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Business analytics in supply chains – the contingent effect of business process maturity

Abstract

The paper analyzes the effect of the use of business analytics on supply chain performance. It investigates the changing information processing needs at different supply chain process maturity levels. The effects of analytics in each Supply Chain Operations Reference areas (Plan, Source, Make and Deliver) are analyzed with various statistical techniques. A worldwide sample of 788 companies from different industries is used. The results indicate the changing impact of business analytics use on performance, meaning that companies on different maturity levels should focus on different areas. The theoretical and practical implications of these findings are thoroughly discussed.

Keywords: business analytics; supply chain management; process maturity; information processing capabilities; performance

1 Introduction

Business analytics (“BA”) are becoming an important tool to improve the efficiency, competitiveness and profitability of businesses. Their positive impact is not self-assured though thus the center of discussion moved to how to best realize the opportunities of BA use (Bose, 2009; Davenport, 2006; Emblemsvåg, 2005; Kohavi, Rothleder, & Simoudis, 2002; Liberatore & Luo, 2010; Trkman, McCormack, Oliveira, & Ladeira, 2010).

An important area of BA use is in supply chain management (“SCM”) since an improvement in SCM can considerably improves performance of single companies and supply chain (“SC”) as a whole (Cagliano, Caniato, & Spina, 2006; Stadler, 2008; Trkman, Indihar Štemberger, Jaklič, & Groznik, 2007). Thus the research of BA use in SCs is growing (Kohavi, et al., 2002; Trkman, et al., 2010). It shows that an investment in BA is likely to improve SC performance and to bring a competitive advantage. Thus several expert systems for statistical and quantitative analysis for optimization of planning, sourcing, production and transportation in supply chains were developed (Chan & Zhang, 2011; Li, Tserng, Yin, & Hsu, 2010; Perko, Gradisar, & Bobek, 2010; Wu, 2010).

However the organizational factors that influence the impact of BA on SC performance remain unclear. Although an investment in BA has been statistically proven to be beneficial (Trkman, et al., 2010), it means a considerable undertaking for any organization. Due to the finite nature of their resources, companies are pressed to prioritize their efforts and identify
those areas where positive effects of the development of BA capabilities are most likely. In this sense, a company may not be able to make simultaneous efforts in different areas of SCM. Thus it is needed to investigate which factors influence the magnitude of BA impact on performance. We argue that the effect of BA on performance depends on the supply chain process maturity of the organization.

Therefore the main contribution of the paper is the analysis of the impact of the use of BA on performance in companies at different process maturity levels. An analysis of data from 788 companies at different maturity levels is used to show how the SCM areas, where the impact of BA is the highest, change with the change in process maturity.

The structure of the paper is as follows: firstly, the conceptual research model is explained. Then the impact of BA on performance is outlined. The role of BA in increasing information processing capabilities is shown. Process maturity and its influence on the impact of BA is outlined. Methodology and statistical analyses are presented. The findings are discussed and illustrated with practical examples.

2. Conceptual research model

The paper argues that the main role of BA is to increase information processing (IP) capabilities of an organization. However, such an increase per se may not be sufficient. In order to provide the benefits these increased capabilities need to be a good match the IP needs of an organization. Since it is likely that different companies have different IP needs it is important to analyze the potential contingencies that influence their IP needs. This would enable a more deliberate focus on the increase of IP capabilities in the areas where it is most likely to lead to the desired benefits.

In order to test that firstly the factors that influence the IP needs have to be identified. Supply chain process maturity (“SCPM”) has been chosen as a suitable proxy since it has been shown that SCPM importantly influences the business processes of a company/SC and consequently its performance (Aryee, Naim, & Lalwani, 2008; McCormack & Johnson, 2001; McCormack, et al., 2009; Škrinjar, Bosilj Vuksić, & Indihar Štemberger, 2008). IP needs to be closely connected to business process design to maximize the payoff by the right choice of action (Raghu & Vinze, 2007). Further advantages are that maturity model is generic across manufacturing settings and that improvement occurs in stages hence the notion of maturity (Aryee, et al., 2008). This gives a chance to compare companies at different maturity levels and from different industries. In the paper we argue that IP needs are changing with the change of SCPM. In order to measure the maturity level a comprehensive and empirically validated maturity framework SCPM3 (Oliveira, Ladeira, & McCormack, 2009) was chosen. The framework has five maturity levels which are described in more detail in “Supply chain process maturity” section.

