SUPPLY CHAIN ANALYTICS: LITERATURE REVIEW AND PAPER CLASSIFICATION

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ABSTRACT:

Supply chains (SCs) represent the complex network of different organizations with the main aim of satisfying customer demand. On the other hand, each organization involved in SC has its own goals and objectives which need to be met to maintain the financial stability of the organization and individual position on the market. To do so, organizations need analytical tools. Accordingly, they strive towards a set of contemporary analytical tools to enhance the effectiveness of logistics and supply chain processes. This is exactly the topic of this paper where a comprehensive literature review is conducted in the area of supply chain analytics. This paper aims to summarize and describe the existing knowledge about supply chain analytics and to explore how much this issue is being studied in the literature and potentially discover gaps for further enhancement of this area.

Keywords: *supply chain analytics, literature review, logistics performances*

1. INTRODUCTION

Logistics is generally the detailed organization and implementation of a complex operation. In a general business sense, logistics is the management of the flow of things between the point of origin and the point of consumption to meet the requirements of customers or corporations. The resources managed in logistics may include tangible goods such as materials, equipment, and supplies, as well as food and other consumable items.

In military science, logistics is concerned with maintaining army supply lines while disrupting those of the enemy, since an armed force without resources and transportation is defenseless. Military logistics was already practiced in the ancient world and as the modern military has a significant need for logistics solutions, advanced implementations have been developed. In military logistics, logistics officers manage how and when to move resources to the places they are needed.

During the late 1940s, the complexity, working environment and impact of logistics grew very rapidly. At that time Military was the only agency that used logistics in the 1950s, and 60s. It was a saying in the 1950s and 60s that those with strong logistics ideas would improve their chances of winning. Then after this time, the scope of logistics increased beyond the army. Logistics was recognized as an important tool for the development of an organisation. Logistics provides a platform with a mechanism to deliver the desired goods to the consumer as effectively as possible without any losses to the business. As time went by the Logistics sector became the reason for the company's rise in mass production. In the early days, Production processes and distribution processes are used to operate in a sequential order here the logistics aim was to ensure the availability of all the materials required to continue for the processes listed. Logistics also provides a smooth functioning area for every involved process. Logistics is referred to as the system approach. It always works with various supply chain nodes providing the appropriate environment for organizational ease. And eventually, make an optimal route for supply chain nodes to deliver the finished product to customers in order to meet their demand and get good feedback for the organization. Coordination between departments is required for the proper flow organization. In the earliest times, suppliers' works in distribution sectors were seen to spread activities all over the structure, resulting in overlapping and colliding in activities. But every organization, nowadays, operates according to logistics. Logistics helps the company work in a structured and formal way (Paswan, 2020).

Supply Chain Management is a large field dealing with the movement of product from raw to final state involving the partnership of various nodes coming in between i.e, from Supplier to Customer and creating different cycles during this period. Supply chain management needs proper logistics and supply chain analytics to complete those cycles successfully (Paswan, 2020).

Supply chains are longer, more complex, and geographically diverse than in the past. Customer demand patterns are more complex and there are more data sources available in real-time. All of these mean that forecasting processes are adapting to this environment. In order to understand how analytics may best be used in the forecasting process, it is necessary to understand how these forecasting processes may work. For example, analytics will enable more granular forecasting than is possible with human judgment, as a forecasting system that uses machine learning can detect demand patterns, causal relationships, and SKU dependencies. This in turn frees up the manager's time that can be used to focus on exceptions that are dependent on special circumstances that may not be identified by the system (Aloysius, 2020).

As an integral part of supply chain management, logistics plays an important role to keep the supply chain strong. It plans, implements and controls the flow and storage of goods and services in order to meet customer's requirements. Why is logistics training so important to Supply Chains? Logistics management cannot be overlooked as it contributes greatly to the success of any company's operations and has a direct impact on its bottom line. During times when freight volume grows and transportation becomes more complicated, the need for logistics management rises. Thus, training in logistics management is highly felt by organizations nowadays due to the evolving corporate world. Employees with more training can lead to increased profits. It is clear that logistics training is a fundamental factor to successfully manage any company's operations (Yves Bemelmans, 2018).

