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The Impact of Big Data Analytics on Supply Chain Management

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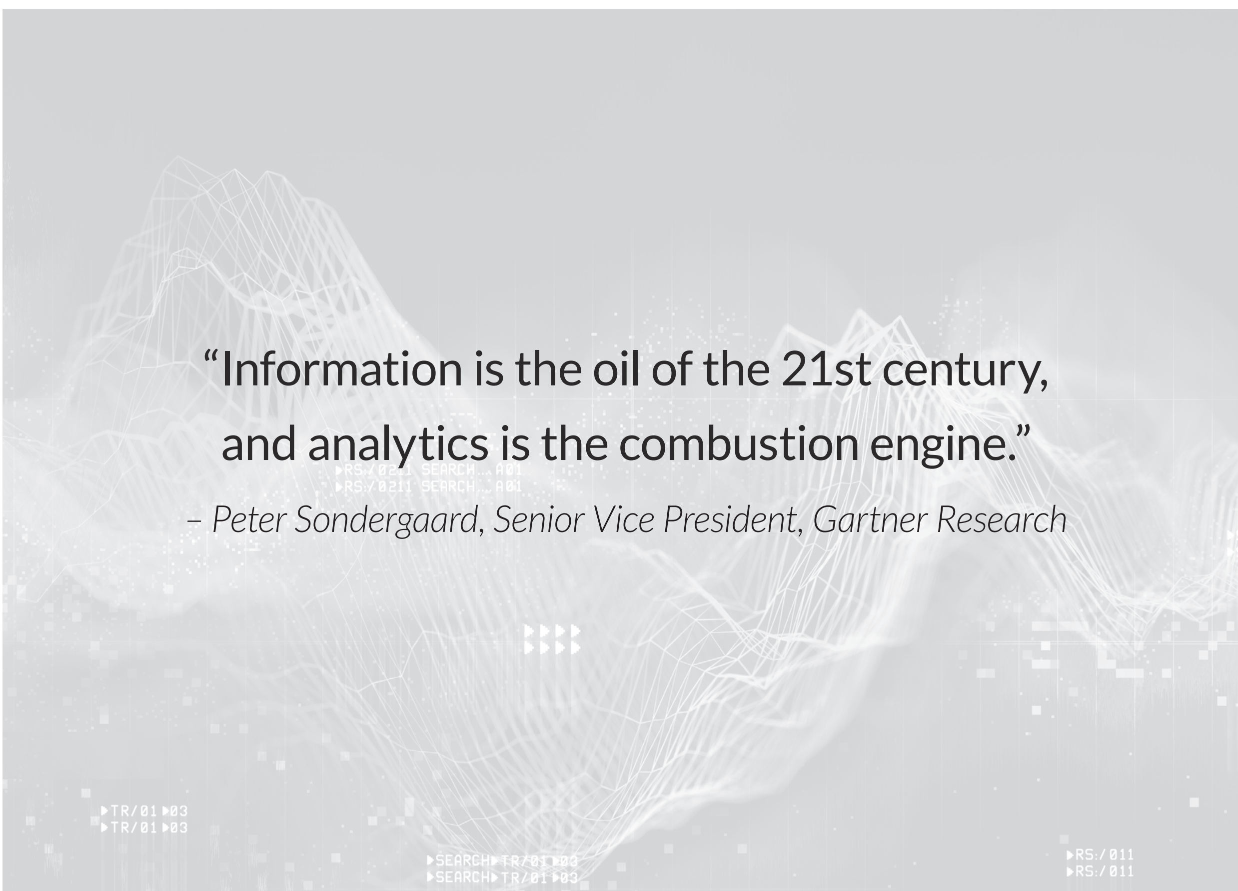


"Information is the oil of the 21st century, and analytics is the combustion engine."

– Peter Sondergaard, Senior Vice President, Gartner Research

The technological advancements of Industry 4.0 have giving companies around the globe the tools necessary to analyze and harness unprecedented volumes of data, across various entities of the enterprise both inside and outside the four walls, presenting unique sets of opportunities and challenges never before envisioned.

Today, businesses are confronted with the difficulty of analyzing data collected from different supply chain units and obtaining vital information for making data-driven decisions. Supply chain processes involve the flow of goods and services, operational information and financial flows. Managing these complex transactions efficiently is often the key to business success.

In the past, these flows were in sequence from the suppliers to the consumers. The sequence has become non-linear because of the real-time availability and accessibility of data that exists now across the supply chain and simultaneous in the present era of industrial transformation. The inherent complexities of supply chain processes make it imperative to use Big Data analytics to process the large amount of data from convoluted supply chain operations.

What is Big Data? Big Data has been traditionally characterized by seven Vs: volume, velocity, variety, veracity, value, variability and visualization. The amount of data (volume) flowing through the supply chain network—that is data in motion (velocity)—along with the variety of data formats—including structured, unstructured and semi-structured data sourced from texts, audio, videos and sensors—pose an enormous challenge for making sense of the data all at once. In addition, since the volume of data is large and generated from different sources, it is important to understand the biases in the data, the potential for fabrication and the possible existence of misleading information (veracity).

Used wisely, Big Data analytics can boost efficiency in the supply chain, which ultimately benefits consumers and simultaneously increases profit opportunities for the enterprise.

Big Data involves more than just data from a variety of sources (human and machine generated), every time a specific data source is mined, the meaning of the data constantly changes (variability). Thus, for example, data mining algorithms must be able to translate different meanings of the same words received from a sensor or words used in a tweet based on the context in which the word appears. These complex data structures, once collected, stored and analyzed, must be presented to decision makers in an understandable way (data visualization), such that data-driven decision making can yield meaningful outcomes (value).