Secondly the decision how to structure the SCM activities is needed to enable the study of the importance of each area at different maturity levels. Such a division has to be both theoretically plausible and understandable to practitioners. Therefore the Supply Chain
Operations Reference ("SCOR") framework was chosen. It divides the SCM activities in the four main areas: Plan, Source, Make and Deliver (later also Return was added) (Supply Chain Council, 2008). It has been recognized as a systematic approach for identifying, evaluating and monitoring supply chain performance (Cai, Liu, Xiao, & Liu, 2009a).

To summarize: we theoretically argue that the maturity is an important factor influencing the information processing needs of an organization (several such examples are shown in the Discussion section). The paper thus attempts to identify those SCOR areas where an investment in BA is most likely to bring positive results at each of the five maturity levels. Consequently a roadmap to pinpoint in which areas companies on different levels should invest can be prepared.

The conceptual research model is shown in figure 1.

*Figure 1: Conceptual research model*

These connections are thoroughly theoretically grounded in the continuation of the paper. The constructs in blue/bold are also empirically studied.

### 2.1. The impact of business analytics on performance

The use of BA can have a profound influence on performance on operational, tactical and even strategic levels (Popovič, Coelho, & Jaklič, 2009). The professional press has thus quickly touted BA as an approach adopted by leading companies to achieve faster cycle times, greater flexibility and a higher “metabolism” for processing information (Brynjolfsson, 2010; Davenport, 2006). This applies to SC as well - monitoring and improving the performance of a SC has namely become an increasingly complex task. A complex performance management system includes many management processes such as identifying measures, defining targets, planning, communication, monitoring, reporting and feedback (Cai, Liu, Xiao, & Liu, 2009b). Properly implemented and used, BA can increase performance in each of these processes (Trkman, et al., 2010). The application of BA can maximize the value of the data and use it to improve processes (Gottschalk, 2006)
However, the positive impact of a BA investment in SCM operations should not be taken for granted. Despite major investments in SCM in the last decade, businesses are struggling to achieve a competitive advantage (Sahay & Ranjan, 2008). Although the volume of the information available in data warehouses is increasing and the functionalities of BA tools are becoming ever more sophisticated, this does not automatically mean that companies and individuals are able to derive value from them (Petrini & Pozzebon, 2009). Even more so since Elbashir et al. (2008) claim there is a complete absence of a specific and rigorous method to measure the realized business value of BA.

Therefore, the impacts of expert systems supported by information technology (‘IT’) and the BA on improving the productivity and success of knowledge work have been mixed. While some firms have realized gains, many others have found the benefits to be elusive. Companies differ in terms of performance not only because of their unique SC’s IT and organizational structure attributes, but also due to how their efforts “fit” the context of the firm (Buttermann, Germain, & Iyer, 2008).

A compelling and specific vision for how an organization will use information to improve their performance is needed (Williams & Williams, 2007). This further increases the need to analyze in which area the impact of BA may be most beneficial. This is especially so because many organizations with systems already in place to collect data and gather information find themselves in a situation where they have no roadmaps to put their vast data and information into use (Ranjan, 2008). This is even more important since investments in both IT and BA are likely to be path dependent (Qu, Oh, & Pinsonneault, 2010) and a previous investment can increase the capacity for further change (Gregor, Martin, Fernandez, Stern, & Vitale, 2006). An improper investment in an early stage of implementing BA may thus hinder further development. On the other hand, successful efforts may lead to a long-term continuous increase in performance since the path dependency and irreversibility in the development make it difficult to imitate (Fink & Neumann, 2009).

The impact of BA does not mainly depend on technology or numerical methods. In fact, BA are more about culture, creativity and people’s view of the value of information rather than technology (Howson, 2008). Which business processes to support with BA has to be established and how added value is to be achieved must be identified (Laursen & Thorlund, 2010). IT and consequently BA need to be implemented with the intent of maximizing project and financial outcomes in a way that fundamentally improves the firm’s capabilities which, in turn, will improve project- and firm-level performance (Bardhan, Krishnan, & Lin, 2005).

