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Big Data Analytics In Supplier Chain Management-A Literature Review

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***Abstract*— Big Data Analytics offers vast prospects in today's business transformation.Big Data in different aspect is helping the businesses in the areas of Logistics and Supply Chain. Through Big Data, businesses are in a position to collect, update,store, use versatile set of data relating to different processes and activities of the business. This paper intends to explore the premises where big data analytics plays more crucial roles in Supply Chain Management (SCM).The investigation ranges from the fundamentals of big data analytics, its taxonomy and the level of maturity of big data analytics solutions in each of them, to implementation issues and best practices. This paper describes the current situation, actual solutions and presents exemplary use-cases for illustration. A classification regarding the area of application and potential benefits arising from Big Data Analytics are also given. Furthermore, this paper outlines general technologies to show capabilities of Big Data analytics.**

Keywords*— *Big data analytics, value, adoption and use, review,supply chain management ,Business Transformation, Data Science, Predictive Analytics.

I. INTRODUCTION

Nowadays, many companies are planning to extend the existing IT-Infrastructure with Big Data solutions. This is needed due to the challenges result on the ongoing globalization, increasing data volumes and customer needs in more individual products and service configurations. The globalization enables acquisition of new customers and requires new and changing business models due to changing market requirements. New suppliers and distributors have to be integrated into the supply chain. Additionally, the supply chain operations and processes have to be constructed for global application by considering new product variants. The products and offered solutions themselves are more and more custom-designed as a result of adapted requirements related to region specifics and competitors' offerings. This economic competition leads to short product life-cycles, not only in the mobile phone and IT sector.

Next to the direct operational aspects, the focus of each company lays more and more in the company's context and the supply chain environments. Both are not only influenced by the market itself, but also by risks or bottlenecks that might occur along the supply chains or within production lines. For example, supply chain risk management is in focus of many companies, but is limited supported by IT systems. Disturbances are treated reactively in most cases. An early identification of upcoming or future risks is typically missing. According to this, the required reaction time for almost all actions is not available. Even the transparency of the first level of the supply chain – the direct suppliers and customers – is not always given. All these issues are in the focus of companies with different emphasizes due to individual business strategies, manufactured products and offered services. Therefore, data becomes more important and it is turning to be one main part of new business models in the future as it has been shown by [1]

Big Data solutions have to be adapted to the company's requirements and environment. Instead, data of every enterprise is individual due to different semantic meanings and structure changings not only between different companies, but also within departments and divisions. Big Data activities are starting often by setting up a (Big) Data strategy for the entire company. Therefore, the value drivers and targets, which have to be archived with the new IT solutions, should be clarified [2]. For these issues a general classification of (Big) Data strategy targets for companies and a potential usage based on the categorization are illustrated by two exemplary use cases as shown by [2].

This paper is structured as follows: In the next chapter ,the purpose is to increase the overall understanding of big data in SCM context by exploring practical insights into the definition of big data, which could align practitioners' and scholars' views on big data.. In the 3rd section current trends in the generation of Big Data in SCM are analyzed. The 4th chapter shows categorization in terms of the area of application and shows exemplary use cases of big data analytics. Finally, a conclusion of the explained approach and an outlook of future work are given.

II. RELEVANT LITERATURE

This section describes relevant literature to frame the phenomenon in focus in this paper and is organized

Into three subsections. First, the terminology of big data is examined. Second, an overview of how usage of Big Data analytics in some areas may lead to the improvement of companies' effectiveness is discussed. Third, by research on previous scientific work, what BDA means in the context of Supply Chain Management, and how it differs and has evolved from previous analytics technologies is provided. Finally, Supply Chain Analysis (SCA), an application of Big Data Analytics (BDA) in Supply Chain Management (SCM) is presented.

A. The Big Data

The field of Big data analytics still isn't standardized by any organization so many definitions of Big data can be found in the literature. The often-quoted definition is the one that was defined by McKinsey Global Institute – "Big data refers to datasets whose size is beyond the ability of typical database software tools to capture, store, manage, and analyze" (McKinsey Global Institute, 2011). 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 [3]. 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 [4][5]. 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 [6].

