Big Data for Supply Chain Management: Opportunities and Challenges

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Abstract— **For modern industry, data generated by machines and devices, product lifecycle management (PLM) solutions, production planning systems or quality and inventory management systems has reached a volume of more than a thousand Exabyte annually and is expected to increase in the next years. This has led to the need of "Big Data" technologies to store, manage, process, interpret, and visualize such amount of data. This paper outlines the value that Big Data offers for supply chains that are increasingly complex. Indeed, Big Data have the potential to revolutionize supply chain dynamics. In this survey, we analyze Big Data applications, their opportunities and challenges in the different supply chain processes of the SCOR model.**

***Index Terms*—Big Data, Supply Chain Management, SCOR Model**

I. Introduction

In the current environment, competition is shifting from "firm versus firm" perspective to "supply chain versus supply chain" perspective. Therefore, the ability to optimize the supply chain is becoming the critical issue for companies to win the competitive advantage. The focus on supply chain management (SCM) has forced many companies to rethink their competitive strategies [1]. They tend, by necessity, towards collaboration with exchanging a lot of data. Additionally, many of them are seeking to "win with data" [2]. Indeed, the use of big data can offer significant value in such areas as product development, market demand predictions, supplying decisions, distribution optimization and customer feedback.

Data exchanged by supply chains from service and manufacturing sectors is increasing sharply and lifts up a growing enthusiasm for the notion of Big Data. According to several studies and surveys, companies operating in transport and logistics are those who exploit the most from Big data technologies. For instance, the logistics leading companies like DHL (Germany), UPS (Unites States) and Maersk (Denmark) have taken some steps in Big Data field to enhance their competitiveness [3], [4], [5].

In this paper, we investigate the role of big data in the competitiveness of global supply chains. First, we remind the key notion of big data and its characteristics. In the second section, we present the Supply Chain Operations Reference (SCOR) model as the standard diagnostic tool for supply chain management. Then, we identify how Big Data provides opportunities along supply chain processes.

II. Big Data

The term Big Data has been first used in 1997 by two NASA researchers to refer to the visualization challenge for computer systems with quite large data sets [6]. Since then, researchers and specialists in the information Management have been progressively interested by it until it become a phenomenon in different areas. Indeed, Big Data has a positive impact in various domains; it helps revamping supply chains, increasing sales and managing customer loyalty in marketing, optimizing real-time route and reducing costs in transportation, minimizing risks in finance and even enhancing the efficiency of some treatments in medicine. Big Data has originally described extensive heterogeneous datasets in the digitized, networked, sensor-laden and information-driven world. However, the name has come to be the technologies improving the storage, management, processing, interpretation, analysis and visualization of the huge flood of data [7][8]. Big Data covers 5 dimensions: Volume, Velocity, Variety, Veracity and Value. That is the 5 V's of Big Data.

The logistics sector is ideally placed to benefit from the technological and methodological advancements of Big Data. Big Data is initially driven from the service and supply chain management (SCM) such as finance, manufacturing, information technology (IT) etc. Recently, Auto-ID technology (e.g. RFID, Barcode) has been widely used in supply chain. Big Data brings a new source of competitive advantages for logistics involvers to carry out supply chain management so as to obtain enhanced visibility, the ability to adjust under demand and capacity fluctuations in a real-time basis, as well as the insights into customer behaviors and patterns to achieve smarter pricing and better products [9]. The Council of Supply Chain Management Professionals (CSCMP) thus is currently pursuing two complementary

projects, which aim to address what Big Data means for logistics and supply chain management [10].

One is ‘‘Big Data: What does it mean for Supply Chain Management?” carried by Mark Barratt (Marquette University), Annibal Camara Sodero (University of Arkansas), and Yao Jin (University of Arkansas). The other is “The What, How and Why of Big Data in Supply Chain Relationships: A Structure, Process, and Performance Study” collaborated by R. Glenn Richey (The University of Alabama), Chad W. Autry (The University of Tennessee), Frank G. Adams (Mississippi State University), Tyler R. Morgan (The University of Alabama), Kristina Lindsey (The University of Alabama), and Taylor Wade (University of Alabama).