Big Data and supply chain management (SCM) are mutually reinforcing. The ability to mine large amounts of structured and unstructured data accelerates the rise of Big Data analytics for transforming the data from hindsight analysis to oversight of the business processes. The volume of data collected from numerous processes and domains within a business, and the velocity at which new data are generated, necessitate the use of Big Data analytics to explore the impact of such data on SCM. Used wisely, Big Data analytics can boost efficiency in the supply chain, which ultimately benefits consumers and simultaneously increases profit opportunities for the enterprise.

Supply Chain Network Analytics

The introduction of Big Data analytics has transformed traditional analytics that focus on the past (descriptive and diagnostic) to being able to predict or prescribe what will happen in the future. The simulation and representation of the entire end-to-end supply chain can provide crucial information needed for a robust analysis. This additional information can lead to more efficient and adaptive supply chains.

Table 1 presents examples of analysis that business researchers can use to get to the diagnostic answers desired with little overhead costs. Larger enterprises with multiple assets across several networks of supply chains tend to invest in resources that can help them manage qualitative and quantitative research pursuits, relative to insight performance. These investments provide real-time value that reveal hidden treasures by cross-referencing multiple scenarios with the research outcomes and results.

Predicting an outcome within a single network of an enterprise supply chain is a complicated task. Some business functions even cut across multiple supply chain networks, which make it even more difficult. Businesses competing in supply chain networks with interests of making gains in the market must have a centralized portfolio that combines foresight and strategic planning. It is important to anticipate what the future has in stock when developing future strategies. For example, businesses creating strategic plans for 2025 and 2030 should dedicate resources to the application of predictive analytics to stress test and model different ideas and strategies against future possibilities, outcomes and scenario.

The predictive modeling may take advantage of evidence-based assumptions and historical data to better visualize what the future holds and mitigate all forms of business risks. Attempting to predict the future (futurology) is an arduous task, however it is prudent for businesses with growth plans.

With a robust oversight in place, companies can feel empowerment from the shop floor to the top floor and the boardroom will have the necessary tools to make decisions that will grow capital gains for their investors. Businesses with efficient oversight will use predictive and preemptive analytics to identify unknowns before customers realize they have specific needs. Meticulous supervision involves good governance and mitigating damaging hazards to the enterprise in both short and long terms.

Table 1: Applicable Analytical Models and Tools for Supply Chain Management

Analytical Model	Questions to Answer	Analytical Tools to Use
Regular Analytics		
Descriptive	What happened? What is the attrition rate for the last period? Which value chain or asset have I lost?	Reports & ad-hoc querying Dashboards & visualization Clustering, association Patter-based attributes
Diagnostic	Why did it happen? Why has the attrition rate changed (increased or decreased)? What investments brought success?	Root cause analytics What-if analysis Simulation models Numerical/visual segmentation
Big Data Analytics		
Predictive	What will happen? Which value chains are the most likely to attrite if there is nothing done?	Regression algorithms Simulation & deviation detection Casual predictions - classification Sensitivity curves
Perspective	How to gain competitive advantage? What should I do? Which value chain should be the target to maintain?	Deterministic optimization Stochastic optimization Tradeoff analytics Automated resolution
Preemptive	What don't we know? What more can be done? What can be offered to the end-users before they realize a need? What value can be added?	Data mining techniques Artificial intelligence Machine learning Cognitive/self-learning capabilities

People

Intelligent systems are capable of generating more precise and accurate forecasts at desired speeds. However, the forecast execution requires unified solutions bringing together the efforts of several individuals across the enterprise, each with different presumptions, motivations, skills, incentives, predispositions and limitations.

Analytical models and strategies that support working with people, rather than against or around people, present impactful, productive, usable and sustainable solutions that enable cross-functional collaboration and trust, enterprise-wide. This is achievable by making deliberate improvements to how information is accessed, the use of technology to simplify decision making processes and the timely implementation of relevant actions.

Supply chain technology transformation is difficult for most businesses. There is hardly a one-size-fit all template that can be used by all organizations. Solutions should be driven by the unique requirements of each organization and will vary based on many factors, including those listed here. Some organizations attempting to employ Big Data analytics in their supply chain often do not have a specific targeted destination. SCM is a dynamic process that requires a deep understanding of the different segments of the business including technical capacity, organizational structure, cultural norms, active management infrastructure and procedures for people integration. With the right people managing the supply chain transformation, it is easier to do three things; set clear goals of what the end state should look like, take timely advantage of the massive opportunities hidden in the process data and measure the global impact of the transformation.

A comprehensive SCM transformation engages major stakeholders at all levels of the organization through a helix process, to promote capacity building and effective management of change (MOC) system. Significant attention to the development of the MOC helps to properly manage the receptivity of the analytics-driven business intelligence for the SCM. Businesses that struggle with establishing an efficient MOC could seek assistance from external entities that can provide expertise for the initial launch of the transformation, however, significant investments must be made for inhouse capacity building to ensure the process remains sustainable in the long term.

Supply chain optimization is dependent upon the cooperation between the different businesses that are part of a supply chain as well as the people within the different organizations. It is important to develop trust among the participants in the supply chain. Without trust supply chain participants will hold back information to protect their own interests, impeding efforts to achieve performance improvement of the supply chain.

A human-centered approach is needed to utilize Big Data analytical tools for problem solving and decision support in SCM that guarantees straightforward access to pertinent, actionable information and to build confidence with the implementation of best solutions.

It is important for decision makers to understand how the models work and what factors model recommendations are based upon in order to win them over to adopt and support the use of these tools. Time spent bringing decision makers along and giving them input into the development of the models is time well spent. In many cases, if the decision maker isn't comfortable with the rationale behind the model, they won't be willing to abandon their current decision-making processes and adopt model recommendations.

