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Technological capabilities and supply chain resilience of firms: A relational analysis using Total Interpretive Structural Modeling (TISM)

R. Rajesh

Department of Humanities, Indian Institute of Space Science and Technology, Valiamala P.O., Thiruvananthapuram – 695 547, India

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ABSTRACT

Resilience, the property of supply chains to handle impending vulnerabilities and potential disruptions is becoming a success factor for modern firms. Considering the situation, a major question arises whether the companies are technologically capable of bringing supply chain resilience? Prior to take decision on implementation of supply chain risk management practices, companies need to identity their technological capabilities and its impacts on supply chain resilience. Apart from that, many of the technological capabilities are seen interrelated and have the competences to influence the other. A research in this direction could enable companies to be cognizant of their technological capabilities and to ascertain those influential capabilities for which managers should feel quintessential. A total interpretive structural modeling is used in this research to identity, interpret and acknowledge the major technological capabilities of firms that influence the resilience capabilities of their supply chains. A case evaluation of the same was also carried out in an electronics manufacturing industry. It can be inferred for the case that the most influential technological capabilities are *capability to modify supply chain design* and *planning capabilities*. A proper enhancement of these capabilities in the supply chain augments several flexibility and improves resilience capabilities.

1. Introduction

In this competitive world of globalization and vertical integration, supply chains (SC) needs to be smarter with efficient and responsive products. Along with that, the associated risks with supply networks have been exacerbated. Supply chain risk management represents proactive practices to manage risks and to effectively confront them (Colicchia and Strozzi, 2012; Manuj et al., 2014; Markmann et al., 2013; Sodhi et al., 2012). Supply chain resilience, the property by which supply chains are able to handle impending vulnerabilities and potential disruptions is becoming a success factor for all leading firms (Brandon-Jones et al., 2014; Hohenstein et al., 2015; Wieland and Marcus Wallenburg, 2013; Rajesh and Ravi, 2015; Rajesh, 2016). In this milieu, a major question arises whether the companies are technologically capable of bringing supply chain resilience. Before investing much on supply chain risk management practices, companies need to identity their technological capabilities and its influences on supply chain resilience. Companies that are too immature in their capabilities cannot implement several risk management practices altogether.

Apart from that, many of the technological capabilities are interrelated and have the competences to influence the other (Huo, 2012; Lin, 2014; Meyr et al., 2015; Williams et al., 2013). A research in this direction could possibly make companies aware of their technological capabilities and the most influential capabilities for which managers can give primary attention. A total interpretive structural modeling is used in this research to identity, interpret and acknowledge the major technological capabilities of firms that influence the resilience capabilities of their supply chains. Since the model is developed on interpretive modeling logic, the reachability matrices are constructed on relational basis and are interpreted logically. Each relation represented in the final reachability matrix designates whether the causal/ influential relations are strong enough to justify the model.

A case evaluation of the same was also carried out in an electronics manufacturing industry to identity the influence relations and the level of their technological capabilities. A relational digraph was also plotted to represent the prominent causal relations. The relational digraph is prepared on basis of the final reachability matrix and interpretive logic of the relations represented by it. Only conspicuous relations of either direct or transitive are represented in the digraph. The transitive relation logic is one of the equivalence properties for equalities and is a property common to equalities and inequalities. The model has been validated with a panel of experts and the relational digraph is updated. This research could find potential applications for operations managers to identify and relate their technological capabilities to supply chain and operational resilience.

This paper is further organized as follows; Section 2 discusses on the technological capabilities of firms that contribute to the resilience of their supply chains. Major remarks are indicated at the end of every sub- sections. Section 3 elucidates the methodology for total interpretive structural modeling and the detailed systematic analysis. A case

E-mail addresses: rajeshambzha@gmail.com, rajeshambzha@yahoo.co.in.

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evaluation of the proposed methodology was also carried out to gain practical insights. This constitutes Section 4. Section 5 discusses on the results of the case evaluation and the related remarks, which is followed by the conclusions, delimitations of the model and the scope of future works.

2. Technological capabilities contributing to SC resilience

A mature organization can design its supply chain capable of adjusting itself to fine-tune with demand fluctuations and other market turbulences. Most of the companies adopt several risk management practices, still consistent reduction of potential vulnerabilities is not perceived. This occur as the companies are either immature in their technological capabilities for bringing supply chain resilience or the companies relies too much on their capabilities to manage vulnerabilities. Both status quo are dangerous and can lead to situations of lost sales or unfulfilled demands bringing diminished reputations for firms. The major technological capabilities (TC) of firms having a challenging role in building resilience in their supply chains are as follows.

