Big Data and Risk Management in Long Linked Supply Chains

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Abstract

Purpose: This study considers developing strategic use of big data in association with long-linked physical goods supply focusing on risk management.

Design/methodology/approach: Analysis is grounded on a case study of organizing the import of machine parts from Shanghai, China to Norway. An analytical framework is developed through a literature review on long linked supply chains, big data and risk management.

Findings: Analysis reveals that big data use in this scenario encompasses mainly handling risks associated with transformations in the supply chain, a data-driven approach. Complexity is founded in transformation; the flows of goods and information. Supply chain dynamics represent an important source for data acquisition for big data analytics.

Originality/value: This is the first part in an ongoing research project aimed at developing a research approach to study information technology use in the inherently complex setting and scope of a long linked supply network. This scope of investigation enhances big data associated with operations dynamics providing foundation for future research on how to use big data to mitigate risk in long linked supply chains.

Key words: Big data, risk management, long-linked technology, complexity, postponement, supply chains and networks, service-dominant logic, value co-creation.

1. Introduction

The north-western Møre region of Norway is one of leading clusters in the global market producing offshore support vessels (OSV), shipbuilding and shipping (ship services). As pointed out by Hammervoll et al. (2014), this cluster consists of companies representing all stages from upstream suppliers to downstream customers and this geography proximity plays an important role in the value creation process in the whole supply chain. However globalization is counteracting the impact of this proximity. Through enhanced exchange processes, the "globe" is becoming smaller.

Long linked supply is an industrial particularity. This type of supply structure is a feature of physical distribution involving predominately sequential interdependencies (Thompson 1967). In accordance with Thompson (1967) industrial particularities denote variation in interdependencies impacting on how these forms of distribution should be organized and managed. Interdependency is associated with power and provides reason for why actors in a supply chain structures realizes business with each other (Pfeffer and Salancik 1978). These views are founded in contingency theory. In this approach analytical focus is directed to how the workings of firms are impacted by an environmental context including both direct connections through business relationships the wider and more indirect societal impacts. In this study, long-linked supply chains represent the organisational context of the big data (BD) and risk management (RM) constructs applied in this paper. It is therefore natural to commence with features of this specific type of organizational context, a construct associated with the choice of scope of our study.

Management studies commonly focus on intra-firm, single firm or business relationship dyadic research issues. Extending inquiry to a chain of interdependent firms, or even a network of firms, clearly increase structural complexity. This entails also at this relatively initial stage of research on RM and BD limiting details in the inquiry in order to handle this complexity. This is in line with Håkansson and Persson (2004) that if managing sets of inbound and outbound logistics flows, these flows necessarily will impact on each other through supply chain management. The question emerges how this type of supply chain structure, with its complexity founded on the network structure as well as supply chains being organizational entities supporting transformation through flows of goods and information, impacts on BD and RM viewed simultaneously. BD is then viewed as an enabler of RM. This leads to the research issue: What is the role of BD and RM in the context of long-linked supply chains? More precisely, the purpose of this paper is, based on previous research (Engelseth and Græsdal 2011, Wang et al. 2014), to model risk management (RM) in the import supply chain of machine parts from Shanghai, China to Norway to reveal that: 1) what are the data complexity and volume in a long linked supply chain, 2) what characteristics long linked supply chains have with respect to "big" data, and 3) how it may be applied to improve a long linked supply chain involving a service manifest as combinations of goods and service components. The contribution of this study is therefore to enhance application of RM through information use in this type of supply chains. This study is relevant to industrial marketing since it covers how exchange in the supply chain may be carried out through enhanced data use to mitigate risk.

2. Literature Review

It is commonly agreed upon that we are in the era of BD, and it is highlighted in a statement from the United Nations that “the world is experiencing a data revolution” (UN Global Pulse 2012). BD is characterized by 3Vs: high volume, high velocity, and high variety (Laney 2001), It is changing many aspects of human society, especially the business world. Large amounts of data have been collected for decades and data analysis is not a new idea, but “what sets the current time apart as the big data era is that companies, governments, and non-profit organizations have experienced a shift in behaviour…they want to start using all the data …to improve their business” (Dean, 2014). Through a business survey by MIT and IBM, it was detected that top performing companies are more likely to be sophisticated users of analytics than low performing companies and more likely to see their analytics use as a competitive differentiator (Lavalle et al. 2010). In another MIT-based study Brynjolfsson et al. (2011), after surveying 179 large companies, revealed that companies that adopted “data-driven decision making” have output and productivity that is 5-6% higher than what would be expected given their other investments and IT usage. A 5% increase in output and productivity makes a significant difference of winning the fierce competition in most industries. This quantitative study suggested based on the evidence that the effective adoption of BD can enhance a company’s decision making, insight discovery, and process optimization.