B. Big data in management

Big data analyzing of social media may help in better understanding of Internet users' behaviour and discover social and economics laws. According to the report of Crimson Hexagon Big data analysis of social media can improve three main fields (Crimson Hexagon, 2011)[7]:

• Early warning – Information from social media allows to detect the anomalies, trends and events earlier. The quicker it will be detected, the better the response to emerging crises can be.

• Real–Time Awareness: More accurate and up-to-date picture of what a population needs and wants can lead to better, more effective planning and implementation of development programmes.

• Real-Time Feedback: Sooner understanding of changing needs of society allows for rapid, adaptive course correction in development programmes and current policies — making impact evaluation and response more agile.

Big data has also significant value in enterprise management. Thanks to development of methods of Big data analyzing companies are able to take decisions based on the knowledge that wasn't available some time ago. Big data analytics can transform key organizational business processes, such as (Schmarzo, 2013)[8]:

• Procurement – Big data analytics can improve the methods of identification and evaluation of suppliers.

Product Development – The real-time feedback provides information how the products are being used. This information can speed up the development process and improve the new products launches.

• Manufacturing – The data registered automatically by the sensors (e.g. ma-chine statuses, process indicators, etc.) can improve the manufacturing process by the identification of the root causes of quality problems.

• Distribution – The information about external factors such as weather, holidays, and economic conditions, can be used for better inventory levels evaluation and supply chain activities optimization.

• Marketing – By the analysis of the big sets of data about customers' behaviour, engagement and sales figures, Big data analysis can optimize the marketing promotions and campaigns.

• Pricing and Yield Management – The customers' behavior analysis combined with the information about the inventory and with the information about external factors, can improve the pricing and yield management process – especially in the area of "perishable" goods.

• Merchandising – Based on current buying patterns, inventory levels and product interest insights gleaned from social media data, Big data analysis can improve the merchandise markdown optimization.

• Sales – The analysis of huge amount of data can influence the way the sales resources are assigned, optimize the product mix and improve com-missions modelling.

• Store Operations – The prediction buying patterns compared with local demographic, weather, and events data, may lead to inventory levels optimization.

• Human Resources – The Big data analysis can enable the identification of the characteristics and behaviours of the most successful and effective employees.

The usage of Big Data analytics in above mentioned areas may lead to the improvement of companies' effectiveness. The analysis of combined information about customers' online behaviour, consumers' preferences, effectiveness of marketing campaigns, macroeconomics factors or even the information about the weather may lead not only to changes in companies' operations but to a change of the whole companies' current strategy.

C. Information flows in SCM: An Extended Supply Chain

Supply Chain Management is defined by Christopher (2011) as the management, across and within a network of upstream and downstream organisations[9], of both relationships and flows of material, information and resources. Our interest in the extended supply chain considers a model where technologies, such as BDA, synchronise SCM by driving a separate flow of information (Edwards et al., 2001) that enables organisations to capture, process, analyse, store and exchange data about their operations (Smith et al., 2007).

An extended supply chain is a multi-echelon system that connects organisations allowing collaboration and integration, as competition between supply chains is perceived to be more intense than individual firms (Antai and Olson, 2013). Amongst the phases of the SCM information flow (capture, process, analyse, store and exchange), BDA specifically focus on the analysis. Tools that facilitate analysis of SCM data are englobed in the "Analytics" domain[10].

Advanced analytics

Advanced analytics is defined as the scientific process of transforming data into insight for making better decisions. As a formal discipline, advanced analytics have grown under the Operational Research domain. There are some fields that have considerable overlap with analytics,and also different accepted classifications for the types of analytics (Chae et al., 2014). Lustig et al. (2010) proposed a classification of advanced analytics in three main sub-types.

i. Descriptive analytics

These are the data analysis made to describe a past business situation in a way that trends,patterns and exceptions become apparent. The first level of analytics explores what has occurredas a way to gain insight for better approaching the future, usually trying to answer the question of"what happened". Some of the techniques that are included in this group, as detailed in Zeng et al.(2011), include:

• Standard reporting and dashboards: Off-the-shelf packages, executing queries internally implemented.

