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Using Disruptive Innovation for Disaster Mitigation and Ensuring Supply Chain Continuity

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Abstract

Supply chains are a network of intertwined nodes and routes that are normally expected to operate smoothly and allow for seamless movement of material, documentation and information two and fro its entirety. Such large networks spread over a wide area on a global scale are bound to be affected by disruptive factors both natural as well as man-made.

Though some amount of research has been done on supply chain disruption, mitigation efforts, risk management, etc. a proper linkage is normally missing. Also very little research has been done on continuity. This paper does a selective literature review of selected papers covering various areas of supply chain disruption management under exogenous shock conditions like natural disasters and solutions and links the recent innovation of drone technology to disaster recovery and mitigation efforts and ensuring supply chain continuity. While commercial drones are under test usage by variety of organizations, this paper also assesses certain selected drone types for their compatibility and future modified usage in disaster recovery and supply chain continuity after natural disasters.

Keywords: *supply chain disruption, disaster recovery, supply chain continuity, disruptive innovation, disruption, drones*

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Introduction

Globalization has allowed organizations to tap into cheaper resources from as well as access markets in other countries. Increasing needs of competitiveness in the face of global competition has further forced them to move forward to having integrated supply chains, lean inventory management and demand driven supply chain management. Organizations following the concept of using single source of procurement for maximum number of requirements are heavily dependent on few suppliers for all their needs. These suppliers are normally spread over a large area sometimes spanning countries.

Similarly the Organizations focus on using single or few production units to produce and deliver products to consumers spread across various countries. These many-to-one Inbound to Manufacturing [I2M] and one-to-many Outbound to Consumer [O2C] strategies have been so designed so as to allow for seamless movement of material, documentation and information flow.

This widespread network of suppliers, manufacturing points and consumer base has increased the level of vulnerability of the supply chains getting affected by variety of disruptive factors both internal and external. In reality, facilities and the links connecting them, fail from time to time due to poor weather, natural or man-made disasters, or a combination of any other factors (Shukla et al., 2011)[1]. Even the routes used for movement are vulnerable to disruptive forces normally external in nature because different types of risks are associated at different areas. Disasters can happen anytime and anywhere putting supply chains at risk of partial or total failure. Fridgen, G. et al. (2015)[2] also lays stress on the fact that external shocks to the supply chain can threaten the entire supply chain, including all its partners.

The supply chain normally consists of three parts – (a) Source, (b) Logistics and Manufacturing, and (c) Consumers. Because of globalization the spread of each of these parts of the supply chain has increased. The source or suppliers, irrespective of the tier, whether immediate or not, can be spread over various geographical regions or countries. Similarly the logistics may encompass storage and movement of goods whether raw material, work-in-process or finished products, through multiple countries. Similarly manufacturing operations may also be spread over multiple

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countries. Globalization has opened up global markets and customers will be spread across countries.

While natural disasters may also entail loss of lives, infrastructure destruction and spatial disfigurement, this paper puts particular focus on the supply chain part only and takes into account all parts of the supply chain, i.e. source, logistics and consumption points.

This paper aims at doing a literature review of the published papers on the topics of supply chain risk management, disaster mitigation and recovery and then discusses the use of drones for disaster mitigation and supply chain continuity efforts

Methodology of study

To facilitate the discussions highlighted in this paper and to come to a common understanding of using drones at high risk areas of the supply chain network, we do a literature review of available research papers on the subjects of disruption management, disaster recovery and supply chain continuity and also do a comparative analysis of certain types of drones available in the market to understand their suitability for ensuring continuity after a natural disaster.

For the purpose of this literature review, Abstracts of 1853 relevant research papers were studied for selection of most relevant research papers numbering over 120. Preference has been given to research papers having a focus on natural disasters or supply chain continuity.

Supply Chain Failures

Normally supply chains are designed to ensure that the facilities, links and the operational processes will always work as planned. A supply chain is an intertwined network of nodes and routes that is normally spread over a large area and is affected by various disruptive factors on a regular basis. These disruptive factors may be internal to the nodes or external to the nodes and routes. Shukla et al., (2011)[1] in their paper said that in reality, facilities and the links connecting them, fail from time to time due to poor weather, natural or man-made disasters, or a combination of any other factors.