In the seminal paper of (Chen et al. 2012), big data analytics (BDA) is considered in the wider context of business intelligence and analytics (BI&A). With several decades’ development of BI&A, we have many successful database-based technologies for structure data and webbased technologies for unstructured data. Furthermore, the overwhelming and fast-increasing number of mobile devices and sensors has inspired a lot of innovative technologies and created new businesses. At the same time, this new development brings a lot of value-adding opportunities to existing business sectors. E.g., the RFID technology with real-time data visibility brings instant location-awareness to commodities, vehicles, personnel and etc., which could fundamentally change how a supply chain is operated. Another example is that FedEx collects and processes data from airlines, connections hubs, location of assets, weather forecasts, and traffic information, which allows for real-time routing information to be pushed out to individual drivers and optimization of pickup/delivery and asset utilization (Løvoll & Kadal 2014). This scenario is commonly termed "the internet of things" (IoT). We can see that real or near-real time information delivery is one of the defining characteristics of BDA. Another change BD brings to business is that it creates new possibilities for international development (Vital Wave Consulting 2012).

In our globalising economy, RM is an increasingly pertinent management issue: how should a business predict and cope with future risks? However, RM is hardly a “one size fits all” approach to business management. Lamming et al. (2000), when discussing elements in “an initial classification of a supply network”, point out the importance of discerning industry-specific product features (or particularities) in managing supply networks. Based on empirical findings from the above-mentioned case study of the supply chain of a small Norwegian machine parts importer, conceptions of risk and associated data are discussed. Focus is directed to developing analytics through modelling the studied flow of goods from Shanghai, China to the importer's customers in Norway. Intuitively, more data is created taking an end-to-end scope of the supply chain simply because the business case complexity is increased. This is true simply because the number of sources of data increases as the number of firms involved in the supply chain increases. This entails increased network complexity, considering a multitude of suppliers and customer intermediaries that need to coordinate supplies. Taking a complete supply chain perspective also positions this research in a natural manner within the borderlines of supply chain management (SCM) as well as multi-tier business-to-business (B2B) marketing. Risk mitigation, a prime focus of RM, will accordingly have to involve supply chain integration taking the end-to-end scope and involve the challenging task to coordinate risk mitigation efforts between different companies.

Kaplan and Garrick (1981) propose that risk assessment involves three fundamental questions posed by a manager: 1) "What can happen?", 2) "How likely is this outcome?", and 3) "If it does occur, what are the consequences?". This entails considering two components: 1) the magnitude of potential losses and 2) the probability of losses (Manuj and Mentzer 2008, Ellis et al. 2010). An important aspect of a risk analysis system is the likelihood of detection when an incident occurs (Christopher 2011, p. 202). Detection is associated with the information flow, and accordingly with the potential of BD analytics. The importance of risk is increasing. This, due to 1) the universalization of risk meaning more people are impacted by risks than before, 2) the globalization of risk associated with the increasingly globalized economy where more and more things and people are interlinked, 3) the institutionalization of risk meaning more and more companies associate risk as their main business purpose, and 4) the reflexiveness of risk associated with increasingly modern and following port-modern production modes involving the complex pooling of resources. It is especially the reflexiveness of risk that is particular to managing goods in long-linked supply chains. This is because managing supply encompasses an increasingly larger number of resources that need to be pooled and transformed as the analytically chosen scope of the supply network increases.

