consume 25% to 90% of what it delivers, depending on the convoy composition.

Discussion

In understanding the effects of speed and dispersion, it is important to recognize that these factors affect the cost both directly and indirectly. Speed and dispersion affect the multipliers, which in turn affect the total cost of the operations.

If the speed of onset is higher due to urgent demand, the frequency of deliveries to the demand nodes increases. It also reduces the amount delivered per trip due to shortened lead-time for procuring commodities from the suppliers. Another aspect of urgent demand is using the available, at times inefficient, modes of transportation. All these factors increase the consumption rate along the supply chain. Since transport and handling are more inefficient and consume a greater portion of the resources at any point in the supply chain, leaving less to be delivered to the affected population, the increase in the speed of onset of a conflict or disaster increases the multiplier effect on the supply chain, resulting in increased total cost.

If there is larger dispersion in the affected area, this may increase the scope and scale of the demand in terms of both larger distances for delivering the demand and a larger number of demand centers. Our intention, as indicated in Figure 3, is to model dispersion in terms of both distance and number of demand centers and finds both increased cost and the multiplier effect of self-sustaining supply chains. It is interesting to note that if either one (distance or demand) increases, cost increases much faster if the other is also increasing, that is, if there is an interaction effect.

There is a similar positive interaction between speed and dispersion. That is to say that we find that the complexity of operations increases not only due to increase in the speed of onset and affected area but these factors themselves interact positively.

The multiplier effect in a supply chain intensifies the supply costs and resource requirements due to a self-sustaining network. Therefore, for an SSRSC with several stages, a sudden-onset disaster will have a larger total cost than estimated in an analysis that neglects the impact of self-sustainment.

Conclusion

We set out to study the issues and challenges for SSRSCs. The multiplier effect associated with SSSCs has been examined. The primary considerations in an SSSC are the length of the supply chain, in terms of both distance and the number of stages, and the characteristics of the transport vehicles. However, in this study we added the complexity of “response,” typically in expeditionary or extreme environments. The complexity of humanitarian operations depends on speed of onset and dispersion of demand in the affected area. The issues and challenges have been studied through lessons learned after a disaster strikes. Combining self-sustainment with these major factors increases the complexity further. One of the significant insights we gained from this study is that the resource demands associated with logistics operations are more costly than their direct acquisition and operating costs. Total cost in an SSRSC increases considerably due to the indirect cost the transportation and handling incurs by requiring delivery of additional supplies, to sustain the supply chain activities.

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