• Ad-hoc reporting: Queries customised by the final user on the interface of the package.

• Query drilldown (OLAP): A first level of data mining that allows obtaining complex information from databases by aggregating multidimensional structures such as information cubes, where the data can be interrogated from different variables perspective.

• Alerts: Developed on any of the previously cited groups by aggregating a rule-based mechanism that generates a "lead" to the user when a certain variable of interest or other measures cross a baseline value.

• Visualisation: Data into visual forms in order to enhance facts and patterns that may not be easy or feasible at all to identify in other formats.

ii. Predictive analytics

Predictive analytics (PA) analyses real time and historical data to make predictions in the form of probabilities about future events. They encompass technology able to learn from data (Siegel, 2013), based on the machine learning techniques and other computational algorithms of data mining. Predictive analytics are typically algorithmic-based techniques that include (but are not limited to):

• Time series methods and advanced forecasting, vastly used in SCM for marketing measures such as predicting sales or safety stocks. Models have evolved from basic ones,e.g. Holt-Winters to ARIMA or ARMA.

• Supervised learning, which includes Regression (linear and logistic), statistical algorithms such as Discriminant Analysis, k-NN, Naïve Bayes (NB) and Bayes Networks (BN);Decision trees, CART and Random Forests that use a hierarchical sequential structure;Kernel methods: Support Vector Machines (SVM, LS-SVM) and Neural networks/multilayer perceptron.

• Clustering, the most extended unsupervised learning technique that includes hierarchical, k-means and density based models.

• Dimensionality reduction, such as t-distributed stochastic neighbour embedding.

iii. Prescriptive analytics

Prescriptive analytics use predictions based on data to inform and suggest proposed sets ofa ctions that can serve to take advantage or to avoid on a particular outcome. They also include the study of addressing variability on the expected outcomes by what/if scenario analysis or game theory. Prescriptive analytics are mainly associated with optimisation and simulation, and have special relevance in contexts of uncertainty (i.e. where deterministic algorithms are infeasible) relying on stochastic computational programming of random variables (e.g. Monte Carlo).

D. Supply chain management with Big Data

Big data analytics has a great impact in Supply Chain Management (SCM) especially (Wamba, Akter, Edwards, Chopin & Gnanzou, 2015). The cause of in-creasing attention of Big data analytics in SCM is its complexity and the influence that SCM have on the overall performance of companies.In the area of strategic planning and management of supply chains, Big data analysis is especially important. It supports sourcing deci-sions, supply chain configuration, and design and development of products or services (Wang, Gunasekaran, Ngai & Papadopulos, 2016).

Wang, Gunasekaran, Ngai and Papadopulos, (2016) specify in the studies a concept of Supply Chain Analysis (SCA) which is an application of Big Data Analytics (BDA) in Supply Chain Management (SCM). As a result of their studies, the researches presents a maturity framework of SCA[11]. The framework defines 5 different levels of SCM analysis based on different supply chain goals, including:

• Functional SCA – The functional level of supply chain analysis helps keeping the costs on low level by synchronization of activities and processes and integration between supply chain partners.

• Process-based SCA –The Process-based SCA level compose tools and techniques used to solve problems with integration of internal supply chain processes within an organization. The purpose of this SCA level is to help companies to achieve operational effectiveness in supply chain processes.

• Collaborative SCA – The goal of the collaborative SCA level is to improve the communication integration of the key activities between different partners in the supply chain.

• Agile SCA – The Agile SCA level are techniques used to improve the ability to respond to changes. The purpose of real time monitoring is to speed up in addressing changing customer demands, and short lead times related to the transformation of supply chains, if needed.