Certain investigations for research and applications were carried out by Wang, Gunasekaran, Ngai, and Papadopoulos (2016) for reviewing the Big Data analytics in logistics and supply chain management. Recently, a special issue edited by Sanders and Ganeshan in POMS (Production and Operations Management) focused on the Big Data in Supply Chain Management.

III. Supply Chain Management (SCM)

Supply chain members are interconnected by a significant physical flow that includes raw materials, work-in process inventories, finished products and returned items, information flows, and financial flows. In today’s ever-increasing competition and globalized business environment, manufacturers have been exploring innovative technologies and strategies to achieve and sustain competitive advantage. One of the strategies, which has wide acceptance and agreement among academicians and practitioners, is supply chain management (SCM) [11] [12] [13] [14]. Managing the increasing complexity in supply chains is necessary to companies to compete better in global market. Complexity in supply chains is associated with material and information flows between supply chain partners.

A. Supply Chain complexity:

Complexity in supply chains is associated with material and information flows between supply chain partners. Traditionally, these flows are organized sequentially from supplier to customer. Today, information flows do not follow this linear form. Information flows rather now look like a simultaneous exchange, especially through electronic exchanges between all supply chain partners. [15]

A supply chain consists of many parts or elements of various types, which are linked each other directly or indirectly. These various elements and their interrelationships are significant for complexity occurring in a system [15]. There are some key characteristics of complexity occurring in a supply chain system, which need to be discussed to understand the impact of these characteristics on the occurrence of complexity. We summarize them as follows:

- **Number of components:** products, processes, supply chain partners, relationships, interactions, goals, location.
- **Diversity:** Related with the homogeneity or heterogeneity of a system.
- **Interdependency:** Interdependence between items, products and supply chain partners. Complexity increases in direct proportion to the increase of interdependence.
- **Variety:** Variety represents dynamical behavior of a system.
- **Uncertainty:** Uncertainty represents all difficulties to be able to make a clear picture of a system due to the lack of information or knowledge. The more uncertainty in a supply chain system is the more complexity occurs in this system.

There are internal networks in the firm with simultaneous exchange between all units. Indeed, the emergence of information and communications technology facilitating exchange between all partners, produced a change in the organization of the supply chain flows [16], [17].

In order to respond to these requirements and to have tools to model, evaluate and improve the entire SC, it is necessary to have clear understanding the current supply chain business processes in developing countries. For this purpose, we have used the SCOR model.

B. SCOR Model

By modeling, logistics systems, SCOR will create common language for actors in the supply chain and harmonize their practicesé. It lays a tool to diagnose the business flow between a firm’s first & second tier customers and suppliers.
The SCOR model offers users the following benefits: performance-standard metrics to describe process performance and define strategic goals, process-standard descriptions of management processes and process relationships. SCOR model is based on five basic management processes:

- **Plan:** Processes include gathering customer requirements, collecting information on available resources, and balancing requirements and resources to determine planned capabilities and resource gaps.
- **Source:** Processes describe the ordering and receipt of goods and services.
- **Make:** Processes describe the activities associated with the conversion of materials or creation of the content for services.
- **Deliver:** Processes describe the activities associated with the creation, maintenance, and fulfillment of customer orders.
- **Return:** Process describe the activities associated with the reverse flow of goods back from the customer.

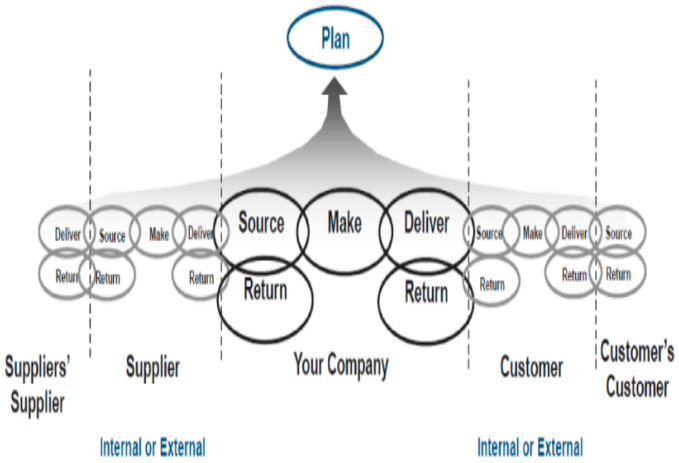

Figure 1. SCOR model

C. 5V of SCM

For a long time, firm have focused on the collection and storage of enormous data [13]. However, it is facing great challenges when contemplating to make full use of such data. The challenges are summarized as 5V in the table 1.