Managing risks is accordingly interwoven with informing in the supply chain and therefore dependent on data provision to decision-makers attempting to mitigate risks. It increases rationality in decision-making through this informing of the possible future. As a phenomenon, risks are accounted for through a range of metrics and approaches considering attitudes towards a particular risk and this risk's observable outcomes. "Risk" is, however, never straight-forward. "People's perceptions and attitudes are determined not only by the sort of unidimensional statistics used in tables, but also by the variety of quantitative and qualitative characteristics..." (Slovic 2000:231). Yates et al. (1994), point to how, even when objective data is available to support decision-making, interpretation may cause bias when assessing the strength of risks. March and Shapira (1987) propose that risks should be viewed from either a managerial or economic perspective. The managerial perspective involves accounting for the probability of negative outcomes. Given an economic perspective, the concept of risk is widened to encompass probabilities of both negative and positive outcomes. The economic perspective concerns probabilities of variation regardless of perceptions of attractiveness. Commonly supply risk is understood in line with Zsidin's (2003) definition as "the probability of an incident associated with inbound supply from individual supply failures or the supply market occurring, in which its outcomes result in the inability of the purchasing firm to meet customer demand or cause threats to consumer life and safety" (Choi and Krause 2006, Cooper et al. 2006, Kull and Closs 2008, Neiger et al. 2009).

When risk is identified it is transformed from perception into information and may be managed. The identification of risk is associated with receiving data and transforming this data into information to enable understanding the risk. Identifiable risk in a supply chain setting is associated with incidents related to customers, operations, information and the environment. In addition, different types of risk are interdependent, impacting each other when the incident in question takes place. Cousins et al. (2008: 181) propose that the term “risk” be used to describe how firms cope with uncertainty. Uncertainty is not the same as risk. Risk is more narrowly defined. It is associated in business predominately with the potential economic loss. By evoking the human state of “uncertainty” as core to RM, a human perception as opposed to “variation” which is measurable, risk is also to some degree manageable. For instance, when car-driving, the speed could be adjusted as the road changes and incoming traffic is observed (context) to avoid accidents. According to Sztomka (1993, p. 84-85) uncertainty has a several sources. These sources are: 1) design faults, 2) operator faults, 3) the inevitability of unrecognized (latent) effects, 4) "the reflexivity of social knowledge, which, at the very moment that it explains society and makes it seemingly more predictable, may influence the course of social processes in unpredictable ways" (ibid. p. 84), and 5) "extreme differentiation of power, values and interests among members of society and their groupings, which results in rampant relativism and eliminates simple consensual guidelines for defining and appraising social situations" (ibid. p. 85).

Modelling uncertainty and associated risks in operations is vital especially in managing activities with high probability rates for malfunction, thereby increasing control through adjusting internal activities to perceptions of supply risk. RM is accordingly viewed here in line with Cousins et al. (2008) as how businesses handle uncertainty dependent on two factors: degree of manageability and the technicalities of risk itself. In a network picture, one of the main challenges is to understand the risks from a taken focal firm perspective; traceable upstream and downstream through tiers of companies traced through a supply chain configuration. Managing supply risk involves accordingly continuously probing into the future of product integrated manufacturing and logistics processes to increase procurement readiness in handling emergent supply variations. Data analytics facilitates this probing effort. From a SCM perspective Christopher and Peck (2004) point out that five different forms of risks that are either internal or contextual to the firm: 1) supply, 2) demand, 3) process and 4) control; these four risks embedded in 5) environmental risk. This perception of risk is taken from a single firm perspective; the network rendered contextual to firm decision-making. When taking a complete chain perspective each supply chain actor must take into consideration that each firm has a divergent perception of risk and these perceptions interact, although not necessarily coordinated. No single firm's perception of risk is either more or less important that the other. They are simply different and this difference is analogous to marketing channels' understanding of marketing channel roles: raw materials supplier, assembler, manufacturer, distributor, retailer and end-user.

Information is a central component in managing risk. However, the use of data in decision-making is also impacted by the supply chain structure. The structure represents the long-term pattern of supply through a network configuration. Ellis et al. (2010) point to the important role representations of risk play in the risky decision-making process, suggesting that risk be handled through 1) contingency planning, 2) suppliers' investment in flexible manufacturing, back-up systems, and spare capacity, 3) buyer's investments in in-house manufacturing capabilities, and 4) buyer's and supplier's joint investment in the development of relational norms. Manuj and Mentzer (2008) provide an overview of six risk management strategies in literature: 1) postponement (Alderson 1950, Zinn and Bowersox 1988, Chiou et al. 2002), 2) speculation (Bucklin 1965), 3) hedging 4) control/share/transfer (Achrol et al. 1983, Agrawal and Seshadri 2000, Cachon 2004), 5) security (Downey 2004), and 6) avoidance (Miller 1992). The same authors continue by suggesting supply chain complexity and inter-organisational learning as moderators to risk management outcomes (Manuj and Mentzer