• Sustainable SCA – the purpose of the sustainable level of supply chain analysis is to provide the appropriate information that can be used for effective and efficient decision-making on sustainability issues

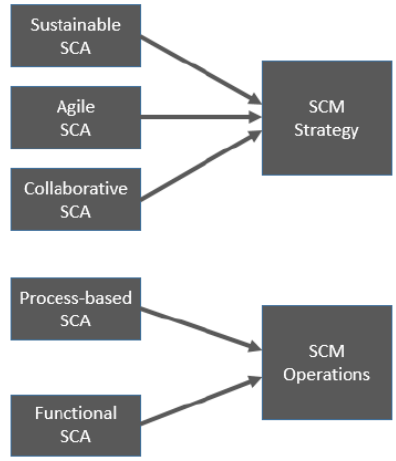

Fig. 1. *SCA Maturity framework (Wang, Gunasekaran, Ngai & Papadopulos, 2016)*

III. BIG DATA DRIVEN SUPPLY CHAIN MANAGEMENT

In this section, current trends in the generation of Big Data in SCM are analysed. Our understanding of the supply chain revolves around four main activities: buy, sell, move and store;associated with four main SCM levers: procurement, marketing, transportation and warehouse operations[12]. The identified data sources that may be considered for decision-making purposes in each of that SCM levers are classified in the taxonomy according to their features in the 3 Vs framework.

A. SCM Big Data and the 3 Vs

A full identification of data sources used in the business cases and guidelines/methods for successful implementation obtained from the systematic review produced a list of 52 mainstream sources of Big Data across the supply chain[13]. Each of the sources was reported in one or more of the SCM four levers, with a level of incidence from 0 (does not appear in that lever) to 4 (core for processes at that lever). In the same way, each data source was classified according to its reported volume and velocity in a 0-4 scale. Variety was described in a 3-level classification: Structured, Semi-Structured or Unstructured. Although these three subcategories are statistically dependent in the scores of a given data source, in order to facilitate analysis of some patterns of interest later discussed, they are reported separately.

Figure 2 shows the average volume and velocity versus the variety of the data sources in a

model such as $E(Y \mid X) = f(X, \beta)$ with $Y=0.5(Volume+Velocity)$ and $X=Variety$.

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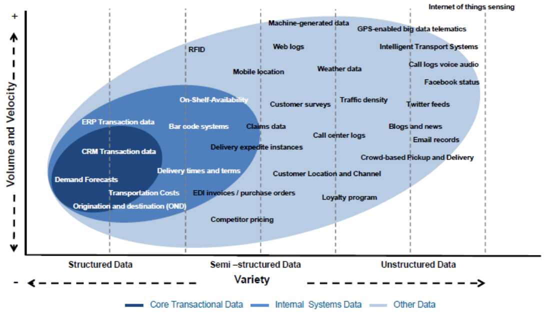

Fig. 2. *SCM Data Volume and Velocity vs. Variety*

Each of the three shaded areas includes data sources that fall between core transactional data, internal systems data or others, respectively. The frontier of all three areas has a much wider horizon when moving along the variety of formats (horizontally) than on the other two dimensions(vertically). If the model E above is a linear regression, all parameters in vector β are strictly positive. In practical means, that fact relates to a positive correlation between larger volumes and velocity of information in unstructured formats. This proposition is supported by many practitioners and academia, and although there is no previous conclusive quantitative analysis, it is considered as rule of thumb that 80% of usable business information is unstructured [14](Roberts,2010).

B. Four levers in the Big Data Driven Supply Chain

BDA can work across all SCM levers, conveying information from one area to another but the aggregation requires accuracy, timeliness, consistency and completeness (Hazen et al., 2014).For instance, marketing captures and tracks demand through Point of Sale (PoS) data, transportation creates records from GPS transponders, RFID data identifies stored goods and electronic data interchange sends automatic buying orders

Marketing has transformed customer knowledge into an agile system that sends large amount of information flowing upstream in the chain (Jüttner et al., 2010). Intimacy with customers can be achieved through increasingly more sophisticated methods of analyzing customer data, and at this lever, data sources that include social media, mobile apps, or loyalty programmes can be found; all of them are the enablers for the *sentiment analysis*. Similarly, recording omnichannel sales information can be facilitated by the electronic and cloud PoS, and by machine generated data that record transactions. Butner (2008) stated that customer inputs need to be better aligned to SCM systems, and that supply chain managers have a tendency to focus more on their suppliers than their customers, but for our interest, he also reflected that technology
has made it more feasible than ever to access and understand customer data, as Big Data enables sensing of social behaviour (Shmueli et al., 2014).