The emergence of new terms, such as Supply Chain Analytics (SCA), reflects a broad interest in leveraging the business value of supply chain data and harnessing the power of various analytical technologies and methods. Top performing companies are better at utilizing their data for business planning and execution (Kiron et al. 2011, Lavalle et al. 2011) and this has led to the increase in supply chain integration and visibility (Viswanathan and Sadlovska 2010, O'Dwyer and Renner 2011). In general, academic research expects the benefits of analytics in supporting supply chain operations (Trkman et al. 2010, Davenport and O'Dwyer 2011).

Data analytics is the most significant phase in the data value chain from raw data to meaningful insights; analytical tools and techniques are leveraged to slice through the data to data-driven insights (Arunachalam et al., 2018).

Analytics methodologies and techniques are used to optimize the routing of goods, vehicles, as well as crew (Novoa and Storer, 2009; Lei et al., 2011; Minis and Tatarakis, 2011) to balance between transportation costs and margins, and pay attention to maintenance and safety (Wang et al. 2016).

Big Data Analytics (BDA) can play a pivotal role in transforming and improving the functions of the supply chain (Arunachalam et al., 2018). BDA has the potential to govern Third Industrial Revolution (TIR), along with digital manufacturing, mass customisation and adaptive service (Tien, 2015).

The last decade has seen a tremendous increase in the adoption of a variety of Information and Communication Technologies (ICT) for Supply Chain Management (SCM), (e.g. radio frequency-based identification RFID, Enterprise Resource Planning (ERP) to the Internet of Things (IoT)). This has triggered huge data generation in the supply chain (Arunachalam et al., 2018).

In general, data can come from three different domains 'business, the Internet, and scientific research. Adoption of supply chain technologies such as Advanced planning and scheduling (APS), RFID, ERP, CRM systems and Warehouse management systems (WMS) (Autry et al., 2010), are the primary sources and antecedents for the occurrence of data deluge in supply chains. The supply chain data generation was further revolutionised with the advent of IoT technology facilitating real-time sensing and transfer of events data (Arunachalam et al., 2018).

The primary sources of data are from Enterprise information systems (EIS), which are mostly structured and transactional in nature. However, IoT, sensors, and RFID devices have the ability to convert the physical world into a virtual environment, which in turn generate a huge volume of unstructured data. The installation of RFID tags and readers on logistic objects can convert them into 'passive smart logistics object' and 'active smart logistics object' (Arunachalam et al., 2018).

The adoption of electronic supply chain management (e-SCM) such as Internet-based inter-organisational systems, Internet-based electronic data interchange (EDI) has enhanced communication, coordination, and collaboration across organisational boundaries. The adoption of these systems would also generate a volume of data through data exchange from the members of the supply chain network (Arunachalam et al., 2018).

Massive amounts of data are collated from several sources, including ERP systems, distributed manufacturing environments, orders and shipment logistics, social media feeds, customers buying patterns, product lifecycle operations, and technology-driven data sources such as global positioning systems (GPS), RFID tracking, mobile devices, surveillance videos, and others. As such, organisations are currently dealing with big datasets characterized by 4Vs: large volume, velocity, variety, and veracity (Govindan et al. 2018).

The focus on better business process has led some authors such as Grimes (2000) to identify Supply Chain Analytics as a business process reengineering enabler.

The evolution of Business Intelligence (BI) enabled wider possibilities of data integration, and Supply Chain Analytics targeted enhanced visibility across the whole supply chain (Sahay and Ranjan, 2008).

Organizational culture is a key factor in supply chain management practices and innovative information systems adoption (Khazanchi et al., 2007; Liu et al., 2010). Leidner and Kayworth (2006) argue that an organization is more likely to adopt an information system if the values embedded in the system fit its culture.

Golicic et al. (2003) argue that trust is a critical factor for effective coordination in a supply chain network. Dubey et al. (2019) argue that BDA capability and swift trust are complementary, in the sense that each demands and supports the other.