2008). Bahli and Rivard (2003) integrate agency theory and transaction cost theory to describe risk scenarios concerning 1) lock-in based on investments, 2) contractual amendments, 3) unexpected transition and management costs and 4) disputes and litigation. The same authors underline that these four scenarios not be viewed as 'acts of God' suggesting that risk mitigation mechanisms be developed for each of these risk scenarios (Bahli and Rivard 2003). In a complete network, RM involves also designing the supply structure including features of exchange encompassing dependency, trust and opportunism in relationships (Williamson 1979). Furthermore, managing risk encompasses taking into account the role of high volume, high velocity, high variety and the veracity of information assets requiring new forms of processing to enable enhanced decision making, insight discovery and process optimization. Efficient RM is in a natural manner associated with BD and this association needs to be adapted to supply particularities associated with the long-linked supply chain of goods. This provides foundation for strategic development of data use to ensure customer responsiveness through multiple tiers of purchasers and marketers, in the complete scope of the product flow following goods from original source to end-user.

With timely and correct BD analytics results, a company can have an accurate mapping of service needs so as to predict demand and supply changes globally. A lot of BDA technologies are data-driven, but process-driven BDA like process mining (van der Aalst 2011) has emerged as a new area, highly relevant to business process improvement. Process mining makes use of event logs in e.g., health care or supply chain and enables new process discovery and conformance checking. In supply chains data driven BD is associated with efficiencies in data capture, processing and transmission. In the preceding discussion, it was, however pointed out that when choosing to model complete supply chain from end-to-end, this entails increased complexity. In this long-linked picture, more date is associated with both structure and process. In the wider scope of analysis, there are more data producers and more data produced. Furthermore, in physical distribution, typical of using "long-linked technology" (Thompson 1967), goods being a *transformed* resource, this feature indicates that a simple product also entails a higher volume of data. Thus indicates a process-drive form of BD. *Process-driven* BD is associated with using the chain's or external data sources to acquire knowledge pertinent to supply. These two forms of BD may be interlinked in relation to decision-making. BD encompasses in relation to supply decision-making accordingly the provision of information resources. Intermediaries are the vital users of BD in a long-linked view of supply. The intermediary is sandwiched between suppliers and customers. Provision of information can come from both suppliers and customers and needs to be adapted to the fundamental sequential interdependencies in the supply chain meaning, sorts need to be coordinated with each other, also using information. An intermediary may use databases to "mine data", possibly mainly for marketing purposes. In daily operations, however, in managing exchange processes and supporting economical goods supply, it is the more shallow form of BD that needs to be managed.

Managerial focus in the supply chain as an inter-organizational long-linked structure is more about data capture and the efficient processing of large volumes of different types of data form different sources that needs to done efficiently, a systemic wide-scoped trawling for data that is need rather than focused mining efforts. To support supply operations predominately process-driven BD analytics is accordingly called for. This renders an initial perception that IoT with is support of supply chain integration is more interesting than BDA to develop a long-linked supply chain.

Although BD may seem as a major management opportunity dependent on harnessing the potential of new technology, it is neither data as artefact that is the obstacle, nor is it the technology of handling this data. As LaValle et al. (2011, p.23) state, "The leading obstacle to widespread analytics adoption is lack of understanding of how to use analytics to improve the business…". It is primarily an organizational, challenge. This directs the framing of our inquiry as to concern why and how to develop the use of BD in an organisational-focused context rather than a technical-focused context. This is why RM in a long linked supply is incorporated into this study, both from an empirical as well as a theoretical side. This entails embedding supply management encompassing multi-tier business-to-business relationship handling and considering risk management embedded in these business relationships. Empirically we provide a case study of importing mechanical parts from Shanghai, China to Norway to illustrate business challenges and to empirically ground conceptual modelling of what constitutes the role of BD in association with risk management in a long-linked supply chain. Thompson (1967) characterizes goods distribution as "long-linked technology" involving predominantly sequential interdependencies. This points to that integration in goods supply, and handling risk, involves how value-creating transformations are interlinked as a series of activities following a timeline: what in logistics commonly is described as a "flow" pattern.

