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Supply Chain Intelligence

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ABSTRACT

This chapter provides on overall picture of business intelligence (BI) and supply chain analytics (SCA) as a means to support supply chain management (SCM) and decision-making. Based on the literature review, we clarify the needs of BI and performance measurement in the SCM sphere, and discuss its potential to enhance decision-making in strategic, tactical and operational levels. We also make a closer look in to SCA in different areas and functions of SCM. Our findings indicate that the main challenge for harnessing the full potential of SCA is the lack of holistic and integrated BI approaches that originates from the fact that each functional area is using its own IT applications without necessary integration in to the company's overall BI system. Following this examination, we construct a holistic framework that illustrates how an integrated, managerially planned BI system can be developed. Finally, we discuss the main competency requirements, as well as the challenges still prohibiting the great majority of firms from building smart and comprehensive BI systems for SCM.

INTRODUCTION

Today, business organizations operate in global and dynamic business environments characterized by continuous change, uncertainty, radical advances in technology development, rapidly changing customer needs, and continuously intensifying competition. To be viable and successful, firms need to have accurate strategies in place to respond to these challenges in profitable and competitive ways. For this reason, in this chapter we address issues related to business intelligence (BI) and supply chain analytics (SCA) as a means to support supply chain management (SCM) and decision-making, in order to enhance a company's business performance in today's volatile environment.

In this context, SCM is a central component in firms' competitive strategies, directly affecting firms' competitive advantage and success (Gunasekaran, Patel & McGaughey, 2004; Qrunfleh & Tarafdar, 2014; Sangari & Razmi, 2015; Ireland & Webb, 2007). Generally speaking, SCM can be understood as a set of approaches utilized to integrate suppliers, manufacturing, warehouses, and stores so that merchandize is produced and distributed in the right quantities, to the right location, and at the right time, in order to minimize system-wide costs while satisfying service-level requirements (Qrunfleh & Tarafdar, 2014) and customer needs. Therefore, SCM ensures that products and services are available when they are needed and consumed, and that they are produced at the right cost and optimal quality levels. For example, Dell's success was powered by a "build to order" approach that enabled it to offer customers a personalized solution while avoiding inventory hold until the order was received. Dell's innovation in SCM fueled its meteoric stock market performance — 92 % (cumulative appreciation of Dell's stock price during the 1990s). Accordingly, SCM capabilities are both an important competitive advantage and a determinant of a firm's business performance (Tracey et al., 2005).

The importance of SCM has increased remarkably within the last decades. Its role has changed from taking care of tactical operations to a strategic issue. Even traditional manufacturing firms have focused increasingly on their core business processes, outsourcing other non-core processes and activities, which gives rise to a reliance on external resources and services. This has been a growing trend since the 1970s. For example, many manufacturers outsource 70 to 80 percent of the content of their finished products (Corbett, 2004). Consequently, more often than not the supply chains are global and complex, including multiple market players in many different geographical locations and from different cultural backgrounds. In this context, it is easy to agree that firms' ability to satisfy their customers' (rapidly changing) needs, and respond to competitors' strategic movements and the requirement for quality and efficiency in product and service delivery, depends strongly on their ability to develop and manage their supply chain relationships, activities, and processes (cf. Meixell & Gargeya, 2005).

Competitive advantage rarely depends on only a single firm; instead, competition takes place among complex supply chains, and even in larger networks or ecosystems. For this reason, several horizontal alliances have been established to achieve cost efficiency and market effectiveness. Good examples can be found of alliances to deliver cost efficiency in the automotive industry, where companies use the same platforms in manufacturing but still compete fiercely in the customer market (e.g., PSA Group, Citroën and Peugeot, Fiat and General Motors). Airlines have also formed horizontal alliances to be able to extend their market offering and customer experience to deliver enhanced market effectiveness (e.g., Oneworld, Star Alliance, SkyTeam). Both types of alliances are based on effective and streamlined supply chain systems (Gulati et al., 2000). This kind of logistics integration has a significant effect on operations performance. Information technology capabilities and information sharing both have significant effects on logistics integration (Prajogo & Olhager, 2012).

Managing large and complex supply chains is a challenging task, where intelligence regarding supply chain partners, intrafirm and interfirm functions, processes, and performance levels is an essential asset for decision-makers (Adelman et al., 2002). Information technology (IT) and its many applications have a central role in SCM, and the application of IT has been considered the backbone of the supply chain business structure (Sanders & Premus, 2002; Varma & Khan, 2014). Particularly in the era of the internet and digitization, advanced IT systems and SCA are critical tools for firms to support decision-making and facilitate their intentions to achieve competitive advantage (Sahay & Ranjan, 2008). For example, a global engine and power solutions provider for marine and energy markets addressed the importance to develop Big Data analytics and applications to scan efficiently their massive internal data base to find quickly the most promising suppliers amongst hundreds of potential ones. Another global manufacturer in lift and elevator industry sector, in turn, highlighted the importance of developing Big Data analytics enhancing their risk management in supplier markets based on external data sources. They expect that big data analytics can create intelligence to detect possible risks regarding suppliers' court suites and unethical behavior (e.g. the violence of environmental regulations or the use of child labor). Moreover, several scholars have claimed that organizations have reached a point where they *need* to use effective analytics and tools to support decision-making (e.g., Sangari & Razmi, 2015).

Figures describing the development of the SCM-related software market provide evidence for this trend. For example, Gartner estimates that the market for SCM software, maintenance, and services has been growing constantly. It generated a market close to $9 billion in 2013 (including applications for procurement software), showing a 7.4 % increase compared to 2012 (Trebilcock, 2014). This also includes software solutions such as enterprise resource planning, warehouse management inventory, logistics, spend management, and so on. Moreover, big data analytics, while still in its infancy in the SCM context, is gaining more attention as a potential investment area (e.g., Accenture). However, the extent to which firms rely on these applications varies remarkably.