2. SUPPLY CHAIN ANALYTICS

Analytics in supply chain management is not a new thing (Souza, 2014). For a long time, supply chain management has use statistics and operation research for optimizing the objectives of matching supply and demand. Business analytics using information system support has a strong relationship to supply chain performance (Trkman, McCormack, de Oliveira, & Ladeira, 2010). However, the development of big data indeed brings out new opportunities. The term supply chain analytics can be used to define advanced big data analytics in supply chain management (Wang, Gunasekaran, Ngai, & Papadopoulos, 2016a). SCA can be categorized into descriptive, predictive and prescriptive analytic.

Descriptive analytics deal with the question of what has happened, what is happening, and why.

- Predictive analytics deal with the question of what will be happening or likely to happen, by exploring data pattern using statistics, simulation, and programming.
- Prescriptive analytics deal with the question of what should be happening and how to influence it, by driving alternative decision based on descriptive and predictive analytics, using mathematical optimization, simulation or multi-criteria decision-making techniques.
- Statistical analysis, simulation, and optimization are popular techniques in supply chain analytics (Wang et al., 2016a). These techniques are the basis for supply chain decision making besides other techniques such as the meta-heuristic method.

Souza (2014) described supply chain analytics for decision making on the five SCOR model domains: plan, source, make, delivery and return. Wang et al. (2016a) reviewed the potential application of supply chain analytics including the analytic techniques and relate them to maturity, sustainability, and holistic business analytics. Addo-Tenkorang and Helo (2016) reviewed big data applications and develop a taxonomy based on 5Vs of big data related to supply chain management. Zhong et al. (2016b) discussed big data technologies and models, current application in several service and manufacturing sectors and its global movement. Hofmann (2017) studied the big data volume, variety and velocity properties to reduce the bullwhip effect of the supply chain. Gunasekaran et al. (2017) also confirmed that big data analytics improved supply chain efficiencies, quicker response to changes, enhance relationship and planning capabilities (Tiwari, Wee, Daryanto, 2018).

Supply Chain Analytics is the consistent and organized computational representation of data, similarly, analytics of the supply chain provides meaningful observation, representation of the organization’s data. Later these data are modified or manipulated for advancing supply chain processes based on the requirements. The data which are driven from the supply chain cycle can be converted into the form of charts, graphs or any other means of representation of data. This analytics reveals all the hidden patterns and lagging behind sections of the supply chain cycle that needs improvement. Supply Chain Analytics also helps the organization to learn the patterns from the past data to make better decisions for the organization profits. The insights of the organization are divided into 3 main phases which are described below :

1. Data Analytics: Data Analytics is the process of examining the data using different software and pieces of information are drawn out from the analysis of data.
2. Studying the Data: After analyzing the data, Data Visualization comes into the picture for knowing the trends and patterns and correlations of the data.
3. Technology Selection: To increase the organisation's infrastructure, it is necessary to adopt the latest technology available in the market for proper and rapid processing.

Technologies that can manage the enormous amount of data perfectly with the data collection, analysis and storage are to be selected as a platform (Paswan, 2020).

The recent surge of interest in SCA is accompanied by new challenges and opportunities in both business and information technology (IT) environments. These challenges include issues arising from managing large amounts of data (e.g., data availability, data quality) and dealing with environmental uncertainties (Handfield and Nichols 2004, Liberatore and Luo 2010, Huner et al.2011, Lavalle et al. 2011, Manyika et al. 2011).

In the past, enhanced basic metrics and reporting were sufficient to increase supply chain efficiency. Today, supply chain executives need to knowingly invest in advanced analytics to be better positioned and empowered to make the necessary critical decisions.

SCA research is in its early stage and there is a general lack of theory and empirical studies. Using the resource-based view (RBV) as the theoretical base, this study expands the understanding of components and performance of SCA. The principal idea of the RBV is that the competitive advantage of a firm lies in its heterogeneous resources, which are valuable, inimitable, and non-substitutable (Barney 1991).