IV. Data applications in SCM

Companies are learning to turn large-scale quantities of data into competitive advantage. Their precise forecasting of market demand, radical customization of services, and entirely new business models demonstrate exploitation of their previously untapped data. This section intends to provide some assistance to practitioners to understand where they could begin to incorporate Big Data Analytics (BDA) across their supply chains, allowing them to potentially solve complex problems relevant for SCM. Table 2 briefly summaries some practical applications on how BDA can transform particular areas of SCM in its different processes.

In this table, we highlighted the importance of Big data for supply chains for all the SCOR process. We have particularly noticed that most studies concern only one or two supply chain process. To summarize the table, we can say:

- **Planification:** The Big Data reduce the risk of infrastructure investments and contracted external capacities.
- **Supplying:** Big data is revolutionizing how supplier networks form, grow, proliferate into new markets and mature over time.
- **Production:** The combination of analytics techniques enables to optimize manufacturing processes, shop-floor management and manufacturing logistics [18, 19] which allows producing new products in a more way [20] and reducing logistics cost [21].
- **Distribution:** big data analytics can be used to forecast demand changes, and accordingly match their supply. This can increasingly benefit the manufacturing, retail, as well as transport and logistics industries.
- **Return:** the use of big data analytics enables to know customers' perceptions of offered products and services and discover their unobservable characteristics in order to understand market demands and anticipate future consumer product variety desires. The customer's knowledge enables to develop new products and services more customized and consequently improve their satisfaction [19, 22].

By applying such analytics to big data, valuable information can be extracted and exploited to enhance decision making and support informed decisions. We argue that in order to succeed in Big Data, we need to consider the data no longer as an information asset but as a strategic asset. By doing so, organizations in SCM could realize the economic value inherent in the data and the potential to capitalize it when combined with BDA through revenue generating activities.

The use of simulation with statistics and visualization techniques allows analyzing markets, production and sales data on a real time and computing the key performance indicators relative to supply chain for developing strategic, tactical, and operational decision making [23].

However, Chae et al. [24] argue that for improving operational performance and increasing big data analytics value, it is necessary that supply chain analytics techniques be combined with SCM initiatives such as "Total Quality Management", "Just in time", and "Statistical Process Control" which can be used to monitor and control data quality in a supply chain.

Aspects	Big Data	SCM
Volume	Refers to the vast amounts of data generated every second; all the emails, twitter messages, photos, video clips, sensor data etc.	An enormous amount of data is generated tremendously every second thanks to the use of sensors, bar codes, ERP, and Database technologies.
Velocity	Data produced and collected in real time and streaming way.	The velocity mainly relies on the speed of data collection, reliability of data transferring, efficiency of data storage, excavation speed of discovering useful knowledge, as well as decision-making models and algorithms.
Variety	Multiplication of data sources, from structured, semi-structured and unstructured data.	The vast data from SCM are usually variable due to the diverse sources, heterogeneous formats and various sensors used in manufacturing sites, highways, retailer shops, and facilitated houses.
Veracity	Refers to the messiness or trustworthiness of the data.	This process verify the quality and compliance issues may consider different situations, some of which may be so complex that it is challengeable to address.
Value	More subjective aspect dealing with the non-exploitation of these massive datasets	It is challengeable to examine the impacts on the insights, benefits and business processes within both sectors and the value of reports, statistics, and decisions.

Table 1. The 5V for Big Data and Supply chain management

Notwithstanding the above, this review highlights several avenues for future research on this research area. We summarize the challenges as the following:

- Determining the theories, which can be mobilized for studying big data in supply chain.
- Developing metrics to measure supply chain performance in big data setting.
- Determining the way of integrating SCM initiatives into big data analytics programs.
- Studying the impact of big data on external supply chain.

V. Conclusion

In this paper, we highlighted the importance of Big data for supply chains. We have presented a review of literature related to this topic. We have particularly noticed that most studies concern only one supply chain process. In our analysis, we have identified the main processes modeling the global supply chains based on SCOR model. For each process, we have defined data sources, opportunities and challenges of Big Data for supply chains. We believe that these new tools and technologies will transform the way supply chain are designed and managed, presenting a new and significant challenge to supply chain management.