Now (1-2 years)

As access to Big Data becomes more commonplace in industrial manufacturing, workers, suppliers, managers and the end users are expected to experience the impact, such as improved productivity and higher quality goods and services. Services for example have dominated the list of other sectors especially with the advancements in ride-sharing technology, smart delivery operations, logistical services and worker-managerial connectivity. A direct impact of Big Data analytics integration in SCM can be discussed in the servicing industries on the supply side of the manufacturing process. While the end users (and not the personnel of the enterprises) are central to this aspect of future manufacturing, it is an important case of people enjoying the benefits of big data analytics, and the general trend of user-tailored servicing in all manufacturing industries is remarkable. Importantly, ride-sharing services will be able to make large gains by analyzing and synthesizing user's requests, needs and expectations. The impact of Big Data on network planning, route optimization, intelligent marketing and lower shipping costs are potential benefits to transportation industries and companies that transport goods for integrating Big Data analytical techniques in SCM.

For example, to lower the cost of production and strain on workers, companies could use SCM analytics from the manufacturing line to understand several factors that can help improve the process. This will potentially help to lower production costs, improve work quality and reduce work overload. This will eventually shape the work environment. For example, analyzing large data sets to understand the workflow in the manufacturing processes could yield insights into the availability of unexploited capabilities. An aerospace company implemented Augmented Reality (AR) work instructions into its assembly, which helped to reduce error rates from 3% to nearly 0%, and productivity went up by 30% (Goering et al, 2018).

This example highlights the encouraging impact of people and Big Data analytics integration in SCM. It outlines the benefits of manufacturing businesses using smart technology enabled real-time monitoring across the supply chain, changing data into value and readily-available action points that decision makers can utilize. The current industrial transformation ultimately aims to improve the society for people to have better goods, services and care. Some may be in the forefront while others work behind the scenes. People in the supply chain network carry out actions towards promoting the same goal, to ensure the satisfaction of the end-user.

Businesses like Delta Airlines that use Big Data analytics to improve supply chain operations are able to provide better benefits to employees, consequently, employees and customers show sustained loyalty and continue to patronize the business (Jessop, 2020).

Continuous improvement can be expensive and requires significant resources, however by using centralized logistical planning that efficiently integrates people into the quality outcomes that exceeds customers' expectations, profits are maximized, which saves money and reinvents the entire business (LaBombard, 2019). In addition, the global benefits are garnered when the right person supervises the collection and analysis of the right data. The importance of human interaction, experience, and intuition for the management of supply chains cannot be overstated (Canzaniello, et. al., 2018).

Near (2-5 years)

The impact of Big Data analytics on SCM may affect people undesirably in the near future due to human job replacements with advanced and smart machines, which would inevitably lead to job and morale losses. From a historical perspective, innovation has always been preceded by necessity and then uncertainty. Each stage of the industrial transformation has been powered by capitalism with preference for competition and profit. As the focus of businesses shifts farther from the workers towards profound interest for the consumers, the workforce will be affected. The future workforce will need to continue to reinvent and transform themselves to grow with the way of the future. Professionals that have technical skills, and ability to leverage data and apply predictive analytics will be in the best position. Transformation often converges attention on immediate innovations and advancements during the implementation of novel technology without consideration for potential drawbacks.

Aside from the obvious job losses expected from automated advanced manufacturing, the prospect of Big Data analytics could also directly or incidentally compromise the anonymity of individuals within the supply chain network. The identities, mode of operation and business strategies of companies may be at risk of cyber-attacks. The potential for data breaches was raised in a U.S. government White House report released in 2014 citing huge future concerns of data management, coupled with the carelessness and lack of concern demonstrated by companies using this information. Senator Edward Markey of Massachusetts bluntly emphasized in the report that; "The era of Big Data shouldn't become the era of big danger for consumers' personal information. The increased use of data holds promise, but at the same time there are perils from a privacy perspective." Implementing a robust cybersecure network that protects end users is key to sustainable business growth.

The good news is that with adequate preparations and proper planning, there are potentials for smooth transitions with little or no disruptions in the supply chain. Studies on the long term effects of Big Data on the society have pointed to positive outcomes relative to the transformation, primarily with advancements in visibility and management infrastructure, there would be potentials for cross-functional collaboration, which may allow for workers in different areas of the business to meet common goals across complex operational requirements (Goering et al, 2018; LaBombard et al, 2019).

Far (+ 5 years)

The market for supply chain analytics is projected to grow exponential by 2025 and is expected to more than double the current market capital (Intelligence, 2020). In 2025 and beyond, as technology improves the supply chain ecosystem, three approaches will be prominent: 1) Revolutionary approach 2) Evolutionary approach and 3) Hybrid approach (Dewey, 2014).

The revolutionary approach will involve using commercial Big Data to improve the supply chain networks. Exploring structured and unstructured analytical tools in the evolutionary approach will result from Big Data analysis sent to data warehouses. Standard models and tools will be assessed for creating other Big Data elements. The hybrid approach will consider Big Data and the traditional business intelligence solutions in the data analysis process. This technology is expected to benefit enterprises by increasing data velocity, accelerating foresight and memory planning capabilities, improving decision making strategies, and boosting performance of the supply chain networks.

Stepwise planning using SAP HANA, for example, for in-memory performance process planning functions, will help supply chain network planners to use data to plan daily, or even yearly, in fine detail. Availability of open source databases, adequacy of data governing authorities and access to low-cost training for all businesses will further expand opportunities and innovation for SCM.