While SCM-related applications are widely used, firms are still struggling to harness the full potential that analytics and BI systems can provide. We believe that one of the main reasons is a lack of holistic and integrated BI approaches, resulting from the complexity pertaining to SCM. As such, SCM itself is a broad concept, which typically includes many different functions, activities, and processes, and it yields many different decision-making levels (strategic, tactical, and operative). Unfortunately, often these functions and processes operate in silos, with each having their own IT applications (e.g., Gibson et al., 2005). While these applications can produce an enormous amount of data, the different datasets are not integrated or shared between the different functions or processes inside the firm, or between supply chain members. Another important reason inhibiting firms from taking full advantage of SCM-related IT is that the information generated is not tied to the company's strategies and strategic objectives (Prajogo & Olhager, 2012). In addition, there is a lack of accurate performance measurements and metrics.

In this chapter we aim to provide an overall picture of BI and SCA as a means to support SCM and decision-making. In the next section, we describe the concept of SCM and need for BI. Then, we take a closer look at SCA in different areas of SCM. Following that examination, we construct a holistic framework that illustrates how an integrated, managerially planned BI system can be developed. Finally, we discuss the main competency requirements, as well as the challenges still prohibiting the great majority of firms from building comprehensive BI systems for SCM.

SUPPLY CHAIN MANAGEMENT AND BUSINESS INTELLIGENCE NEEDS

During the last decades, several definitions of SCM have been presented. In these definitions, SCM has been—and still is—regarded as a synonym for logistics, supply, and supply chain control (Sillanpää & Sillanpää, 2014). Accordingly, it is seen as the chain linking each element of the manufacturing and supply process, from raw materials through to the end user, encompassing several functions and organizational boundaries (Scott & Westbrook 1991; New & Payne, 1995). It even includes activities such as sales and operation planning, sourcing, logistics, manufacturing, assembly, transportation, distribution, and post-delivery customer support (Tan, 2001, p. 40).

The SCM concept has evolved to include activities such as supply chain integration, coordination, and collaboration activities, as well as supplier development, lean, agility and "leagile" (lean agile) forms. The Council of Supply Chain Management Professionals defines SCM as

> *the planning and management of all activities involved in sourcing and procurement, conversion and all Logistics Management Activities. Importantly, it also includes coordination and collaboration with channel partners, which can be suppliers, intermediaries, third-party service providers, and customers. In essence, Supply Chain Management integrates supply and demand management within and across companies*. (Mentzer et al., 2008, 32)

From the strategic viewpoint, definitions of SCM also clearly reflect the connection between SCM and firms' success, presenting SCM as a system with clear strategic intent (Braziot et al., 2013), which should bring benefits to and competitive advantage for firms. A good illustration of this is Stock and Boyer's approach, which defines SCM as:

> *The management of network of relationships within a firm and between interdependent organizations and business units consisting of material suppliers, purchasing, production facilities, logistics, marketing, and related systems that facilitate the forward and reverse flow of materials, services, finances and information from the original producer to final customer with the benefits of adding value, maximizing profitability through efficiencies, and achieving customer satisfaction.* (Stock & Boyer, 2009, 706)

On the basis of the above definitions, it can be stated that successful SCM requires both cross-functional integration inside the company, and coordination of inter-organizational relationships and networks, where marketing must play a critical role (e.g., Tracey et al., 2005; Lambert & Cooper, 2000). Following on from Stock and Boyer's definition, the ultimate goal of SCM is to provide value for customers and benefits for the firm (Qrunfleh & Tarafdar, 2014). The benefits associated with successful SCM can usually be placed in three broad categories: value creation, efficiency creation, and customer satisfaction (Lambert & Burduroglu, 2000; Christopher, 2005; Ehrenthal et al., 2014). SCM merges supply chain integration, creating competitive advantage and agility of cooperation between the members and functions in the supply chain. At a more detailed level, researchers have pointed out factors such as increased inventory turnover and revenue, cost reduction, product availability, and decreased order cycle time as the main benefits of successful SCM (Fawcett et al., 2008). Lately, more strategic-level issues, such as supply chain sustainability, agility to respond quickly to external and internal changes to maintain competitive advantage, and collaboration between supply chain members as strategic goals of SCM have increased in importance (e.g., Sangari & Razmi, 2015).

In short, we understand SCM as a concept (or management approach) consisting of many different intrafirm and interfirm activities and processes that should be planned, implemented, and managed so as to produce value for the end customer, and provide competitive advantage and benefits for the firm. However, some scholars have criticized the use of the term *chain* to describe the very complex and even multilayered structure of supply activities and actors. Terms such as "supply network" or "supply system" provide a more up-to-date picture of what we really mean by SCM (e.g., Rice and Caniato, 2003).

In order to manage and monitor the supply chain efficiently and achieve the aforementioned benefits, managers need many types of information and forecasts to support decision-making, ranging from the strategic to the tactical and the operative. Information on (actual and prospective) supply chain members is essential; information that should include their capacities and capabilities, performance levels, and costs. Information on different intrafirm and interfirm functions and processes (e.g., inbound logistics, manufacturing, outbound logistics, sales and marketing, and customers) is also needed (Chan & Qi, 2003a; Chan & Qi, 2003b). Sometimes the necessary information will be qualitative (e.g., supplier innovativeness, quality, flexibility, visibility, trust), or it might be quantitative (e.g., cost, resource utilization, lead time, etc.) (Shepherd & Günter, 2006; Chan, 2003). In addition, several aspects of information are important for measuring performance:

- costs (e.g., prices, logistics, warehousing);

- lead times and punctuality (order delivery time, inbound punctuality, outcome punctuality);
- quality (number of reclamations, reclamation costs, etc.); and
- information to develop the supplier base (cost-competitive sourcing, number of suppliers, supplier innovativeness, supplier capabilities, etc.)