In our future work, we will study two types of supply chains for both services and manufacturing products. These two examples will be taken from Moroccan industry to better understand the specificities of the use of Big Data in Moroccan context.

Process	References	Sources of data	Opportunities	Challenges
Planification	DHL, 2013 [29]	**None**	Risk evaluation and resilience planning.	Business & IT alignment
	Branka & al, 2015 [33]	**None**	Reduce the risk of infrastructure investments and contracted external capacities	**None**
	Elgendy& al, 2014 [34]	**None**	Enabling the monitoring of performance, as well as improving planning and management functions.	**None**
Supplying	MG, 2013 [26]	**None**	Reduce storage capacity and distribution	**None**
	Tre, 2013 [27]	**Smart-phones**	Enabling more supplier networks that focus on knowledge collaboration as the value- add over just completing transactions.	**None**
	Rozados & al, 2014 [31]	**POS, GPS, RFID**	Achieve granular levels on aggregated procurement patterns	Implement Big Data require a holistic change in the strategy
Production	DHL, 2013 [29]	**Lan, GPS**	Market intelligence for small and medium-sized enterprises.	Data transparency and governance.
	Rozados, 2014 [31]	**POS**	The largest clusters of data are related to an automated sensing capability, connectivity and intelligence to material handling and packaging systems applications evolved.	**None**
	Russo, 2014 [30]	**RFID & RTLS**	Getting back a real time capacity availability and providing a quicker response and vendor managed inventory	Cross-functional and cross-company human-technology that can add a much higher dimension of complexity to adoption, acceptance, and usage decisions.
Distribution	Fawcet & al, 2014 [6]	**Linkedin Youtube**	Optimal routing	How can sales data be used for more efficient and effective merge-in-transit operations?
			Real-time route optimization; address verification;	

	DHL, 2013 [29]	**Twitter Facebook**	crowd-based pick-up and delivery; environmental intelligence.	Data privacy
	Louis, 2015 [28]	**None**	Improve Supply Chain traceability	None
	Branka & al, 2015 [33]	**None**	Real-time optimization of delivery routes.	Difficulties in data capture, storage, searching, shearing, analysis and visualization.
	Rozados, 2014 [31]	**None**	Estimated lead times based on trafic conditions, weather variables, real time marginal cost for different channels.	We need to consider the data no longer as an information asset but as a strategic asset.
	Russo, 2014 [30]	**GPS, LAN, RFID**	Optimize logistics activities thanks to costs reduction, improved customer satisfaction and supply chain performance	**None**
	Mondher, 2016 [32]	**None**	Optimize manufacturing processes, shop-floor management and manufacturing logistics.	Determining the way of integrating SCM initiatives into big data analytics programs.
	Elgendy, 2014 [34]	**None**	Reduce lead times and minimize costs and delays, as well as process interruptions.	Studying the impact of big data on external supply chain.
Return	Fawcett, 2013 [6]	**Facebook Twitter**	Reduction in driver turnover, driver assignment, using sentiment data analysis	How can more granular sales be used to improve visibility on the one hand and trust on the other, between trading partners?
	DHL, 2013 [23]	**Likedin Youtube**	Customer loyalty management; Continuous service improvement and product innovation	Appropriate technology usage
	MG, 2013 [26]	**GPS**	Benefits for the government (e.g., urban planning) and companies (e.g., localized advertising, optimized routing).	**None**
	Branka& al, 2015 [33]	**None**	Creating an integrated view of customer interactions and operational performance, ensuring satisfaction of both sender and recipient.	Large amount of Big Data and much more difficult workload of the security.
	Rozados & al, 2014 [31]	**POS, GPS**	Technology has made it more feasible than ever to access and understand customer data, as Big Data enables sensing of social behavior.	We need to consider the data no longer as an information asset but as a strategic asset.
	Mondher, 2016 [28]	**None**	Access and understand customer data, as Big Data enables sensing of social behavior. Know customers' perceptions of offered products and services and discover their unobservable characteristics	Determining the theories which can be mobilized for studying big data in supply chain.

Table 2. Big Data opportunities and challenges for Supply chain management

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