Process

The essential components of global SCM include processes such as customer relationship management, customer service management, demand management, order fulfillment, distribution and logistics management, supplier relationship management, product development and commercialization and return management. In traditional supply chains, there's a linear relationship between suppliers and customers (Figure 1). The flow of information primarily connect each enterprise to its immediate/nearest suppliers and customers and no other entities lower in the supply chain. This traditional approach results in extended delays in the processing of information through the network. Specifically, variations in the system flow and the final demand which are mostly unpredictable, would be altered and distorted as they flow upstream (Ferrantino and Koten, 2019). In the integrated supply chain, communication and data is available across the entire supply chain network, enabling faster decision making and response to changes in demand.

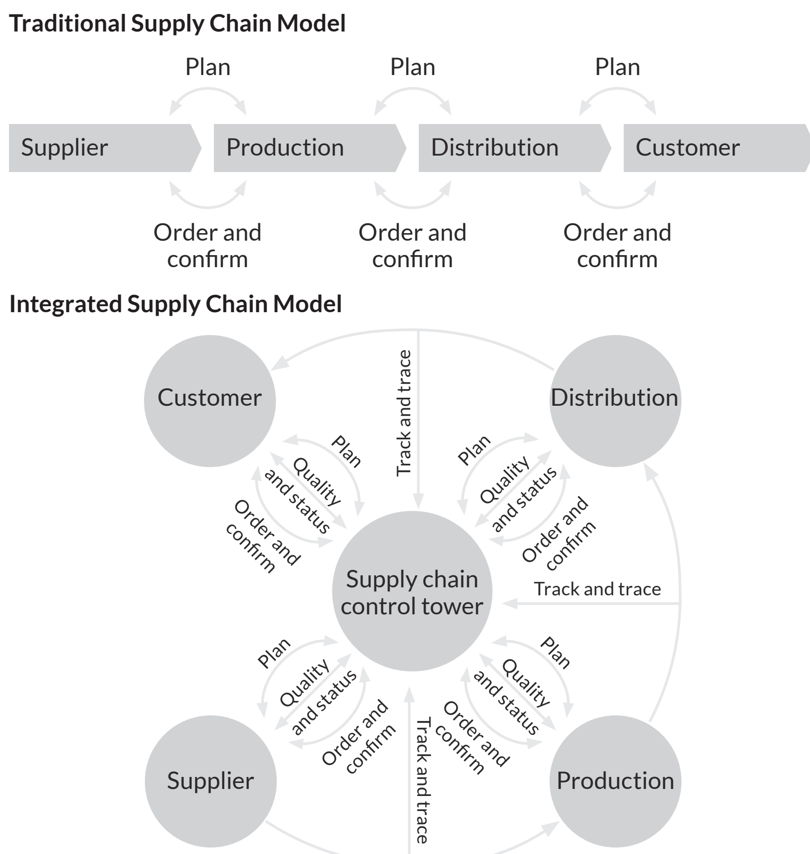
The applications of advanced supply chain analytics are becoming extensively adopted, however, even in mature economies, the techniques are disproportionately applied and are more likely to be used in the electronics industry and in retailing.

Now (1-2 years)

Big Data analytics essentially functions as a disruptive technology in today's supply chain network (Foster et al, 2019). The analytics-driven solution for supply chain networks (also known as Supply Chain 4.0), significantly supports businesses to drive enterprise improvements. It offers supplier networks greater data accuracy, integrity, clarity and foresights, leading to sharable intelligence throughout the network ecosystem. It also enhances visibility across the supply chain, improves planning and scheduling and generally optimizes the process.

Currently, cost reduction, customer satisfaction and traceability are top priorities for most manufacturers. Big Data targeting cost reduction and

Fig. 1: The digitally enabled supply ecosystem vs. traditional linear supply chain (Courtesy Schrauf and Berttram, 2016)



customer satisfaction/experience help improve the ecosystem in the near and far future. Big Data significantly improves the ability for manufacturers to trace products in real time. Traceability is key because it can be used to account for the whole process from start to present. If supply chain managers can use a barcode or other type of scanning system to easily trace a product, businesses can gather more accurate product information, improving traceability and ensuring proper tracking of goods throughout the supply chain process (Dutt, 2019). In manufacturing, this is critical as any lost product or components, or any delay due to parts shortage, can be potentially costly to the business. It's also extremely important for organizations that deal in highly regulated environment and/or have product quality or recall issues. Keeping track of each part from inception to completion in a manufacturing setting is critical to keeping plants running smoothly, which maximizes production and thereby optimizes business profits.

For instance, energy intensive production can be scheduled to occur during non-peak times of the day to take advantage of fluctuating utility costs. Keeping these production costs low will benefit the business by increasing the bottom line and saving money for use elsewhere. In Addition, data on different manufacturing parameters, such as dimensional differences between parts or the force used in different assembly operations can be recorded and used for the root-cause analytics and defect detection in the production process. Regardless of whether the defects occur many years after, archiving the data will be invaluable.

In other industries, for example, in agricultural manufacturing, sensors can be used to collect large amounts of data from machineries and from high-tech cameras. The collected data can be analyzed to assess the quality of agriproducts in real time, with the capacity to analyze each individual seed as desired (Alicke, et al., 2016). The use of Big Data analytics can reduce overhead costs, reduce the cost of operation, improve yield and product quality and decrease time of conflict resolution along the chain, regardless of the industry.

Near (2-5 years)

The market for Big Data-driven supply chain analytics was valued at $3.03 billion USD in 2019 and is expected to reach $7.91 billion USD by 2025, at a compound annual growth rate (CAGR) of 17.31% between 2020-2025 (Research and Market Group, 2020). Advances in information technology (IT), operational technology (OT) and the IT/OT convergence would provide capabilities for enterprises to be able to access, store and process a large amount of data. The supply chain networks are expected to evolve into a complete digitalized ecosystem which is different from the traditional landscape of serial processes.