When managing a supply chain, it is necessary to measure its performance because "*if you cannot measure it you cannot manage it*" (Picard, 2003, 58). Supply chain performance measurement is most relevant when matched to the supply chain operations stages: plan, source, make, deliver and return. Furthermore, both financial and non-financial metrics should be used alongside quantitative and qualitative measures. As Shepherd states, SCM should be measured at multiple levels (Shepherd & Günter, 2006). In practice, this means measuring SCM performance at the operational, tactical, and strategic management levels (Gunasekaran et al., 2004). It is important to develop more non-financial metrics, owing to their ability to deliver more information than basic financial metrics.

De Toni and Tonchia (2001) present time-based indicators as non-cost indicators, where time can be measured as internal or external time. Gunasekaran et al. (2004) present a great deal of time-based measures. Time is also identified as the next source of competitive advantage (Balsmeier & Voisin, 1996; Kessler & Chakrabarti, 1996; Mehrjerdi, 2009; Stalk, 1988; Vesey, 1992). Several scholars also recognize lead time to be a very descriptive indicator when measuring the supply chain.

Figure 10.1 summarizes the different supply chain performance measurement approaches as costs, lead time and punctuality, quality, supplier base development, and supply chain measurement at every management level (Sillanpää, 2015)

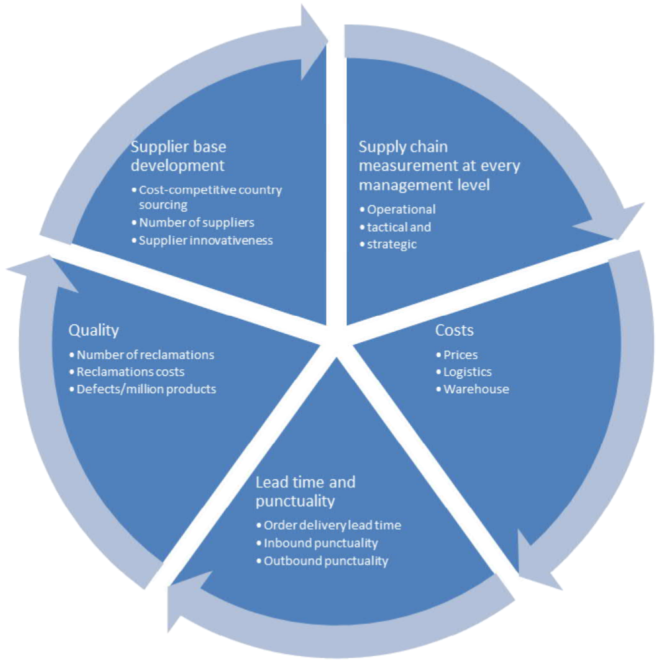

Figure 10.1. Supply chain performance measurement approaches (Source: Modified from Sillanpää 2015)

Recently, supply chain integration has received a lot of attention, both in academic research and SCM practice (Prajogo & Olhager, 2013). Supply chain integration is involving all its members and functions in order to share and distribute BI across the whole supply chain network, resolve SCM issues, and develop cooperation between actors in the end-to-end supply chain (Tsai et al. 2013). Integrating information into the whole supply chain plays a critical role when developing the supply chain to make it more agile, responsible, and capable of creating competitive advantage. A dominant trend in supply chain integration is to utilize cloud services to track and share all members' contributions to the end-to-end supply chain. The concept of supplier development creates practical operational-level supply chain integration, shares BI, and develops the external supply chain where sales and operations planning, sourcing, manufacturing, and delivery are conducted based on BI information (Sillanpää, 2015).

Planning and building BI systems to respond to the abovementioned requirements requires supply chain competence, which can be understood as the ability to provide the supply-chain-related information and knowledge that supports supply chain decision-making at different levels, functions, and processes (Sangari & Razmi, 2015). In the remaining parts of this chapter, we discuss analytics in different SCM functions, and build an overall framework to illustrate what an integrated Supply Chain Management Business Intelligence (SCMBI) system could look like.

SUPPLY-CHAIN-RELATED BUSINESS INTELLIGENCE AND SUPPLY CHAIN ANALYTICS

BI is about producing and providing invaluable information-related input for business needs. It can be viewed as

> *a response to current needs in terms of right, quick, and easy access to relevant information through intensive use of information technology (IT) that enables managers to make better informed decisions in a variety of organizational contexts*.
> (Sangari & Razmi, 2015, 356-357)

In particular, the development of high-speed internet connections, the Internet of Things, and efficient computing power, have opened up new avenues for BI systems and applications. Traditionally, BI has been mainly linked to *descriptive analytics*, which use significant amount of data describing what happened or what is happening. *Predictive analytics* is used to forecast what will be happening in future. These analyses are based on historical and real-time data. On the other hand, *prescriptive analytics* provide recommendations which are derived from descriptive and predictive analytics models using multi-criteria decision-making, optimization, and simulation models. (e.g., Wang et al., 2016; Souza, 2014) These three categories can be seen as a kind of continuum in which SCA support decision-making both in operational/tactical and strategic levels. The role of BI changes when moving from descriptive to predictive and prescriptive analysis. In the context of supply chain management descriptive, predictive and prescriptive analytics support operative-level decision-making whereas strategic decision-making level utilizes mainly predictive and prescriptive analytics (see Figure 10.2).