Procurement deals with the relationships at the upstream supply chain. Data complexities on this side might arise from globalised purchasing strategies with thousands of transactions. In this lever, a strong connection with internal finance reporting led to adopt measures on spend visibility data, to achieve granular levels on aggregated procurement patterns. Nevertheless, according to Ainsworth (2014), data on external expenditure, which can be more than 50% of a company's cost, are "often backward looking, often inconsistently categorised and not integrated with internal costs". A subgroup of data that is still to be fully integrated and appears in the taxonomy as semi-structured are the business documents (purchase orders, shipping notices, invoices) sent through the EDI. Still et al. (2011) concluded that the procurement needs to activate the data sources not only for spending data management process, but also for the entire procurement function.

Warehouse management (particularly inventory management) has been radically changed by modern identification systems after successful introduction of RFID. Within this group, the largest clusters of data are related to an automated sensing capability, especially as the Internet of Things and extended sensors, connectivity and intelligence to material handling and packaging systems applications evolved. Position sensors for on-shelf availability share space with traditionally SKU levels and BOMs.

Transportation analysis applying Operational Research models has been widely used for location, network design or vehicle routing using origin and destination (OND), logistics network topology or transportation costs as "static" data, as described by Crainic and Laporte (1997). New alternatives to manage and coordinate in real time using operational data rely on mobile and direct sensing over shipments that are integrated into in-transit inventory, estimated lead times based on traffic conditions, weather variables, real time marginal cost for different channels, intelligent transportation systems or crowd-based delivery networks among sources of Big Data. A detailed analysis of the 3 Vs in transportation data revealed to be the lever with proportionally higher speeds in data transition

IV. CATEGORIZATION AND APPLICATIONS

A. CLASSIFICATION

A categorization regarding the analysed type of data delivers seven potential scenarios. These scenarios use both, structured and unstructured data, and can be further categorized in click stream-, social media-, server-log-, sensor-, location-, text-, and video-/audio-data [15].

The Application of Big Data Analytics can contributeto different targets and provide benefits in various fields.The following sections can be divided into operational efficiency, customer experience and new business models.Big Data Analytics can enable new business models and generate new revenue streams. Operational efficiency based on Big Data

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capabilities uses data for betterdecision-making and improvement in terms of process quality, performance or resource consumption. The section of customer experience is mainly assigned to marketing and e.g. focusing on more precise customer assessment, which also supports a company's SCM [16]. By focusing on logistics and supply chains, Automatic identification and data capture (Auto-ID) technologies like RFID and bar codes are widely used to track handling units and the transported goods. Therefore,many read-points have to be shared along the supply chain.

Figure 3 shows the overarching model of data categorization. Data in the outer circle is of higher fuzziness, volume and change frequency. A wider distance to the circle´s center implicates less control and increasing ambiguity of both the data and its source. The inner circle consists mostly of data that is owned by the company and administrated within the companies IT infrastructure, e.g. ERP systems.

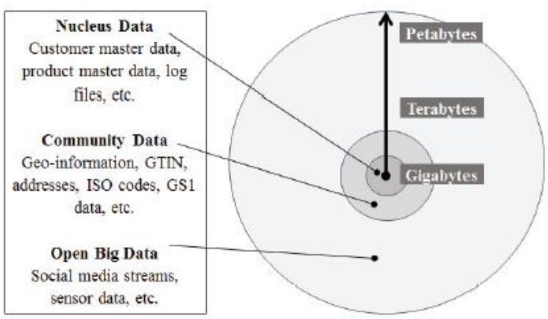

Fig 3. Overcharging model of data categorization

Measuring the benefits of Big Data is possible with specific IT related Key Performance Indicators. These
KPIs refer to qualitative and quantitative aspects, and can either be time-, quality- or financially oriented. The five highest recommended KPIs are lead-time reduction,increase of customer satisfaction, decrease of product costs and time to market and contribution to sales increase
[17].