This digitalized ecosystem would encompass the full realization of several digital technologies such as Big Data sourcing, Industrial and private Internet of Things (IoT), 3D printing, collaborative robots, adaptive manufacturing, 3D cameras/ laser inspections, augmented reality, cloud and fog computing, autonomous driving and delivery, etc. These technologies will promote new business models, digitize products and services flows, eliminate inefficiency and integrate individual connections in a business' value chain. Spare parts can be manufactured as needed at facilities maintained locally, even on-site, if demand is high or critical enough. These digital technologies will generate a large volume of data that can be leveraged in Big Data analysis to generate additional productivity improvements.

Built-in sensors in smart products would be used to simulate the "voice of the customer," feeding information back to manufacturers in real time about customers' preferences, behaviors and the device performance. Enterprises could use information from third-party IoT and edge devices and deploy preemptive analytics to anticipate customer needs before the customers realize these needs.

Cryptocurrencies are beginning to significantly impact the global supply chain. An example of this application is the use of bitcoin for improved efficiency in manufacturing supply chain processes. Blockchain technology is an internet-based technology used to publicly validate, record and distribute transactions in undisputable, encrypted ledgers. Blockchain supports crypto transactions and provides a medium for creating and distributing records of every transaction in a supply chain network to millions of computers linked to different networks all around the world. Due to the encryption, this offers increased security, and provides for instantaneous transactions, thus cutting out system delays. Blockchain technology will provide the power to simplify complex systems resulting in more efficient work process. Ideally, reductions in IT processes and transactions will translate to cost savings (Alicke, et al., 2017).

As factories and manufacturing processes become more electrically powered, more automated, more technology reliant and more digitized, there will be increase access to large amounts of data available, which can be utilized for making processes more valuable and efficient. From keeping track of a machine's performance and reliability or tracking production volumes, to inventory management of parts on the line, Big Data will be analyzed and optimized for improved processes.

Far (+ 5 years)

Supply chain processes are constantly evolving and improving, future supply chain transformations are not expected to be constrained by products and processes, rather by the needs of the customers. There would also be less dependencies on capital-intensive fixed assets and linear flows. The supply chain ecosystem would instead have modular capabilities deliverable through a network of trusted third parties. The networks would be autonomous, self-healing and self-optimizing. As the digitalized supply chain ecosystem evolves, flexible and integrated value chain networks, virtualized processes, virtualized customer interface and standardized industry collaborations will emerge.

Businesses will be attracted to new disruptive technology such as machine-to-machine digital connectivity, IIoT, artificial intelligence (AI), machine learning, advanced automation, robotics and additive manufacturing (Goering, et al, 2018). Advanced analytics such as prescriptive and preemptive analytics would be employed at scale to convert data points into actionable insights, foresights and oversight of the value chain. Robotics and cognitive technologies will be used for self-learning and execution of automated actions and to support knowledge-based human decision making. To improve the quality and efficiency of such decisions, enterprises will need to be able to include external information such as economic indicators and employ self-learning algorithms to aid in automating the decision-making processes. Primarily, future supply chains with the potential to connect shop floor monitors, computers, smart devices and IT systems would provide for fast, real-time market adjustments to be made in real time.

New robotic technology can be implemented into assembly plants, warehouses and logistics systems to enhance the productivity, quality and safety of the various supply chain processes. Automated technology such as autonomous guided vehicles, automated warehouse systems and assembly robots working collaboratively with humans are expected to dominate and perform about 60% of tasks in the manufacturing of the future. Autonomous technology and business to customer (B2C) logistics will dominate the digital supply chain. Widespread use of autonomous vehicles for logistical purposes in the ecosystem will include driverless trucks. These trucks would be faster, follow optimized routes and can be digitally tracked across networks with accurate delivery details (Jagadish, et. al, 2014; Arunachalam et al. 2018).

This transformation will also optimize delivery times, lower labor costs, eliminate human error and provide benefits to the environment, including reduced emissions due to efficient operations and routing and convoying of autonomous trucks. Prescriptive analytics would be relevant to analyze scenarios and provide very fine level details over a range of possibilities, describing how switching to a new supplier might affect product quality, or even whether the introduction of a new kind of autonomous vehicle would impact safety on the warehouse floor.

Technology Evolution

Now (1-2 years)

In current competitive markets, managing massive amounts of data is challenging. Manufacturers must evaluate new techniques and investigate how data is generated, acquired, processed, organized and analyzed to obtain value needed to improve the supply chain (Tiwari et al. 2018). Big Data analytics is efficient, smart and responsive for intelligence sharing and for collaborating across complex supplier networks (Foster et al, 2019). Among other benefits of the high-tech evolution of Big Data analytics for SCM is that it improves user experience and accuracy in demand forecasting, provides improved efficiency in manufacturing, inventory planning and management, creates opportunities to find solutions for more complex distributed network problems and supports the development of better collaborations between stakeholders in the digital supply chain.

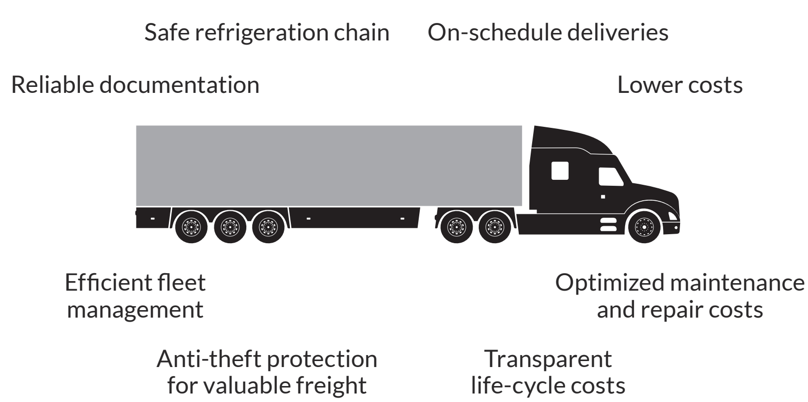
End-to-end solution in the high-tech evolution of supply chain analytics include strategic sourcing, supply chain networks design, product/demand design and development, procurement, inventory, logistical control and distribution, sustainability and supply chain agility (Tiwari et al. 2018). Applications of these solutions have been successful, especially in military services, transportation services, finance, health care and manufacturing supply chain networks.