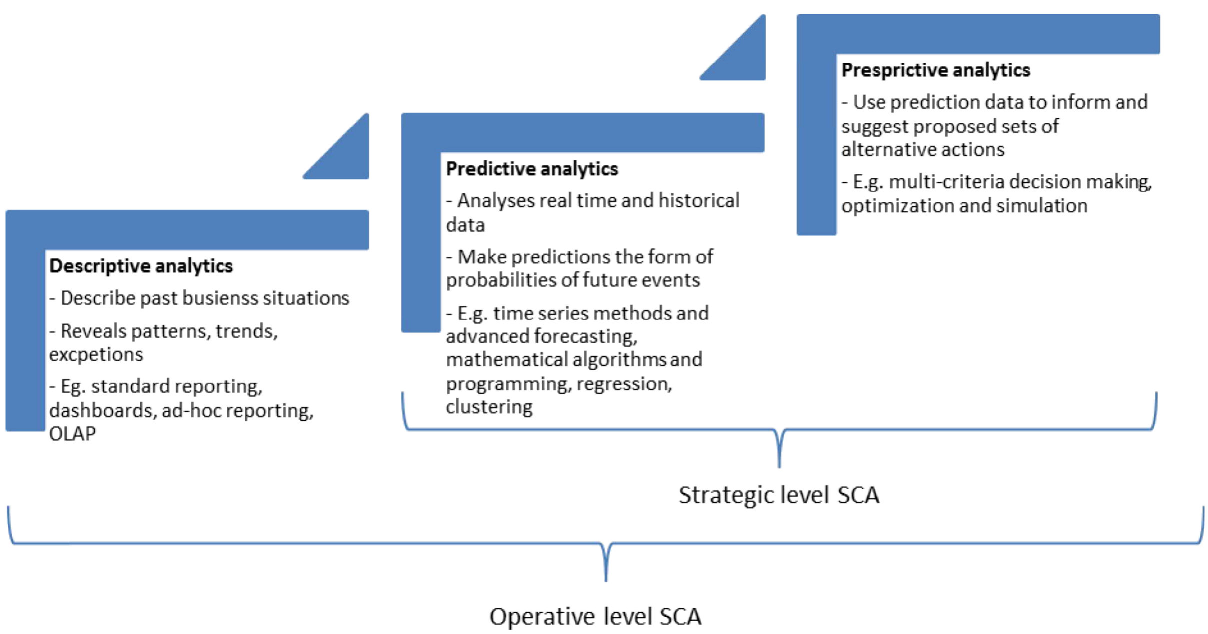

Figure 10.2. Business intelligence analytics continuum in supply chain management (Elaborated by using Wang et al., 2016)

As stated previously, IT and its many applications have an important role in SCM. For example, large companies like Proctor & Gamble and Walmart have improved operational efficiency through the use of data and analytical IT tools, whereas Tesco has experienced cost savings through SCA. (Bongsug et al, 2014) The definitions of SCA (Table 10.1) illustrate the potential of the BI system for firms. For example, Smith (2000) states that:

> *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 processes*. (Smith, 2000)

In the same fashion, Pearson (2011) describes SCA as:

> *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.* (Pearson, 2011; emphasis added)

O'Dwyer and Renner (2011) link the use of SCA to a managerial approach, stating that:

> *Advanced supply chain analytics represents 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*. (O'Dwyer & Renner, 2011)

Table 10.1. Definitions of SCA (Developed from Tjahjono, 2014)

Author(s)	Definition of SCA
Bongsung, Chae & Sheu (2014)	“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.”
Prest & Scott (2014)	“Analytics tools and techniques harness data from a wide range of internal and external sources to produce breakthrough insights that can help supply chains reduce costs and risk while improving operational agility and service quality.”
Souza (2014)	“Supply chain analytics focuses on the use of information and analytical tools to make better decisions regarding material flows in the supply chain. Put differently, supply chain analytics focuses on analytical approaches to make decisions that better match supply and demand.”
Faller & 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.”
O’Dwyer & Renner (2011)	“Advanced supply chain analytics represents 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.”
Pearson (2011)	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.”

Sahay & Ranjan (2008)	"Supply chain analytics provides a broad view of an entire supply chain to reveal full product and component. Supply chain analytics provides a single view across supply chain and includes pre-packed KPI, analytics."
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 processes."

Next, we will present a short overview of the analytics used in the SCM context. We base our overview on the study by Wang et al. (2016), who conducted an extensive analysis regarding supply chain and big data analytics in the SCM sphere. Following their approach, we describe the use of analytics at different managerial levels (strategic and tactical/operative) based on different SCM functions. Although in the real world these functions may be integrated and overlapping, we present them separately for the sake of clarity.

Strategic level

At the strategic level, the main issues relate to questions regarding whether the supply chain includes the right partners in the right locations to deliver everything that is necessary to provide the correct cost and quality levels. Strategic-level BI refers mainly to activities related to strategic sourcing, supply chain network design, and product development. Strategic SCA is able to develop information which helps managers and decision makers to understand better changing marketing conditions, identify and assess supply chain risks, and leverage supply chain capabilities in order to formulate cutting-edge, implementable supply chain strategies, thereby improving supply chain flexibility and profitability (Wang et al., 2016: 101).

Organizations need to capitalize on the importance of supplier integration in business operations, particularly in the new product development process (Handfield & Nichols, 2002). Further, customer and supplier integration in the supply network significantly enhance value creation. This also supports what Vargo and Lusch (2004) called a service dominant logic, where customers and providers together create value.