3. Method

The following case narrative provides an overview of a mechanical parts supplier's product and information flow associated with the maritime industry, as well as an overview of the maritime supply network focused around OSVs produced in the Møre (around Ålesund city) industrial maritime cluster of Norway. The focal processes of the mechanical parts supplier were mapped based on a single interview coupled with understandings derived from consultancy in the mentioned firm over several years. Data collection for the narrative of the supply network was carried out over a period of almost 6 months. Inquiry was carried out using a semi-structured interview technique allowing for open-minded conversation and innovative understanding in the initiating phase of research this study represents. Altogether 20 interviews were conducted in the network before writing the following case narrative providing an initiating overview for further research. First a focal maritime industrial actor working in the financial sector was interviewed to create an initial overview and suggest different types of informants and provide an overall plan for further inquiry. This interview was followed by interviews with different types of actors, choosing to interview at least three different actors carrying out comparable types of business functions in the network. In this manner e.g. three different perspectives of ship design are accounted for. Both interviews and observations were open, meaning that the true intention of research was communicated to all informants. All interviews were taped and transcribed. A follow-up interview was carried out three years after the initial interview, updating the original data and including new managerial insights.

4. The Machine Part Import Case

The focal firm was established in the early 90-ies as a trading firm. It has now 8 employees. The main products are ball bearings and related products, which are used as parts in machines and other types of mechanical equipment. The ball bearings are designed in accordance with DIN and ISO standards. A ball bearing is a simple product since the potential for innovation through design is limited. The company actively uses branding to differentiate itself. There are variations of the products regarding materials usage. The company has never produced these products themselves. However, in 2000 the company started sourcing products from

Chinese suppliers, and in 2005 invested in a joint-venture operation in Shanghai, China to develop efficiencies in product supply. This Shanghai joint-venture company consists of a warehouse facility and has 35 employees mainly working with purchasing and quality control of the products produced at factories within a range of 2-3 hours driving time from the warehouse facility. In addition to the standard machine parts, the company also facilitates machine and parts construction based on designs provided by customers. The supply chain is illustrated in figure 1 with main business relationships and the simplified flow of goods:

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Figure 1. The supply chain

The company has design capability and uses this competence to help customers adapt products produced in the greater Shanghai region in China. There is an abundance of factories in the Shanghai region that can accommodate the production needs of the Norwegian company. The Norwegian company is responsible for mainly sales and sourcing, as well as coordinating the logistics of supplies onwards to customers mainly in Norway. Coupled with its branding efforts, the company strives to reach high qualities in these activities to achieve customer satisfaction.

More than 90% of the sales of the part importer are to Norwegian customers. This is a relatively transparent regional professional network where reputation management is vital. Based on its good reputation recurrent sales are secured. Customers are 35% in the maritime industry, mainly machine producers. The market of the studied import company is divided into about 75% parts for new machinery and 25% are spare parts. The spare parts production is more profitable. In addition the parts are sold for use in agricultural and food processing machinery. Due to the financial crises in 2008, sales fell from 32.2 million NOK to 25 million NOK in 2009. 2010 also has seen only a small increase in sales from 2009. Costs are mainly variable, and therefore the company has achieved profits even with a substantial drop in sales. Sales have in the first quarter of 2011 increased by over 25%.

The machine parts are sent to Norway on a monthly basis. Once a month, at the week at the end or beginning of the month, a 20 foot, or more usually a 40 foot shipping container is loaded at the Shanghai joint-venture facility. The joint-venture company seeks to fill up this container in accordance with FCL (full container load) principles. FCL also implies proprietary container transport, that is, the container is exclusively managed by the focal firm. FCL involves transport by ship to a port in Europe, usually in Germany or Denmark, and then the container is loaded on a truck for transport to Norway. If a critical part that a customer needs quickly is not loaded in this container, air freight or less-than container load (LCL) may be organized at an additional cost to the customer. LCL involves containerized sea transport administered by a logistics service provider (LSP). Using LCL means the goods are sent as individual cargo combined with other goods in a container by the LSP. Goods are shipped in cases of LCL by goods at more flexible times on the first available ship departing for Europe from Shanghai. The container is transported by truck form the European port to a LSP terminal and unloaded. There the cargo is transported by a new truck to the terminal in the city which the importer is located in Norway and is transported by a delivery van or truck to the importer location. LCL is accordingly also more expensive than FCL when the FCL container is relatively fully loaded. Air transport is still by far the most expensive transport form and is only used in emergency cases. To ensure the economy of FCL transport, the importer allows other users transport cargo in their FCL container which could be picked up later at the importer's location in Norway.