How is Big Data analytics being used in end-to-end supply chain management solutions today?

Schmitz Cargobull telematics: Cargobull is a German truck body and trailer maker. The trucks use telematics – data and telecommunications systems with a central display and operational sensors and actuator to monitor trailers locations, temperatures, maintenance and cargo weighs. As illustrated in Figure 2, Big Data analytics allows the company to do the following:

- Intelligent trailer scheduling: which shows in real-time the location and availability of the trailer, monitors just-in-time deliveries and improves capacity utilization by avoiding empty trips.
- Transportation security: the coupling status is continuously monitored and the door locking mechanisms are fitted with sensors where real-time alerts on damages, obstructions or theft of products can be monitored.
- Temperature management: temperature data are registered and archived in a dedicated system through the use of active real-time temperature monitors with alarm functionalities. This function helps to keep products in the desired state until delivery points.
- Preventive maintenance: central diagnostic gateway is used for rapid diagnostics of all the system components, therefore downtimes are shortened through advanced warning about the degradation status of the technical equipment used by the trailers.
- Optimized efficiency: Data analysis helps to avoid empty trips, thereby optimizing the trailer capacity utilization, increase efficiency, reduce CO_2 emissions and lower operational costs and offer quicker payback.

Fig. 2: Use-case telematics solutions for trailers and trucks (courtesy Cargobull.com)

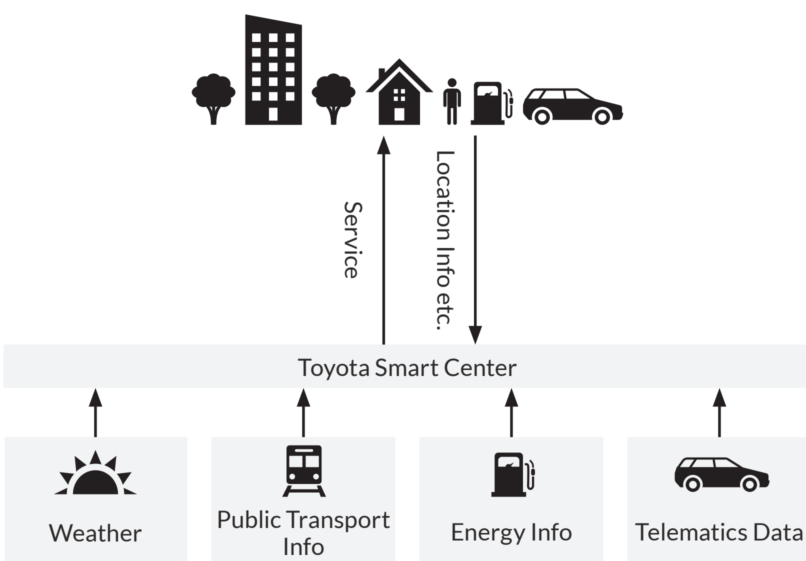


Toyota Smart Center: Toyota's connected cars are one of the emerging and fast growing sources of Big Data expected to propel growth in demand for data generation, use, transmission, storage and processing capacity, integrated with vehicle-to-vehicle (V2V) or vehicle-to-infrastructure (V2I) or vehicle-to-everything (V2E) technologies. Toyota, the world's largest automaker, with its Toyota Big Data Center (TBDC) in the Toyota Smart Center, envisions an IT infrastructure needed to support the major expansion of vehicle data processing.

The concept will use V2E and IoT to offer services for safer and more comfortable car-life. The Big Data collected from vehicles will be analyzed from networks to produce new services for improving customer experience, a strategy others in the automobile market are considering as the future of mobility – shifting from ownership to sharing.

The data can provide relevant information and predictive information services, for example, routing vehicles during disasters such as large-scale earthquake, tornados, damaged roads, collapsed buildings or bridges, etc. The safest routes can be shown on the map with helpful information to guide users. The Big Data collected is used to produce T-Probe traffic information for enabling route guidance that avoids traffic. Displaying passable routes in a timely manner can be achieved by analyzing data from vehicle speeds which can provide information for predicting the tendency of traffic flow with differentiations and specifics based on times and days.