Strategic sourcing aims to create value for the firm by leveraging external resources and capabilities: in other words, outsourcing business processes and activities. As a general-level goal, strategic sourcing targets performance-enhancing opportunities, to enable cost reductions and/or value creation by finding suppliers and partners with distinctive capabilities and innovation ability (Monczka & Markham, 2007; Wang et al, 2016). This is in line with what Russell and Thukral (2003, p. 325) point out when focusing on the total cost of ownership, including both qualitative and quantitative processes or service improvements, strategic sourcing can facilitate better internal and external service, and thereby increase revenue. Applications can produce information for strategy sourcing alignment (e.g., analyzing supplier spend profiles based on history and future estimations, procurement processes, and estimating future demand). In addition, it can feed sourcing strategy optimization (including, e.g., supply market trend analysis, cost modeling, risk management, contracting terms)**,** and produce valuable information for supplier selection and evaluation based on their optimal value offering, and by benchmarking them against industry best practice and market prices (e.g., lead times against industry norms, quality level, cost-saving initiatives, and supplier pricing against the market), and setting performance targets. (Wang et al, 2016)

Supply network design determines the physical configuration and infrastructure of the supply chain. In today's fiercely competitive markets, designing competitive supply chain network design is the inalienable requisite of having successful supply chains (Farahani et al., 2014, 94). Key decisions are made on the number, location, and size of manufacturing plants and warehouses, and the assignment of retail outlets to warehouses, etc. Network analysis software can provide valuable information for managers and decision-makers regarding the number and location of warehouses, cross-dock facilities, return depots, and production facilities for the entire globe that minimize total warehousing, freight, and inventory costs. Analytics can provide information regarding, for example, fixed and operational costs (warehouse location), traffic network design, and reshoring decisions. (Davis-Sramek et al, 2010; Wang et al., 2016) However, several cases indicate that the competitive aspect of supply networks has become a critical issue, regarding how they should be designed. As Farahani et al. (2014) point out, it seems that competitive supply chains are the leading entities of today and future markets. According to them, competitiveness should be considered in all stages of designing new supply chains. Designing the physical network structure of a chain is called Supply Chain Network Design. Because the structure of a supply chain has a great effect on its overall performance, resilience, costs and competitiveness, Supply Chain Network Design is considered to be one of the most important stages of designing a new chain, which impacts all of its future tactical and operational decisions.

Product design and development plays a key role in company success, where information regarding suppliers' capacities and innovativeness, as well as the cost, quality, and lead times of different components, is essential. The aim of SCA in this context is to help increase the competitiveness of firms' products. SCA is able to produce information regarding, for example (Wang et al., 2016):

- quality and reliability prediction standards;
- data on the expected performance of supplied components;
- what-if scenario analysis regarding product design and development costs; and
- real-time data from internal processes or suppliers to monitor and analyze the substance of supplied components.

Tactical and operational levels

Regarding tactical and operative levels, there is little research addressing the supply chain planning problem of integrating procurement, production, and distribution planning activities into a "fuzzy" environment (Peidro et al., 2010). SCA offers tools for analyzing and measuring supply performance in demand planning, procurement, production, inventory, and logistics. SCA is useful at the tactical and operative level to improve an organization's operational efficiency, measure supply chain performance, reduce process variability, and implement the best possible supply chain strategies. These improvements are achieved through seamless interconnected operations between supply chain processes, from the suppliers of raw materials to end consumers (Wang et al., 2016: 101; Davis-Sramek et al, 2010). Decentralized tactical supply chain models are of particular interest in uncertain environments. In particular, the decentralized approach is suitable for companies where the elements of the supply chain belong to different companies and do not share internal information (e.g. Peidro et al., 2010).

Operational level metrics require data that are relevant to low-level management, and metrics that are relevant to routine business practice (Gunasekaran, Patel & McGaughey, 2004). Furthermore, Peidro et al. (2010) suggest that especially in uncertain environments, the so-called 'fuzzy linear programming' models are superior to the traditional deterministic methods for handling situations where accurate data is ill-known or is not available for operative and tactical supply chain planning.

Demand planning is an activity undertaken to manage processes and operations to meet demand—and variations in such demand—to ensure customer satisfaction, and to minimize warehousing and inventory costs. It is essential for supply chain operations planning as a whole, which includes, resource allocation and capacity planning. SCA can be extremely useful as a provider of demand forecasts and capacity planning by utilizing descriptive, predictive, and prescriptive analysis (e.g., time-series approaches, short-term and intermediate-range forecasting, one period forecast, etc.) (Wang et al., 2016).

Procurement consists of activities such as finding, acquiring, and buying goods, services, or works from an external source. Procurement typically generates a large amount of data from various sources and applications, such as monetary spendings, supplier performance assessments, and negotiations. SCA can help decision-making by providing analysis for many important business issues like supply risk management and supplier performance management. The information needed is related to, for example: price, quality, delivery time, location, and negotiation (Wang et al, 2016).

Procurement systems allow comparisons between suppliers for example (Davis-Sramek, 2010), and assist decision-makers by providing information regarding:

- quality problems and material availability
- risk identification by monitoring public and private data
- quality evaluation
- delivery guarantees and time lines
- spend analysis, etc. (Wang et al., 2016)

Production is one of the central functions in manufacturing firms. It consists of many interlinked processes and activities that must be monitored and analyzed properly to deliver efficiency, cost savings, and ultimately, customer satisfaction. Important indicators are, for example:

- the percentage of defects
- cost per operation hour
- capacity utilization
- the Human Resource Productivity Index (Wang et al, 2016)

SCA can enhance the understanding of production costs, production capacity levels, resource allocation for multiple production lines (demand fluctuation), and material waste identification. Advanced planning and scheduling systems can help manage processes by producing schedules for what to make, where, when, and how to make it, while taking into account material availability, plant capacity, and other business objectives (Davis-Sramek, 2010; Wang et al., 2016). This is especially important when parts of the manufacturing processes are decentralized or outsourced to other companies.