Both categorizations show, that there is a high interlinking from an organisational point of view. The application of Big Data Analytics for SCM affects other departments, e.g. marketing and sales. For that reason, KPIs have to consider various facets for a holistic evaluation of use cases.

B. Potential Benefits

Data analysis method change a lot of business areas, large data opened the transformation of a great era, in the era of big data, we can more data analysis and sometimes can even all related data processing and a special phenomenon, rather than relying on random sampling, if the enterprises can integrate data from other sources, to obtain more value. These data may come from the suppliers in the supply chain, such as product name, price and discount; also may be goods into the market data, such as certain goods and increase or plans to reduce its yield; may also is the inventory data. These data are crucial for the successful delivery of demand goods in the supply chain. 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. Some practical applications on how BDA can transform particular areas of SCM in its different processes is summarized below:

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.

Table 1 briefly summarises some practical applications on how BDA can transform particular areas of SCM1.

SCM lever	Functional problem	Type of data	BDA proposed solution	BDA techniques
Marketing	Sentiment analysis of demand new trends	Blogs and news, feeds, ratings and reputation from 3rd parties, web logs, loyalty programs, call centres records, customer surveys	1. Create lexicons from training datasets that identify key terms that relate to the demand of a product. 2. Integrate all data sources that relate to a product into a unified text corpus. 3. Use supervised learning algorithms to predict sentiment scores of the corpus' term document matrix based on training datasets.	Natural language processing Text mining with R tm package: (Corpus, term-document matrix) Logistic regression, random forests, CART, Naïve Bayes, k-NN;
Procurement	Informing supplier negotiations	SRM Transaction data, Supplier current capacity & top customers, supplier financial performance information	1. Capture performance requirements for procurement contracts (SLA or other quality measures). 2. Require or publicly capture data regarding previous transactions of the supplier with other third parties in similar characteristics (delivery locations, lead times).	Suitable supervised learning algorithms, expert systems modelling
Warehouse Operations	Warranty Analytics	Internet of things sensing, user demographics, historical asset usage data	1. Aggregate multiple sensing sources on real time with reports on monitored assets together with user demographics. 2. Aggregate patterns in user and usage clusters in order to generate multidimensional segmentations.	t-distributed stochastic neighbour embedding (t-SNE)
Transportation	Real time route optimisation	Traffic density, weather conditions, transport systems constraints, intelligent transport systems, GPS-enabled Big Data telematics	1. In order to address time variability for deliveries in predefined networks, model the delivery network and update it with current position of delivery units. 2. New requirements for delivery are entered in the system. Taking into account all network availability factors, from each delivery unit a spatial regression predicts time/cost of serving a delivery to other point of the network.	Spatial regression modelling

Table 1.Some examples of practical applications of BDA in SCM

V. Conclusion

The importance of the analysis of huge amount of varied and diverse data in SCM grows quickly. Companies are using Big data analysis not only for one-time decisions but make use of it on daily basis improving operations and reducing costs. Currently managers can take decisions supported by data, in matters in which not so long time ago they have to rely on own gut feeling. Companies can act more quickly and more accurate thanks to the knowledge that Big data analytics gives.

In this article, we highlighted the importance of Big data for supply chains. We have presented a review of literature related to this topic. Through Big Data businesses are in a position to collect, update, store, use versatile set of data relating to different processes and activities of the business. Timely, fast and effective decisions can be taken in businesses with the help of Big Data. Organizations can make better decision with the help of accurate analysis of data. Thus, better decision means greater operational efficiencies, cost reductions and reduced risk.

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