Production is driven by a combination of long-term contracts lasting with different suppliers 2 years. Orders are placed within these contracts. These are mainly for deliveries to new machines. In addition there is a substantial amount of orders for spare parts. The Norwegian suppliers keep an inventory mainly of spare parts for repair and maintenance operations of e.g. ships or machines. The lead-time from order to delivery is between 12-20 weeks. The company expresses that there are great challenges in orders communication. To secure product and logistics quality, the importer conducts business visits to these Chinese suppliers. However, these are large suppliers with a myriad of customers. The Norwegian importer is therefore for the perspective of the Chinese supplier "a mere fly on the wall".

There is an ongoing development to interlink the Chinese-language-based information system of the Shanghai-based joint-venture firm to English, so as to interlink this system with users in the focal Norwegian company to improve information flow transparency. Key to this system is that each FCL is provided with a project number and an individual order therefore is given an accurate position that also informs the expected date of delivery in Norway. This system is at present manual, using Excel sheets to communicate between the joint-venture company and the importer in Norway about goods shipment to Norway. In addition, goods required to sent on a specific FCL shipment, but do not make it into the container either due to the container being full or delayed shipment from the producer to the joint-venture company, are subject to listing on a separate spreadsheet that indicates errors in shipment. This sheet indicates whether the importer needs to inform its customer of delay or may also determine whether airfreight or LCL shipment is required. A major challenge is that the information system the Norwegian importer uses is strictly Norwegian language based. At the current state of information system development between these companies, a new system is called for preferably handling all three required languages: English, Chinese and Norwegian. Furthermore, the Norwegian importer expresses challenges due to cultural differences. For instance, Chinese are very wary of "loss-of-face" and therefore seldom express negativity such as stating "no". This tends to obscure problems and hamper process improvement. To develop the business relationship between the Norwegian import firm and its Shanghai-based joint-venture company, the import company manager visits the joint venture company about 12 to 15 times a year, and the logistics manger is in Shanghai at the joint venture facility about 8-9 times a year to develop the coordination of goods flows between the two companies.

5. Analysis

The case study provides essentially an "as-is" description of how the Norwegian importer manages import of its machine parts to Norwegian customers. The provided case narrative accordingly reveals details mainly about two factors relevant to our inquiry: 1) divergence of supply chain roles and 2) features of the flow of goods supported by information. Firstly, the supply chain consists of four layers of interacting actors: 1) Chinese manufacturers, 2) the Shanghai joint-venture firm, 3) the Norwegian importer and 4) the customers of this importer. This illustrates that information connectivity is the most pertinent issue when considering supporting the studied flow of goods. Several issues are brought up including system compatibility and language issues. Regarding goods, the case illustrates a focus on timely goods supply. Two features of timeliness are indicated: 1) supply to stock of goods destined for use as spare parts, and 2) supply of goods to manufacturing new products in accordance with the postponement principle. Figure 2 describes how transformation is a key feature of the studied supply chain:

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Figure 2. Long-linked supply as transformation through a series of actors

Regarding RM this evokes the importance of managing timely supply. Variation in time is a prime risk in the studied import supply chain. The perceived risk is predominantly logistical and associated with time-related supply failures. Since the principle of postponement is applied for deliveries of new construction, this mitigates risk from a complete supply chain perspective. The risk of out of stock events is imminent, and associated with costly inventory holding. Regarding the other feature of risk, the quality of the goods supply, this is dealt with by the joint-venture company in Shanghai. This actor is dedicated to mitigating risk associated with faulty goods supplies from the Chinese manufactures through two processes: 1) purchasing and 2) quality control upon delivery. By carrying out these activities at a location near to the Chinese manufacturers the Norwegian importer has found a solution involving mitigating risks associated with long-linked supplies. This organizational solution is clearly impacted by the length of the supply chain including both geographical and cultural distances. Mitigating risk is through the case shown as mainly associated with developing connectivity that that includes information mainly as a supporting tool. This connectivity includes especially in the case of manufacturing-driven sales, somewhat unpredictable purchasing of machine parts by industrial customers in Norway (who are not the end-users) with purchasing from Chinese suppliers through tiers of actors.