2.2. Information processing capabilities and needs

IP is the purposeful generation, aggregation, transformation and dissemination of information associated with accomplishing some organizational task (Robey & Sales, 1994; Stock & Tatikonda, 2008). The IP view posits that IP capabilities and IP needs must be aligned; the greater the task uncertainty the greater amount of information that has to be processed (Galbraith, 1974). IP view sees the linkage between a key organizational resource (information) and its management (i.e., the use of information) as an organization’s most
critical performance factor (Fairbank, Labianca, Steensma, & Metters, 2006). The company needs to identify those areas in which an increase in IP needs demands an increase in its IP capabilities (Fairbank, et al., 2006). Even the professional press acknowledges that, when analytical skills are well-matched to knowledge-intensive work, the business is more productive (Harris, Craig, & Egan, 2009). Information system professionals need to work hand-in-hand with business leaders, customers and suppliers to understand the operation and strategy of their company’s business units sufficiently well (Taraftar & Gordon, 2007).

Yet a high level of IP capabilities is not necessarily positive; a company may experience subpar results where its information capabilities are high but unbalanced (Sleptsov & Anand, 2008). When IP capacity is less than what is needed to perform a task, performance standards will not be met. On the other hand, when the organization possesses more IP capacity than is required, the task will be accomplished inefficiently (Stock & Tatikonada, 2008).

In addition, IP needs may change over time and along with organizational development; if the organization does not consciously match its information requirements/needs and information capabilities, reduced performance standards will automatically lead to configurations of misfit (Mani, Barua, & Whinston, 2010). Therefore, a need arises to research the way IP needs are changing in organizations and SCs in order to develop proper BA capabilities. In this paper we argue that IP needs depend on the maturity of business processes. Accordingly, a proper focus on developing IP capabilities (in our case measured by an investment in BA) also depends on IP needs and may vary considerably for different companies at different maturity levels.

2.3. Business analytics as a tool to increase information processing capabilities

Performance differences between organizations and SCs are related to how people decide and act (Carlsson & El Sawy, 2008); decision-making thus needs to be properly supported by IT-enabled BA. The use of BA can be crucial since information technology is ever more important in business processes and consequently SCM (Valente & Mitra, 2007; Yu, Ting, & Chen, 2010). Managerial interest has been stimulated in part by a growing commitment at all levels to fact-based SCM, which is very important for the competitiveness of a firm (Shapiro, 2004). A complex interplay of different companies, processes, data etc. needs to be taken into account. In this sense, many analytical and numerical models have been proposed to handle SC operational and design issues (Huan, Sheoran, & Wang, 2004). However, it is hard to encompass all available data in decision-making.

This underutilization of data raises the question of how to help decision-makers in organizations harness the incredible wealth of the data available in SCM software (Shang, Tadikamalla, Kirsch, & Brown, 2008). The ability to sense and interpret events concerning a changing business environment or customer needs require an event-driven IT infrastructure for making fast and well-informed decisions and putting them into action (Schiefer & Seufert, 2005).

After years of significant investments in technological platforms that support business processes and strengthen the efficiency of their operational structure, most organizations have
reached a point where the use of tools to support the decision-making process at the strategic level is of the utmost importance (Petrini & Pozzebon, 2009). Nevertheless, the most suitable organization and processes to enable the positive impact of these decision support tools are still to be clearly identified.

All of this highlights the growing need for and importance of BA as an approach to decision-making based on facts and analysis rather than on intuition or by following general recipes (Popovič, et al., 2009). However, since a SCM is a relatively broad term a more structured approach is needed to systematically evaluate its role. In this paper, the SCOR model is chosen as such a framework for several reasons. From a process perspective, the SCOR model has been developed to facilitate the construction of a systematic SC performance measurement and improvement tool; it has often been recognized as a systematic approach for identifying, evaluating and monitoring SC performance (Cai, et al., 2009b). Further, the SCOR model provides a common SC framework, standard terminology, common metrics and best practices (Huan, et al., 2004); all these improve the generalizability of this research’s results.

