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Perspective

Understanding greening supply chains: Proximity analysis can help

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ABSTRACT

Supply chain management seeks efficiency. Inefficiencies cause various types of waste and commensurate costs. Supply chain actors differ resulting in proximity issues. Proximity is introduced here as distances on four dimensions; organizational, geographical, cognitive and technological proximity. Industry 4.0 concepts can improve or even worsen each of the introduced proximity dimensions their influence on green supply chains. We propose a need for investigation at the nexus of Industry 4.0 and greening supply chains; proximity analysis provides a vehicle for this investigation.

Supply chain management seeks to get the right material, at the right time and place at minimal cost.

Based on the type of product to be manufactured or assembled, different process chain types exist: 1) Make-to-Stock (MTS) for standard parts, 2) Assemble-to-Order (ATO) for components, 3) Make-to-Order (MTO) for prefabricated materials and 4) Engineer-to-Order (ETO) for customized products (Dallasega and Rauch, 2017). Different process chain types have different lead-times between order release and the product delivered to the manufacturer.

ETO, our focus, requires usually long lead-times throughout the supply chain because components have to be engineered, produced and installed according to a specific customer order. It is often difficult to produce components on-demand and deliver them when needed for manufacture. As a result, this extended lead-time causes two kinds of problems: 1) Late deliveries and in the worst-case expensive production interruptions; or 2) Early deliveries that require a storing of engineered materials on-site increasing inventory costs such as obsolescence, holding costs, or damaging goods.

Late and early deliveries create significant non-value adding activities like searching, waiting or excessive handling of components and high buffer levels throughout the supply chain. These kinds of waste create manufacturing cost increases and budget overruns.

Supply chain actors may also have different physical and cognitive distances from each other that contribute to these inefficiencies and waste. Within this context we introduce the term proximity defined along four dimensions; organizational, geographical, cognitive and technological proximity (Dallasega et al., 2018). These proximity categories can be used to study the distances amongst suppliers and between suppliers and customers; and may influence environmental and green supply chain issues.

- *Organizational proximity:* refers to levels of difference in organizational processes and routines between supplier-supplier and/or supplier-customer organizational relations. As an example, information systems characteristics may ease or cause organizational friction. As a practical example, the alignment between the supplier's environmental management system, and the design for environment system of the customer may be poor; causing difficulties in greening of products.
- *Geographical proximity*: an objective and subjective geographical distance between suppliers and the customer can increase coordination, logistics, and storage costs; in addition lead times, delay and rework risks, and risk perception are influenced. Large distances between suppliers and customers makes synchronization for on-demand production and just-in-time (JIT) delivery difficult. Subjective or perceived distances could be increased due to limited infrastructure or climate conditions. The impact of geographical distance between organizations on the environment is clear, greater energy and resources needed to manage the distances. The natural environment also influences this proximity measure; managing supply chains considering resources and ecological perspectives becomes critical.
- *Cognitive proximity:* different levels of knowledge about products and processes between supply chain actors, and staff expertise and skills differences can lead to misunderstandings and misperceptions. Ways of thinking, values and beliefs are additional concerns. A high cognitive proximity refers to similarities in the way actors interpret, understand and evaluate organizational processes, policies, and

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beliefs. Misaligned environmental beliefs, expertise and values can cause many inter-organizational greening efforts to fail. Managing this proximity has been underexamined.

- *Technological proximity:* technological competencies on tools, devices and processes between organizations relates to other proximities, but becomes critical as digitization and other forces cause supply chains to alter their relationships. Incompatible technologies between supply chain actors hinder efficient information exchange, material flow, financial relationships, creating different kinds of waste. Waste in energy and resources can be greatly influenced by technological incompatibilities.

Industry 4.0 capabilities along the supply chain can improve or worsen each of the given proximity dimensions; further influencing greening of supply chains. Cloud based platforms, web service technology, M-Internet, Geographic Information Systems (GIS), Building Information Modeling (BIM), Radio-frequency identification (RFID) are currently finding their way into practice in all types of supply chains, even construction and service supply chains (Dallasega et al., 2018).

Potentially disruptive technologies of Industry 4.0 such as "blockchain" has so far found little or no actual application in supply chains. However, by using shared geographically dispersed database networks with rigorous verification processes, blockchain bears great potential to increase the transparency, reliability and availability of information throughout a supply chain network (Saberi et al., 2018). Each proximity is affected, usually positively, but careful nuanced investigation is needed, whether the proximity affectation influences greening is an important nuance for consideration.

Most studies have focused on economic efficiency with limited consideration of Industry 4.0 impact on different proximity measures and on ecological or environmental dimensions (Tseng et al., 2018). Having supply chain material information available in real-time and having access to device and location independently, greatly influences environment issues.

For example, a majority of transportation in the construction industry, and other industries, are completed by road (truck) transport (Akan et al., 2017). Why, in developed countries, aren't alternative intermodal freight transport systems which could reduce costs and emissions, seen limited use? It can be partially answered by traditionally weak planning and management, such as the need for flexible transportation schedules and short delivery times.

According to Tseng et al. (2018), the scientific community represented by *Resources, Conservation and Recycling* should leverage the opportunities of technological concepts of Industry 4.0 to reach advancements across Triple Bottom Line (TBL) perspectives.

Consideration of limitations and barriers of new technologies and relationships to proximities, almost self-evidently, is needed. To what extent can supply chain efficiency increases through Industry 4.0 technologies through the improvement of proximity between actors make sense? New technologies that can manage the proximities may bear not only opportunities but also challenges. What is the impact of increasing economic supply chain efficiency to ecological or social aspects? For example, does less perceived geographical proximity, rather than actual geographical proximity, portend more JIT, causing more deliveries and greater emissions?

JIT deliveries to a customer would reduce intermediate buffers, with the cost of under-utilized transports increasing CO_2 emissions. What is the cost of using new technology? When does the new technology pay back in terms of managing proximities and influences on the environment?

Various barriers and enablers exist, each may differ for the technology, supply chain proximity, and ecological linkage. Understanding how these complex relationships are and can be managed from social, cultural, organizational, and political dimensions, at multiple levels, and amongst different types of supply chain processes is important, and less understood.

In summation, proximity analysis of various dimensions, along with differing types of supply chain processes, warrant greening supply chain investigation and consideration. Research in this area has existed at some level, additional investigation is needed for Industry 4.0 adoption and greening development; a supply chain proximity framework can be a helpful mechanism to understand and advance research.

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