Inventory management is commonly understood as "the practice of overseeing and controlling the ordering, storage, and use of components that a company uses in the production of the items that it sells" (e.g., http://www.investopedia.com/terms/i/inventory-management.asp). Systems such as vendor-managed inventory systems and enterprise resource planning (ERP) collect, process, and report various data to increase efficiency, create cost savings and improve performance related to inventory. Managers need information regarding demand based on historical data and forecasts, replenishment lead times, desired service levels, holdings costs, and the fixed costs of placing a replacement order. Supply chain inventory analytics produces information regarding inventory performance improvements, accurate inventory needs predictions, and cost reductions, so providing a holistic view at the inventory levels across the whole supply chain. Furthermore, analytic inventory software can create information on optimal safety levels and reorder points at various facilities, in order to maximize profitability (Wang et al., 2016; Davis-Sramek, 2010).

Logistics and delivery create much of the data when shippers, logistic service providers, and carriers manage their operations. Here, predictive analytical tools in particular are important to assist the design of flexible logistics operations, and to optimize the routing of goods, vehicles, and crews. (Wang et al., 2016)

TOWARD INTEGRATED SUPPLY CHAIN BUSINESS INTELLIGENCE SYSTEMS

Even though many kinds of software applications and analytical tools are available, most firms are still far from harnessing the full potential of BI systems and SCA. A major reason for that is the lack of integration between BI and other systems in the firm. Integration involves linking various systems and their applications or data together, either physically or functionally, so that value can be created above and beyond that provided by each individual system. While much of the discussion of integration in BI focuses specifically on data integration and its associated tools, the integration of both related systems and data stores presents a significant challenge in many sectors (Işık et al., 2013). Sahay and Ranjan (2008, 43) have also argued that "…the cost of deploying of a large data warehouse to support BI system is still high for many organizations".

The abovementioned problem becomes clear in at least three aspects. First, applications often operate in function-based silos where interaction and coordination between the different functions, processes, and supply chain partners remain weak or non-existent. This may create inefficiencies through overlapping or even duplicated data collection and analyses. It can also lead to a situation where the information located in one place does not reach the decision-maker in the other place, a party who could benefit exactly that information. For example, strategic sourcing, procurement, and production activities can all benefit from spend and cost analysis, lead-time information, and suppliers' performance and quality-related information. Demand planning, production, warehousing, and logistics are very closely linked to each other, and the close coordination and interaction between them can increase flexibility and efficiency, and create cost savings. Therefore, the challenge is: (1) to integrate information from many different sources and databases; (2) to provide proper user access for decision-makers at the different organizational levels and units (Işık et al., 2013; Sahay & Ranjan, 2008; Varma & Khan, 2014; Swafford et al., 2008; Siddiqui et al., 2013).

Second, a common problem relates to the quality of data: the metrics and performance measurements are not clearly defined and, even more importantly, they are not linked to companies' strategies and objectives (Yeoh et al., 2008). As a consequence, it is difficult to measure and evaluate the performance of different functions and processes. Basically, the previous literature contends that there are two main, but partly overlapping, purposes for measuring BI: to evaluate whether BI is worthy of investment, and to help in the management of BI processes. Moreover, due to the lack of a holistic approach to SCM and weak integration, it is nearly impossible to evaluate the total performance of the entire supply chain. So, it seems to be important to develop a kind of balanced performance measurement approach to BI, to link BI creation to the strategies and objectives, and link those to key performance indicators when necessary (Lönnqvist & Pirttimäki, 2008).

Third, despite the tempting value proposal that big data analytics provides, and SCM managers' positive attitudes toward it (Ramakrishnan et al. 2012), firms have been extremely conservative about, and careful of, what is entailed in building big data-enabled BI systems. (e.g., Sanders, 2016; Accenture) One reason for this may lie in the fact that building such systems takes time, requires resources and commitment, as well as coordination effort. However, the market is evolving, and BI software providers are gaining a foothold though their development efforts. In addition, at the moment the most advanced most companies are building their proof-of-concepts in order to gain competitive advantage over their less advanced counterparts, and some leading-edge companies, like Walmart, eBay and Progressive, have even reported benefits in their use of big data (Sanders, 2016; Olszak & Ziemba, 2006; Gessner & Volonino, 2005).

Bearing in mind the abovementioned challenges, we constructed an integrative framework (Figure 10.3) to illustrate how the integrated SCMBI system could be developed from the managerial viewpoint.