Internal disruptive factors may include strikes, accidents, and all other incidents affecting a particular node which may be a warehouse, a factory or a point-of-sale. External disruptive factors on the other hand will include floods, epidemics, landslides, earthquakes, war, etc., that may affect one or more nodes and routes. These factors may come into force randomly, individually, in group or concurrently. The combination of factors can further intensify the spread and depth of supply chain disruption, and making supply chain recovery either a long term process or a herculean task. In certain cases the entire or a part of the supply chain may need to be remodeled with new nodes and routes. Fridgen, G. et al. (2015)[2] also lays stress on the fact that external shocks to the supply chain can threaten the entire supply chain, including all its partners. Abe, S. (2014)[3] also confirms about the impact of blackout of a part of the supply chain on the entire chain and lays stress on disaster mitigation efforts to plan out the continuity of the entire chain when a certain portion becomes inaccessible. Penchev, G. (2016)[4] says that even limited damage to physical assets and infrastructure can play havoc with the regional supply chain.

With increasing globalization and focus on cost reduction, supply chains are becoming increasingly vulnerable to disruptive factors. Cost reduction methods such as single point of sourcing and lean inventory management, and increasing shift to pull-method of supply chain, further increase the chances of even a small disruptive shock creating a domino effect and become catastrophic for the entire supply chain system. Han, J., & Shin, K. (2016)[5] discussed on the impact of disruption propagation on the structural robustness of a supply chain using propagation. Also as Świerczek, A. (2014)[6] discussed not only on disruption propagation but also on increasing magnitude as the disruptive ripple spreads across the supply chain in the case of integrated supply chains.

Supply chains irrespective of being organization or region specific, has to normally contend with 2 kinds of risks i.e. supply risk and environmental risk. Supply risk normally affects a single supplier and the factors can be both internal as well as external. Environmental risk affects on a broader scale wherein all suppliers of an entire area or region is affected. Environmental risk is exogenous in nature, widespread and may affect supplies from or supplies to the affected area.

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Kamalahmadi, M., & Parast, M. M. (2017)[7] in their paper on “An assessment of supply chain disruption mitigation strategies” discusses the risks that a firm’s supply chain is exposed to. The environmental risk is actually on a wider scale and affects all suppliers in the affected area. As such environmental risk has a wider scope of affecting people and installations along with suppliers. They also discuss the interdependence of suppliers in a supply hierarchy and effects of disruptive factors on one supplier along the entire chain. Ivanov, D. et.al. (2016)[8], Świerczek, A. (2014)[6], Tokui, J. et.al. (2017)[9], Fridgen, G. et al. (2015)[2], Abe, S. (2014)[3], Penchev, G. (2016)[4], and Sahu, A K. et.al. (2016)[10] also laid the stress on interdependence of suppliers and the risk of failure of the entire supply chain. Tang, C. S. (2006)[11] is also of the same view that outsourced product manufacturing wherein the manufacturing is done by a third party at a different location increases the vulnerability of the supply chain at the cost of reducing manufacturing costs. However Todo, Y. et al. (2015)[12] shows the positive effect of an extensive supply chain due to localized impact of a natural disaster leaving some partners out of the affected area.

Supply chain failures whether on Firm level or Region level, have a wide ranging effect on flow of goods and provisions from and to the affected area. These failures are on variety of supply chains when the region is affected by a natural disaster or calamity.

Impact of Supply Chain Failures

The Japanese earthquake and the consequent tsunami and nuclear crisis of March 2011created a massive supply chain disruption and the global economic effect (in terms of value added) of this disruption amounted to US$139 billion. The most affected (groups of) countries were Japan (39%), the USA (25%), China (8%) and the European Union (7%). The most strongly affected industries were transport equipment (37%), other business activities (10%), basic and fabricated metals (8%), wholesale trade (7%) and financial intermediation (4%) (Arto, I. et al. 2015)[13].

The production loss caused by the supply chain disruption was 0.35% of the GDP of Japan (Tokui, J. et al 2017)[9].

The Taiwan Earthquake of 1999 showed that pull type supply chains are more prone to onset of losses when the earthquake disrupts the single source of supply.

Supply Chain Disaster Mitigation & Recovery

As discussed above, natural disasters may affect any part of the supply chain and at any time. Whether it is the point of source, the nodes and routes, manufacturing plants or customer base, ensuring continuity throughout chain is critical.

Mitigation is the effort to reduce loss of life or property by lessening the impact of disasters. Supply chain disaster mitigation will therefore address the efforts to reduce the impact of disasters whether natural or man-made, whether caused due to internal or exogenous shocks, on the entire supply chain.

Though good amount of research has been done on supply chain disaster mitigation strategies, we find that some of them won’t stand in the face of widespread natural disasters like earthquakes, tsunamis, super storms, etc.