In supply chain management, there is growing interest in business analytics, which is also called Supply Chain Analytics (SCA). SCA refers to the use of data and quantitative tools and techniques to improve operational performance, often indicated by such metrics as order fulfilment and flexibility, in supply chain management (Handfield 2006, Davis-Sramek et al. 2010, Davenport and O'Dwyer 2011, O'Dwyer and Renner 2011).

SCA is viewed as a combination of IT-enabled resources for manufacturing-related data management, supply chain planning, and data-driven process and quality improvement. It is a data-driven, analytical decision-making approach to SCM supported by IT resources for data management, supply chain planning and evidence-based management methodologies.

The extensive use of supply chain analytics is a relatively new innovation in SCM practice. This research has been exploratory and theory building. While there is growing interest in SCA (Shapiro 2010, Davenport and O'Dwyer 2011, Jander 2011, O'Dwyer and Renner 2011), there is a lack of theory or theoretical framework to study SCA and its impact on SCM performance. This led us to develop a theoretical framework for SCA and identify relevant latent variables and indicators for empirical research. The results from this exploratory research have several implications for practice.

The key challenges for modern supply chain analytical systems include:

- Data explosion – supply chains need the right tools to make sense of the overwhelming amount of data generated by a growing set of data internal and external sources.
- A growing variety of data – most of the new data is unstructured or comes in different types and forms.
- Data speed – data is being generated at high velocity which makes data processing even more challenging.
- Real-time analysis – in today's turbulent business climate the ability to make the right decisions in real-time brings real competitive advantage. Yet many supply chains do not have the infrastructure, tools and applications to make timely and accurate decisions.
- Achieving simplified deployment and management – despite its promise, big data systems can be complex, costly and difficult to deploy and maintain. Supply chains need

more flexible, scalable and cost-effective infrastructure, platforms and services, such as those offered in the cloud (Stefanovic et al. 2017).

Definitions of analytics in Supply Chain Management Smith (2000) "Supply chain analytics is the process by which individuals, organizational units, and companies leverage supply chain information through the ability to measure, monitor, forecast and manage supply chain related business process." Marabotti (2003) "Supply chain analytics is the process of extracting and presenting supply chain information to provide measurement, monitoring, forecasting and management of the chain. Sahay and Ranjan (2008) "Supply chain analytics provide a broad view of an entire supply chain to reveal full product and component. Supply chain analytics provides a single view across the supply chain and includes prepackaged KPI, analytics." Pearson (2011b) "Supply Chain Analytics is […] using quantitative methods to derive forward-looking insights from data in order to gain a deeper understanding of what is happening upstream and downstream, being as a result able to assess the operational impacts of prospective supply chain decisions." O'Dwyer and Renner (2011) "Advanced supply chain analytics represent an operational shift away from management models built on responding to data. Advanced supply chain analytics can help supply chain professionals analyze increasingly larger sets of data using proven analytical and mathematical techniques". Waller and Fawcett (2013) "SCM data science is the application of quantitative and qualitative methods from a variety of disciplines in combination with SCM theory to solve relevant SCM problems and predict outcomes, taking into account data quality and availability issues." Sanders (2014) "Analytics is applying math and statistics to these large quantities of data. […] big data without analytics is just lots of data, Analytics without big data is simply mathematical and statistical.

Analytics involves the ability to gain insight from data by applying statistics, mathematics, econometrics, simulations, optimizations, or other techniques to help business organizations make better decisions (Accenture Global Operations Megatrends Study, 2014).

Big data analytics in LSCM has received increasing attention because of its complexity and the prominent role of LSCM in improving the overall business performance (Wang et al. 2016).

Big data analytics implies two perspectives: big data (BD) and business analytics (BA). BD refers to high-volume, high-velocity, and high-variety sets of dynamic data that exceed the processing capabilities of the traditional data management approach (Russom, 2011; Chen and Zhang, 2014). BA is the study of the skills, technologies, and practices used to evaluate organization-wide strategies and operations continuously to obtain insights and guide the business planning of an organization. Such evaluation ranges from strategic management to product development to customer service through evidence-based data, statistical and operations analysis, predictive modelling, forecasting, and optimization techniques (Russom, 2011; Chen et al., 2012). BDBA offers new opportunities for competitive advantage by extracting significant value from massive amounts of data. In particular, BDBA can help organizations make better decisions and improve their strategy, operations efficiency, and financial performance.