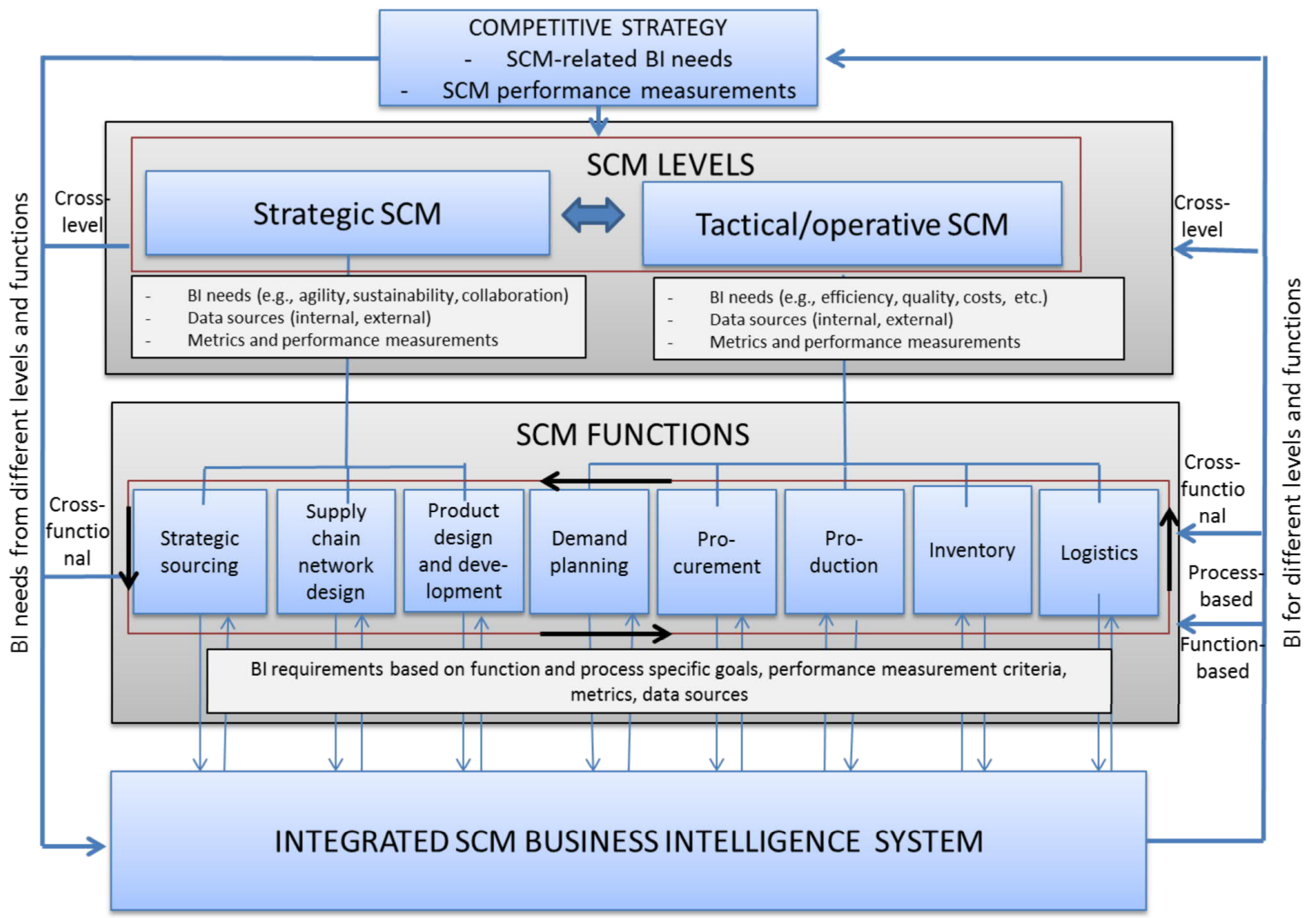

Figure 10.3. A framework for an integrated SCM business intelligence system.

The very core idea of the framework is that the managerial understanding **at different SCM levels and functions** defines what kind of information is needed, what kind of data should be collected and analyzed, and what kind of results the analytics should produce. Managers required to measure performance should have a clear understanding of the relevant metrics and of how data relates to the strategic, tactical, and operative levels of objectives.

In addition, managers should have a clear understanding of which functions and processes are interlinked (**cross-functional and cross-level**), the extent to which they can benefit from the same information, what kind of collaboration and coordination (intra and interfirm) is needed, and what kind of BI requirements they possess. In order to reach that level of understanding, managers in different roles and positions need to communicate and interact in order to create an understanding regarding the need for cross-functional and cross-level information.

The information must serve as a building block for **integrated SCMBI system** development that through technical IT solutions produces intelligence for managerial needs to support SCM at different managerial levels. It is important to ensure BI incorporates and integrates the information for the entire supply chain.

In summary, we provide a list of basic questions to propel research toward the development of integrated SCMBI systems.

- What kind of information is required at different levels, functions, and processes (e.g., quantitative/qualitative, behavioral/numeric)?
- What is the format of the data (function-based, process-based, cross-functional, cross-level, etc.)?
- Which functions or processes are intertwined, and what is the share or benefit from the same data and analytics?

- Where is the data bank or storage located (internal vs. external data sources)?
- What kinds of results should the analytics produce in order to enhance decision-making and performance monitoring (e.g., performance data related to processes and/or outcome, decision-making based on descriptive, predictive, and prospective analytics)?
- How are the BI data linked and connected to the strategic goals and objectives of the company? Do they allow performance monitoring and key performance indicator assessment?

COMPETENCE AS A BUILDING BLOCK FOR SUCCESSFUL BUSINESS INTELLIGENCE SYSTEMS

Supply chain management challenges and requirements

Developing an integrative BI approach for SCM is not a simple task. The preceding sections have stressed the role of business managers and their needs as a basic foundation for supply chain BI system development. However, managerial competence alone is not enough to succeed; supply chain BI is a multidimensional concept, where different competence areas have to be developed and managed in a complementary manner.

As proposed by Sangari & Razmi (2015), supply chain BI competence consists of managerial, technical, and cultural competences, which together enable the development of a well-functioning BI system (see figure 10.4.).