While (Habermann, M. et al.,2015)[14] found out that co-location with the supplier base is beneficial to reduce the disruption risk in terms of duration, they did not consider the expected impact of natural disaster leading to flooding or spatial disfigurement if it occurs in the area where they are located. This is also true for positioning of resources in or very near to disaster prone areas. As (Kamalahmadi, M., & Parast, M. M., 2017)[7] also divided the supply chain risk a firm will face into supply risk with one supplier getting affected and environmental risk wherein a large number of suppliers get affected due to natural disaster. So co-location with the supplier base will be the worst supply chain design when the area falls under high risk zone for natural disaster. Also any disruption to a supplier or a supplier base used as a source by the firm’s supplier will also become a disruption.

(Su, P and Liu, S., 2015)[15] found out the improvement in redundancy by dual sourcing after studying a US OEM. Having a dual source will also help in case one of the sources become inaccessible due to a natural or man-made disaster. (Todo, Y. et al. 2015)[12] shows the positive effect of an extensive supply chain in the face of localized impact of a natural disaster leaving some partners out of the affected area.

(Kumar, S. and Havey, T., 2013)[16] prepared a decision support risk assessment and mitigation framework for disaster relief supply chain and applied the same to example of March 2011 disaster in Japan for a scenario assessment and found out that the development of a robust communications plan and system will help coordination of all groups, prior to, during, and after a disaster, and will provide a more effective response. The same also holds true for a firm or a supply chain suffering from the effects of a natural disaster.

Usage of flood modeling and tsunami modeling for land use planning and evacuation routes is another method of disaster mitigation that can be used by governments and has a direct impact on reducing supply chain disruption risks (Saunders, A. et al. 2015)[17].

Roads getting affected by floods, forest fires or spatial displacement are also a major disruptive factor both for supply chains as well as disaster recovery. A model designed by (Freiria, S. et al., 2015)[18] represents an innovative approach for prioritizing roads and routes for channeling resources to the affected areas, and allows for selective risk management of such roads and routes.

Supply Chain Continuity and Innovation in Drone Technology

Advances in Drone Technology and the move from being a military stronghold to commercial and personal usage, has created lots of opportunities for usage during natural disasters. Whether the routes are blocked or the humanitarian supply chain is affected, drones can help mitigate the risk of a total failure and also aid in fast recovery or ensuring continuity.

Natural disasters like earthquake, flooding and tsunami normally causes spatial disfigurement and makes large tracts of land inaccessible for long periods of time. This may result in either closing down a source of material, non-availability of motor-able roads, or destroying the connectivity to end consumers. Another important aspect of most natural disasters is the loss of communication capabilities in the affected area. This is in addition to the human population stranded in the affected area.

Most of the commercially available drones have a maximum flight time of 30 to 45 minutes with a max payload capacity between 12 to 30 Kilograms. Unmanned aerial vehicles, or drones, have the potential to significantly reduce the cost and time of making last-mile deliveries and

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responding to emergencies (Dorling, K. et al, 2017)[19]. Though this gives good room for material movement over disfigured or flooded roads but will normally require large deployment of drones, making it unviable. More so when the routes fall in the disaster affected area and stops transportation of material at either end.

This paper selected two types of drones shortlisted for their usability in terms of various capabilities of payload, airtime / flight time, radio range, thermal imaging, etc for use in ensuring supply chain continuity as well as effective disaster response.

1. GRIFF SAVIOUR S2 – From Griff Aviation has a lifting capacity of 200 Kgs, Air time approx – 30 – 45 mins, is capable of moving material over 7 kilometers in flood affected area. (GRIFF has higher range of drones that can be modified from battery to petrol engines with payload capacity of up to 800 Kg).
2. SKYF – 2 machines can be easily put in a standard 20ft container. Maximum load capacity is 400 Kilograms with flight range of up to 350 km and is petrol operated.

Conclusion

Currently in absence of economies of scale the cost of such drones are very high at about USD 250,000 and may be a limiting factor in their usage. With economies of scale the cost of such drones will fall and be within range of even small transport and logistics companies.

GRIFF models can have similar range with petrol engines instead of batteries further reducing their cost of operation. Normally with a range of even 250 km such heavy duty drones can be easily used to move material deep within or over the affected area, maintaining supply chain continuity.

Except in the case of earthquakes, most natural disasters can be predicted nowadays and the time window of detection will allow for deployment of such drones in the concerned zones. For earthquake prone zones such drones maybe pre-deployed in certain areas and in countries like

Japan and Indonesia they may be pre-deployed at safe zones. Safe zones will be facilities like a bunker over land high enough to be out of reach of most tsunami waves.

Future Research Potential

There is a lot of research potential in designing a drone operated operational theater for disaster mitigation and recovery activities or even drone controlled battlefield theaters.

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