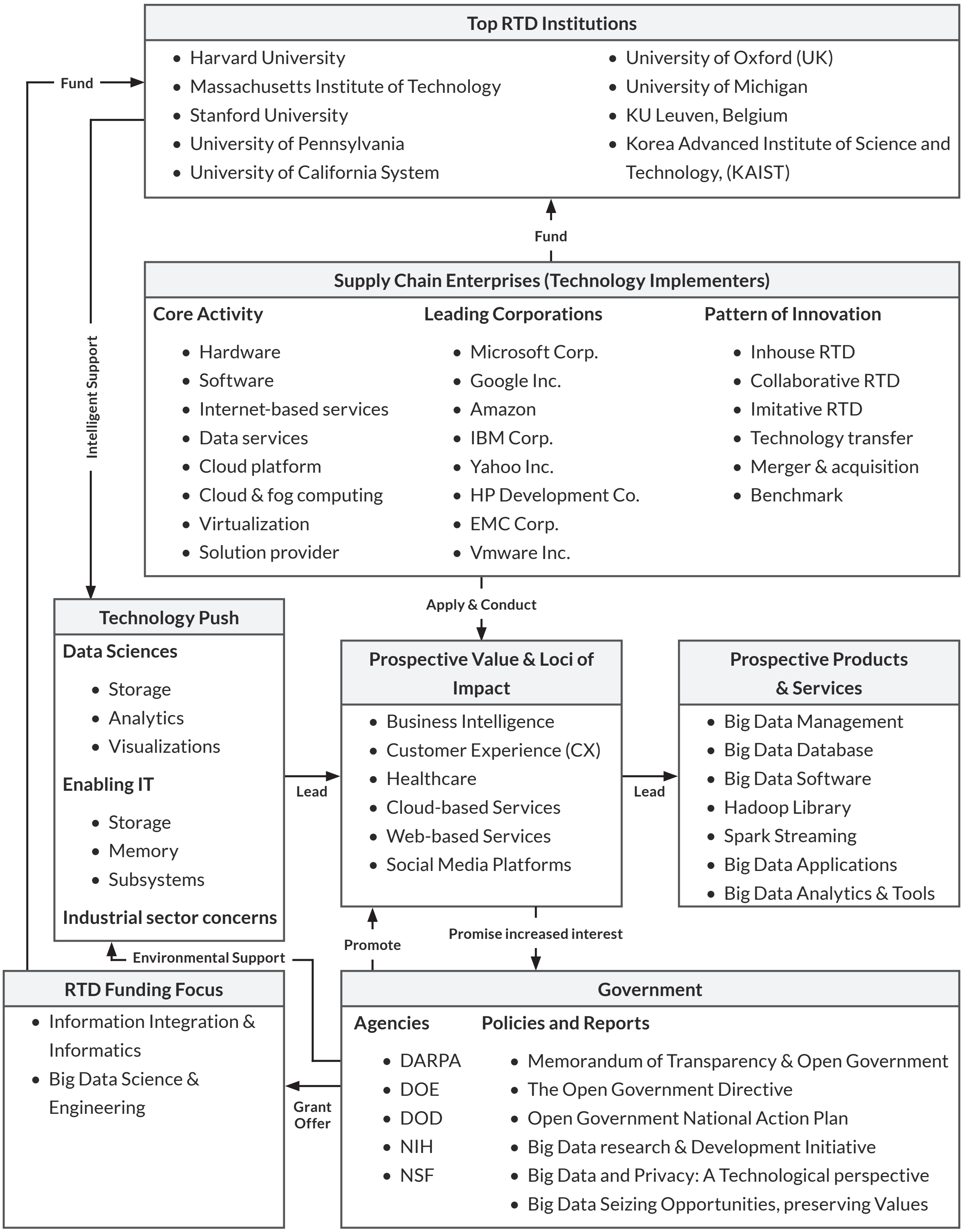
Fig. 3: Toyota's Smart Community (courtesy Toyotaconnected.co.jp)



Other value from the analytics for managing the supply chain for vehicles may include; safety and security services such as emergency services, theft tracking services, operational services and auto-map data updates. Toyota also uses Big Data analytics to provide feedback to Toyota's design and quality control divisions to view and solve market problems. The analytics support failure predications and encourage individuals to perform maintenance checks. Toyota Insurance Management Solutions provide solutions to insurance companies by collecting data on customer's driving behavior (Tiwari, et.al 2018).

UPS fuel-efficient transportation: As automotive manufacturing continues to face many disruptions to expand new technologies such as autonomous, connected, electric and e-mobility, large carrier companies like UPS have begun to take advantage of data-driven analytics to optimize locations and fuel efficiency. UPS has developed and is testing out programs to improve its sustainability. UPS is focusing on fuel efficient transportation delivery trucks. Also, driving algorithms are analyzed to optimize the route and achieve the fewest stops and quickest routes, especially in congested urban areas. UPS anticipates to save an average of six to eight miles per driver per day with these new strategies. (Kaplan, 2019)

Fig. 4: Technology Delivery Systems as part of a large perspective of innovation ecosystems (Cunnigham et al., 2018)



Near (2-5 years)

Constraints to the widespread applications of Big Data analytics for SCM include; workforce reskilling, data capture, storage, searching, analysis, visualization, data inconsistency, data variety and incompleteness, scalability, noise, timeliness, information security and cyber security. Research and technological development (RTD) into data preprocessing techniques such as data cleaning, data integration, data transformation, and data dimensionality reduction will be needed to address these problems (Foster et al, 2019).

Manufacturing-resource-planning systems support fully automated solution to difficult production-scheduling activities. Practically, these are mechanistic, inflexible approaches which often struggle to handle uncertainties and volatilities of the real world, where machines could break down, suppliers fail to deliver and customers change their minds (Alicke et al., 2017).

Researchers are proactively working on solutions to these problems. The data boom from the popularity of social media in Taiwan, for example, is being used to identify methods for generating industrial guidelines to reduce risks and uncertainties (Wu et al. 2017). Similarly, new predictive analysis technologies for sustainability are being developed to address different issues in the supply chain (Oncioiu et al. 2019). A big part of the supply chain network that will benefit from RTD in the next 5 years is accessible mobility. The RTD solutions in this domain will include upgrades to the levels of automation and robotics, open IT platforms and on-demand transportation.

In the Big Data lake, there is significant interconnectivity between research institutions, government funding for RTD through numerous agencies and the industry. Fig. 4 illustrates a technology delivery system (TDS) modelled for Big Data analysis, and the relationship between big data assets, research and enterprise, which are all connected by technology. This is relevant not only for the technological needs and impacts in RTD, but also for the symbiotic relationship between enterprises and agencies funding RTD solutions. For example, there is interest in prospective products and services based on Big Data expansion including data management, Big Data databases, Big Data application and software; Apache Hadoop, spark streaming and innovative analytical tools (Cunningham, et al. 2018). Comparably, this expansion of Big Data from an enterprise and RTD standpoint leads to a larger technological push in the area of data sciences, IT and concerns in the industrial sector, each of which pushes for advanced technology for Big Data sciences.