BDBA in logistics and supply chains is supply chain analytics (SCA). The consideration of BDA and the connection within a range of operational and supply chain practices (such as procurement, inventory, logistical, and planning activities) is gaining popularity (Wang et al., 2016; Gong et al., 2018).

When the focus is on logistics and supply chain strategy, SCA is applied in sourcing, supply chain network design, and product design and development at the strategic level. SCA can assist managers and decision-makers in understanding changing marketing conditions, identifying and assessing supply chain risks, and leveraging supply chain capabilities to formulate cutting-edge, implementable supply chain strategies, thus improving supply chain flexibility and profitability. For tactical/operational level decisions, SCA involves analyzing and measuring supply chain performance on demand planning, procurement, production, inventory, and logistics. Hence, SCA is useful for improving organizations operations efficiency, measure supply chain performance, reduce process variability, and implement the best possible supply chain strategies at the tactical and operational level (Wang et al. 2016).

Wang et al. (2016) presented five different levels of SCA, based on different supply chain goals: functional SCA (resolves problems of the absence of coordination between SC partners, eliminates duplication of processes), process-based SCA (focuses on helping companies achieve operational effectiveness in SC processes), collaborative SCA (deals with situations on a strategic level, in which an organisation collaborates with external business partners to perform SC operations), agile SCA (s to cope with high uncertainties in SC operations) and sustainable SCA (SCA has the role as the 'glue' that enables information to be transformed in the format needed for taking strategic decisions related to sustainability, generally just sustainability-related data).

Although SCA has an extremely important role in LSCM operations, it should be integrated into other business activities, such as financial/accounting performance analysis, marketing, human resource management, and administration, to facilitate integrated business analytics capabilities (Wang et al. 2016).

Chen et al. (2015) have conceptualised the use of BDA in SCM into three categories; (i) Coordination/Integration process (Warehouse operations improvements, Process/equipment monitoring, and logistics improvements), (ii) Learning processes (sourcing analysis, purchasing spend analytics, CRM/customer/patient analysis, forecasting/demand management – S&OP, and Inventory optimisation), (iii) Reconfiguration processes (network design/optimisation, production run optimisation, inventory optimisation).

Adopting and practising BDA comes with some organisational and technical challenges, some of them includes time-consuming, insufficient resources, security concerns, problems with data scalability and quality, lack of skills, techniques and procedures etc (Arunachalam et al., 2018).

During our research, we were able to find some examples of SCA usage in the literature. Souza (2014) illustrated Whirpools demand forecasting for tactical and operational supply chain decisions. In this case, predictive analytics techniques were used. Also, Souza (2014) showed an example of a market basket analysis clustering method used for data mining. Tiwari et al. (2018) presented examples of BDA in Deutsche Bank, General Electric, financial firm Barclays, manufacturers like Raytheon Corp., Toyota Motor Corporation etc. These are examples of companies that use BDA not as supporting activity but as one main way to keep their superiority in business.

3. LITERATURE REVIEW

In this research, for the needs of further SCA research, about thirty papers from various sources were singled out for the purpose of determining which areas were more researched in the papers on the topic of SCA. They exclusively selected papers related to the application of SCA and their research. The keywords used when searching the papers were: SCA in practice, SCA research papers, SCA case study, supply chain, logistic etc.

Papers found for reading were classified according to different criteria, each of the read papers was classified in one or more areas listed in the table in the first place. These criteria represent the topics that researchers are most concerned with when studying the SCA field. As can be seen from the table, the main criteria by which SCA is studied are:

- Terminology and the general role of SCA.
- Case studies.
- Key elements of SCA.
- Mathematical models.
- Software implementation.