2.1. TC 1: Capability to modify SC design

Designing the supply network is a critical strategic decision needing time and efforts. The supply networks should be designed in such a way that the design changes could be incorporated into it at any stage of the supply chain (Holweg and Helo, 2014). Design should avoid any bottlenecks and the nodes must be positioned in supply network to reduce node density, node complexity and node criticality. Too many nodes placed in near vicinity increases node density and reduce network reliability. When the number of inter nodal connections increases, the network resilience decreases. Also, the nodes must be designed in a way to reduce the criticality of the design. If the number of connections of a node increases without any parallel network connections, the network design becomes critical and the vulnerability increases. *NB 1: Whether the supply chain is technologically capable of altering its network design according to demanding needs is one of the major factors influencing supply chain resilience.*

2.2. TC 2: Capability of supply flexibility

Supply chains must be designed to have good supply flexibility (Esmaeilikia et al., 2014). Single sourcing can be seen as the root cause for many supply side disruptions. Multiple sourcing is a potential alternative but this reduces the visibilities in supply chains. Information sharing with too many partners can tamper the security of the supply chain. Keeping a chief supplier and making other suppliers available in emergencies could be a possible solution. Supply flexibility can be imparted through flexible suppliers and through flexible supply contracts. *NB 2: Whether the supply side is flexible enough to handle demand fluctuations strongly favor the resilience capabilities of the firm.*

2.3. TC 3: Capability of capacity enhancements

Capacity is an essential buffer. A part of the demand fluctuations and bull whips can be managed through varying the production and distribution capacity utilizations. Capacity can be used as a buffer by utilizing the material pipelines (Hu et al., 2013). Too much capacity utilizations can create bottlenecks and too low utilizations can results in increased costs of capacities. Capacity must be carefully planned and utilized properly in a supply network. This can reduce the risk of delayed responses and postponements and the associated vulnerabilities. *NB 3: The capabilities of the firm to plan and effectively utilize its capacities have a positive influence on the resilience prospective of the firm.*

2.4. TC 4: Level of standardization

Standardizations determine the level at which the operations adhere to standard operating procedures and the level at which the products and production flexibilities are offered. Increase in level of standardized parts for products increases the production flexibility and helps in having interchangeable product assemblies. This helps in the quicker incorporation of any product design changes (Serdarasan, 2013). Also it is advantageous when there are multiple products in the markets of the same part families. Standardization levels are more for mature or technologically advanced firms. *NB 4: The capacities for process and product standardizations of the firm have a direct positive influence over the resilience of its supply chain.*

2.5. TC 5: Agile capabilities

Agility of the supply chain refers to the level of visibility and the level of responsiveness of the supply chain. Quick acting supply chains are said to have high supply chain velocities and more information sharing practices increases the visibilities of supply chains (Eckstein et al., 2015). When the supply chain operations are transparent to partners, there is an increase in the trust levels and a noticeable increase in the level of resilience. Agility is imparted through increased visibilities, enhanced velocities and better transparency of operations in supply chains. *NB 5: Technological capabilities of the firm to become more agile makes its supply chain least vulnerable to potential disruptions.*

2.6. TC 6: Collaborative capabilities

Increased information sharing practices enhances the trust among partners. This will enhance the collaborative capabilities along with opportunities for risk hedging. The supply chain can bend together rather to break at a point during times of disruptive events. The levels of collaboration depend on the nature and volume of the shared data among partners (Ramanathan et al., 2014). Collaboration can be well utilized in the planning and forecasting phase of supply chains. Increase in collaboration levels makes it easy to manage inventories in the network. *NB 6: Integrated supply chains with enhanced collaborative capabilities can reduce the associated vulnerabilities of networks.*

2.7. TC 7: Postponement capabilities

Postponement or delayed differentiation is a strategy adopted to delay the assembly of products up to a point where exact customer information are available. Postponement is usually practiced by established firms through enhanced information sharing practices (Chaudhry and Hodge, 2012). The companies that are technologically capable of adopting postponements must have customers willing to wait for their products. This could enable them to shift inventory across time. Increased level of product flexibilities along with reduced level of inventory at stages are the key benefits of postponements. *NB 7: Companies that are technologically capable of postponements can effectively utilize time buffer to handle demand fluctuations and to enhance supply chain resilience.*

2.8. TC 8: Inventory capabilities

Inventory is an immediate buffer to deal with sudden demand perturbations or bullwhips. Inventory can be in the form of raw materials, work in process or as finished goods. Inventory is always associated with holding costs (Kristianto et al., 2012). The benefits of utilizing inventories should justify the holding costs and/or obsolescence costs. Companies are recommended to improve their capabilities to take decisions on inventory for different products differently, named as strategic stocking. Capability for strategic stocking based on the product risk profiles will reduce the risks of piling of inventory. *NB 8: Strategic stocking*