The case indicates that in relation to information needs, data driven BD associated with efficiencies in data capture, processing and transmission, is most pertinent; more important than BDA. The supply chain is in essence a flow; a setting where product changes is focal. It is information about how goods are supplied, where they are, where they are going to, and where they have been and their characteristics at different stages in the flow that needs to be informed about. Given the large number of different products in supply, with variations in origins, variations in destinations, and risks of failure of supply through the entire supply chain indicating the need to account for a reverse flow too, the information complexity is high. Process driven BD may, however give a strategic perspective considering developing the structure of the supply chain.

The "bigness" of data is in this long-linked flow in its sequentially interdependent network is mainly associated with operations, transformations are registered and informed. Risk is not associated mainly with a distant future, but with immediate and continuous changes in flows of goods. Complexity emerges as a key feature of this long-linked supply chain. This exemplifies the workings of the flow of information supporting the flow of goods, to track, trace and forward the import goods, to support quality supply and avoid risks of supply failure. The main route to developing the use of BD associated with the more immediate information complexity to better harness and inform about the dynamics of goods supply. This involves developing the exchange economy in the supply chain, making interaction between the suppliers and their customers more efficient in two respects. Enabling information systems to cope with BD features of high volume, high velocity, and high variety of information assets is therefore a vital quest in this type of production economy using long-linked technology.

BD is accordingly mainly of descriptive value in this case analysis; not the BD analytics in themselves. Firstly, the information flow may become more efficient. Secondly, efficiencies of information flow must directly impact on efficiencies in the flow of goods. IoT as an expression of supply chain connectivity is clearly a technological opportunity in this case. Provided that risk in investing in such technology is mitigated through developing sufficient trust in the sets of business relationships that the studied supply chain or actual network consists of, the IoT as an efficient provider of BD represents a technical facilitator of RM associated with this long-linked form of supply.

6. Conclusion

BD, being characterized by "3Vs" high volume, high velocity, and high variety (Laney 2001), in cases of long linked supply necessitates interpretation. High volume is associated with transformed goods, high velocity associated with connectivity to reveal transformation, and high variety is predominately associated with the degree of variations in goods being produced (transformed) in the supply chain. Data complexity in the studied long-linked import supply chain is associated with goods transformation in the network structure context. Goods supply is inherently quite uncertain, especially since supply consists of many types of parts that are infrequently ordered. BD is associated with informing about this flow of goods; the transformations in time, place and form of goods. Risk is in this case associated with not being informed properly about this transformation. Connectivity is important and IT is a facilitator of the. IoT may be used to express this connectivity. IoT, however, may therefore seem to be conceptually redundant as a term in a context focused in analysing supply-related factors. “Connectivity” is a more appropriate term and this encompasses also connectivity of people and documents, not only “things”. This indicates there may be need for academic debate on the use of IoT and BD for specific types business management purposes. In any case, this study pointes out the this use of IoT and BD as academic terms at least needs to be adapted and refined to the business function in a particular industrial context.

Properly managed process-related BD has potential to be a facilitator of efficiencies in the exchanges associated with efficient machine parts supply. Further research should accordingly be directed operationalising types of connectivity-supporting technology (including IoT) may be used and experimenting with this technology considering how it could mitigate risks and thereby provide customer value. This operationalising effort should be superseded by developing a refined conceptual model of the inter-linkage between RM, BD in a long-linked supply chain. The expression of customer value may still be differently perceived by different supply chain actors. The development of RM through BDA should therefore highlight RM and BD as joint facilitators of responsive supply in a complex and dynamic supply network through aligning the divergent actors who manage the goods flows. "Analytics" in this picture involves not optimization, but human-oriented continuous Kaizen-type adaptation to navigate in the marketplace environment. Complexity is placed in focus. Since this study encompasses conceptual modelling at an initial phase of inquiry, further empirically-based conceptual modelling is required to refine understandings provided in figure 2, to add more detail. These more detailed conceptual models may then be further developed as a basis for understanding the role of BD in a complex adaptive system and thereby enable e.g. agent-based modelling and simulation to develop this system. An alternative to simulation would be to incrementally develop provision and use of BD through dialectically-founded principles on-site in the workplaces in the supply network.

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