Literature review process:

- Material collection, which entails a structured process of search and delimitation of articles.
- Descriptive analysis, which provides general characteristics of the studied literature.
- Category selection, which aims to construct a classification framework based on a set of structural dimensions and analytic categories.
- Material evaluation, which analyses articles based on the proposed classification framework and interprets the results.

Table 1. *Papers classification of SCA based on hierarchy and research topics in period (2000-2021)*

Serial number of the reviewed paper	Terminology and the general role of SCA	Case studies	Key elements of SCA	Mathematical models	Software implementation
1		x	x		
2		x	x		x
3			x		x
4	x	x	x	x	x
5	x				
6					x
7		x			x
8	x	x		x	x
9	x	x			
10		x	x	x	
11		x			
12	x	x		x	
13	x		x		x
14		x	x		x
15	x		x		x
16	x			x	x
17		x		x	
18	x	x	x		x
19		x			x
20	x	x			
21		x			
22	x	x	x		
23	x		x		x
24	x				x
25	x				x
26	x				x

27	x	x		x	x
28	x	x		x	
29		x	x	x	

4. DISCUSSION

In this paper were examined 29 different research papers from various sources. The main criteria for paper classification are terminology and the general role of SCA, case studies, key elements of SCA, mathematical models and software implementation.

The results of the paper review are presented in Table 2.

Table 2. *The results of the paper review*

CRITERIA	NUMBER OF PAPERS
Terminology and the general role of SCA	17
Case studies	19
Key elements of SCA	12
Mathematical models	9
Software implementation	17

In researched papers, the most often mentioned criteria are case studies and software implementation. The least processed are the mathematical models used for SCA.

The graphic presentation of the obtained results is shown in Figure 1.

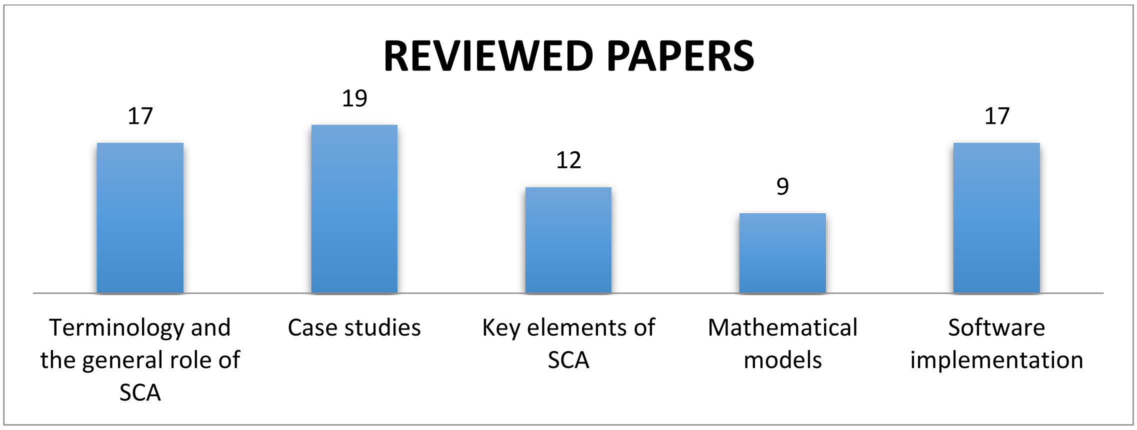

Figure 1. *The results of the paper review*

5.CONCLUSION

In this research, the concept of analytics in supply chains is presented through a review of a large number of papers on the topic of his research. The purpose of this paper was to determine which areas in supply chain analysis are more researched. A review of several papers found that of all the SCA research areas offered, the most studied is the case study and software application in this area. In addition, a large number of papers present research on terminology in this area as well as SCA itself in supply chain management.

It can be concluded that this is a very new area in supply chain management logistics and that it is still not sufficiently researched, ie that its possibilities for improving supply chain performance are still insufficiently used. It is also known that there is not enough theory on this issue. This paper generally includes an insight into which topics are the most researched in the world.

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