Far (+ 5 years)

In the future, technological delivery systems relative to social and economic environments will become even more complicated. In dynamic economic environments with rapidly changing markets, enterprises are motivated to engage in continual technological innovation and development as a reaction to preserving a competitive edge (Wang et al., 2008). This process takes place through complex techno-socioeconomic systems. It is challenging for enterprises to persistently manage the delivery of the most suitable technology. A systematic approach using Big Data analytics to build a TDS is represented in Figure 4. This includes:

1. Identifying the macroeconomic and policy environment, including market competition, financial investment, and industrial policy;
2. Identifying the major public and private institutions and organizations in the ecosystem;
3. Addressing the core technical pairs and their owners, then tracing their interactions through information linkages and technology transfers;
4. Describing the market value prospects and assessing the potential intense stimuli on high-tech transformations and social developments.

Big Data analytics for SCM will continue to play a major role in RTD, where stakeholders in the technology supply and demand, and the social development margins can freely apply and benefit from the RTD (Huang et al., 2018). Industrial manufacturing has been duly transformed in the 21st century especially with the rise of AI and the progression of Industry X (an approach of digital reinvention using advanced technologies to reinvent products and services from concept and engineering design to manufacturing and support, thus hastening operational efficiency and enterprise-wide growth). Technology evolution from the punch card sorter to the use of emerging, connected and smart technologies, for digitally transforming the industry will continue to drastically impact the society.

Businesses are expected to run more efficiently and safer in the future due to the availability of innovative technology such as the abundance of smart sensors in factories and across the supply chain networks, for collecting real-time data, stored in cloud and processed in the fog for intelligence decision making. The amount of data available for analysis will continue to increase exponentially which is projected to reach about a zettabytes (ZB) of data per year (equivalent to 1 billion terabytes) (Daryanto, et al., 2018). This increase will also necessitate the demand on technology to acquire, store and process this data—a direct impact on the technological needs of the future for Big Data. The integration and analysis of these large datasets would improve efficiencies of inventory management, sales and distribution process and continuous monitoring of devices.

The manufacturing industry would be able to transform equipment or device maintenance from a reactive to proactive process by using data analytics technology. Early adopters are already applying predictive models to maintenance to more effectively schedule maintenance based on machine cycles and conditions. This would allow humans to be more creative and efficient.

The traditional value chain will move toward hyper-personalized customer experiences, quality product, immediate delivery and smart services. All which would be driven by innovative business models that result in new sources of revenue for the enterprise. Improving customer experience and increasing profit margins will require manufacturers to expand visibility across their supply chain—through planning, purchasing, fabrication and delivery. With increasing complexities in supply chain networks, businesses must adopt better tools to maximize their data in a fast and efficient way.

According to Accenture, only about 13% of businesses have realized the full impact of their digital investments, and those investments have achieved significant cost savings and created growth trajectory for the enterprises. The optimal blend of technologies is expected to save large businesses up to $16 billion USD (Accenture, 2019). Massive growth projections for Big Data include the expansion of analytics software with an expected market value of $42.7 billion USD by 2026. Similarly, there is a projected expansion in Big Data apps, analytics and tools of nearly 23% annually through the year 2026 (Cunningham, et al 2018). This will create the need for expanded RTD and studies on Big Data simulation techniques and technologies for SCM. The impact on the workforce that would support this expansion for sustainable enterprise efficiency must also be studied (Barghini, 2015). Enterprises that will lead in this emerging market are expected to invest resources and time in the practical applications of Big Data analytics to improve their supply chain processes.

Action Items

- One of the first and most important things for companies to do is to set a Big Data strategy – what are their goals and objectives, what are they trying to achieve? This will help define what data they need and the supporting technology.
- Business units must collect and analyze data from their operations and focus on expanding visibility into areas where resources are allocated enterprise-wide and assess staffing levels, role definitions and establish suitable governance processes. This will help to observe variances in staffing functions, cut redundant capabilities across the supply chain and increase profitability over time.
- Transformative idea generation must be accelerated by creating a culture of innovative solutions with a focus on transforming the way work is done throughout the supply chain network. The outcome will situate the enterprise in an agile position for taking up new business opportunities.
- Ensuring inclusive benchmarking allows for the setting of intelligent targets by comparing processes and productivity levels within a supply chain network, across multiple networks in global markets, on cost per full-time equivalent (efficiency) and failure/error rates (effectiveness).
- With technology changing quickly, businesses must invest in advanced systems that deploy next-generation performance management systems for providing real-time, end-to-end transparency across the supply chain.
- A focus on business-to-customer opportunities will yield good returns using technology tools like predictive shipping or crowdsourcing to initiate innovative distribution concepts, such as drone delivery for flexible transport and agile distribution. Providers in the supply chain network will create economies of scale and scope to meet customers' customization needs and expand the potential for attractive technological opportunities.

About Automation Alley

Automation Alley is the World Economic Forum's Advanced Manufacturing Hub (AMHUB) for North America and a nonprofit Industry 4.0 knowledge center with a global outlook and a regional focus. We facilitate public-private partnerships by connecting industry, education and government to fuel Michigan's economy and accelerate innovation. Our programs give businesses a competitive advantage by helping them along every step of their digital transformation journey. We obsess over disruptive technologies like AI, the Internet of Things and automation, and work hard to make these complex concepts easier for companies to understand and implement.

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