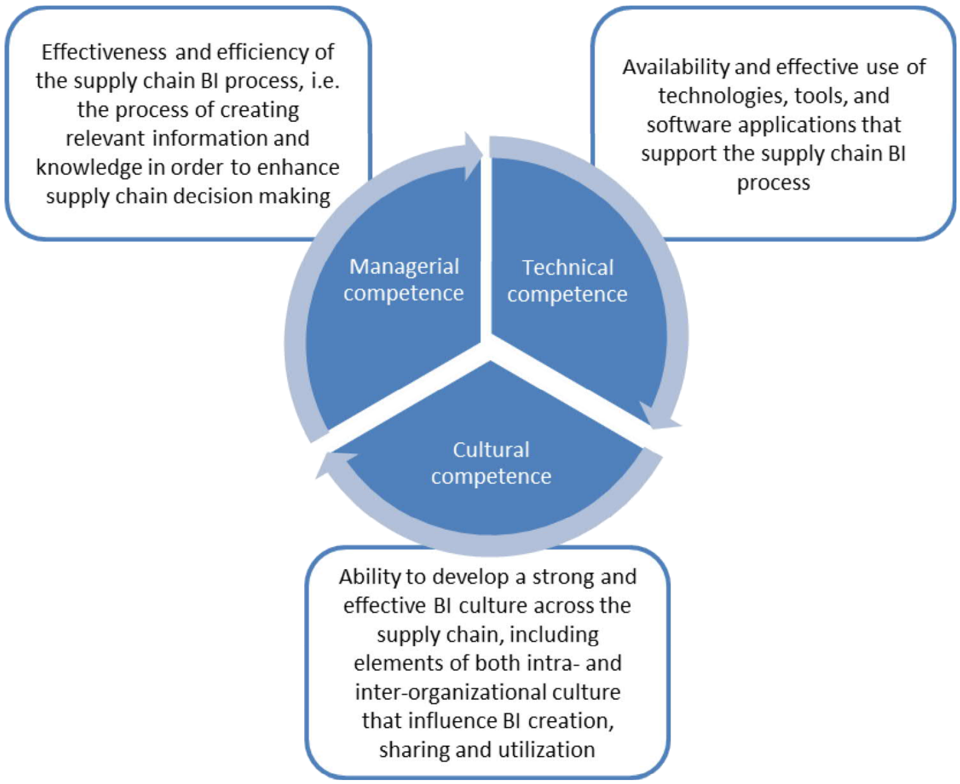

Figure 10.4. Dimensions of supply chain business intelligence competence (Source: Adapted from Sangari & Razmi, 2015)

Managerial competence is needed to ensure the effectiveness and efficiency of the supply chain BI process. Since the creation of an SCMBI system is an involved and resource-demanding process requiring top management involvement and commitment, this can be considered a critical success factor in the development of an SCMBI system.

Technical competence, in turn, is key to ensuring that firms have correct and effective technologies, tools, and software applications to support the BI process. (Sangari & Razmi, 2015) For this purpose, an effective supply chain BI system incorporates widespread analytical applications in combining, evaluating, and accessing huge sets of information (Adelman et al., 2002). People need to access the necessary information and have an efficient data management tool to monitor performance at different levels, functions, and processes. Moreover, firms need IT competence, which can be understood as an "extent to which a firm is knowledgeable about and effectively utilizes IT to manage information within the firm", to support supply chain integration and flexibilities. (Ngai et al., 2011, 235, 245)

In this context, it is important to emphasize that technical competence should ensure that BI users have easy and user-friendly interfaces to access that information. It is important to ensure that collaboration between BI users and IT professionals is emphasized, and also that companies invest in training, educating, and bringing together the right people to use those systems and interact with one another (Fawcett et al., 2008).

Cultural competence is the third important capability necessary to develop a strong BI culture across the supply chain. Cultural competence is based on beliefs, subjective norms, practices, traditions, and values shared among supply chain firms. Inconsistencies in organizational norms and values can negatively affect the information system, as well as decision-making processes.
In this line of argumentation, we want to emphasize that while SCMBI is enabled by modern information technology, its success is also strongly founded on people (Fawcett et al., 2008) and firms' behavior. Scholars and practitioners in the SCM field agree that transparency and trust are the key issues supporting a successful relationship between firms and people. (e.g., Liu et al., 2009; Liu et al., 2010) Often, firms may be reluctant to share information with their supply chain partners due to uncertainty and the risk of opportunistic behavior. However, integrating information flow

throughout the supply chain results in co-value creation, by bringing parties together to facilitate information-sharing. Information flow integration also establishes a functional competence that enables suppliers, manufacturers, and customers to work together effectively to boost operational and process performance (Cepeda & Vera, 2007; Fabbe-Costes & Jahre 2008). Finally, bilateral expectations of information exchange—the beliefs partners hold on what constitutes excellent communication and timely information-sharing—appear to be a useful safeguard against buyer–supplier conflict (Heide & John, 1992).

Trust, transparency, openness, and a cooperative atmosphere are significant and effective factors in sharing information and developing and sustaining a long-term relationship (e.g., Liu et al., 2009; Liu et al., 2010). It is important that firms invest in integration processes for their supply networks, in order to access the right information, at the right time, from the right people. However, there are implementation and validation challenges regarding integrating large groups of organizations into effective networks. For example, small- and medium-sized enterprises may face issues due to a lack of resources, while multinational enterprises need to consider time and cost constraints.

These very operational challenges can be tackled by taking supply chain partners on board through creating confidence levels and giving them a sense of ownership. However, this should be done by considering that firms need to be able to react in agile and flexible ways to market volatilities and dynamisms. Modern IT can play an important role in balancing tensions between supplier network integration and/coordination, and having the agility to respond to market changes (White et al., 2005; Swafford et al., 2008) In more general level, also Wang et al. (2016) have recognized the challenges regarding taking into account the social, organizational, and technological implications of SCA adoption. However, they state that despite these challenges it is important to leverage the *"organizational capacity for extending SCA across the organization and supply chain in order to create holistic business analytics since it will result in benefits across organizational levels, and ultimately, competitive advantage".* (Wang et al., 2016, 106)

CONCLUSION

This chapter has provided an overview of BI and its analytics in the SCM sphere. We hope that our review of current SCA and the integrated SCMBI system framework developed helps to clarify the complexity embedded in SCM. We also hope that our framework and the discussion about SCMBI competences encourages practitioners to be open-minded regarding the potential opportunities of SCMBI system, and prompts those practitioners to take the first steps toward establishing more efficient and integrated BI systems. Finally, we end by repeating the notion stated by Wang et al. (2016), that new challenges stem from the need to constantly improve and update the methodologies and techniques for SCA, as well as to understand the underlying organizational culture and politics that play an important role when selecting business strategies, and subsequently determining and deploying methodologies and techniques to be employed by SCA.

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