The SCOR model divides the processes in a SC into four main areas Plan, Source, Make and Deliver (later Return was also added). BA can be used in each of the four SCOR areas, typical examples include an approach for integrated production-planning in Plan (Jung, 2010) optimal decision about replenishment quantity and reorder point in Source (Pan, Leung, Moon, & Yeung, 2009), integrated optimization model for production and distribution planning in Make and Deliver (Bilgen, 2010) and an algorithm for vehicle routing problem in Deliver (Zachariadis, Tarantilis, & Kiranoudis, 2009).

2.4. Supply chain process maturity

SCPM has been used to measure a company’s potential contingencies. While different concepts could be used to analyze the changing IP needs and the impact on different companies, SCPM was deemed to be the most, especially because it is based on SCOR, which is process-oriented. The concept of process maturity derives from an understanding that processes have life cycles or developmental stages that can be clearly defined, managed, measured and controlled over time. In any business process, a higher level of maturity results in the better control of the results, more accurate forecasting of goals, costs and performance and greater effectiveness in achieving defined goals (Lockamy & McCormack, 2004a; Poirier & Quinn, 2004). It has been shown that maturity importantly influences the business processes of a company or an SC and consequently its performance (McCormack & Johnson, 2001; McCormack, et al., 2009). Companies with more mature SC practices are reducing costs faster than their less mature peers and achieving higher profit margins (Hofmann & Reiner, 2006).

The maturity model represents a methodology whose applications are related to definition, measurement, management and business processes control. A growing number of reports demonstrates the use of maturity models to analyze activities in SC cycles from planning and manufacturing to distribution (Chan, 2003; Gunasekaran, Patel, & Tirtiroglu, 2001).
For the purpose of this research, the Supply Chain Process Management Maturity Model – SCPM3 (Oliveira, et al., 2009) is used to provide the classification of levels and the respective characterization. Although various stage models may differ in terms of the number of stages and what the stages are called, they are all similar in that they break down a phenomenon’s evolution into a series of distinct phases with characteristics associated with each phase (Wixom, Watson, Reynolds, & Hoffer, 2008).

The SCPM3 model (shown in Figure 2) was chosen since previously developed maturity models only outline the general path towards achieving greater maturity, whereas SCPM3 provides a clearer identification of important areas on each of the five levels. Further, while most maturity models (see a review in (Lahti, Shamsuzzoha, & Helo, 2009)) are built on anecdotal evidence or consulting practice SCPM3 was derived from a statistical analysis. SCPM3 is useful for showing which best practices are fully matured at each maturity level.

Figure 2: SCPM3 – Supply Chain Process Management Maturity Model

As illustrated in Figure 2, the model is composed of 13 groups of capabilities hierarchically interrelated and classified on five levels of maturity. The names of each level were defined based on a Delphi study involving members of the Global Business Process Management
Team. The following characteristics were identified for each one of the five different maturity levels.

Level 1 – Foundation – is characterized by building a basic structure, aiming to create a foundation for the processes to avoid ad hoc procedures and to stabilize and document processes. Without a clear strategy any attempt to improve SC operations will be localized and promoted in an ad hoc manner by a few adherents scattered throughout the organization (Fawcett, Ogden, Magnan, & Cooper, 2006). At this level, the critical business partners are identified and order management best practices are implemented. However, the core SC capabilities such as planning, order management, fulfillment, and procurement are still at relatively low level (Chow, et al., 2008). Process changes are hard to implement, there is always a feeling that customers are not satisfied with the company’s performance and the company does not have adequate control over what has been ordered and not yet delivered. In a typical manufacturing company at this level no one ever analyzed the time elapsing from a customer’s order to delivery (Davenport & Short, 2003). Processes are not flexible and thus a company uses many and product/service specifications’ resources to try to meet customers’ changing demand, with these bringing unnecessary expenses. Such rapid process change requirements lie beyond the financial capabilities of most companies, which prefer to leave a well-tested configuration unchanged (Sommer, 2003). Processes are not properly documented; proper documentation is usually a prerequisite for the adaptability and flexibility of SCs and for an overall change management process (Röder & Tibken, 2006).

At Level 2 – Structure – processes start to be structured in order to be further integrated. Each process has a clearly defined beginning, an end, clearly identified inputs and outputs, and a structure for action (Mentzer, et al., 2001). Controls are implemented in demand management processes, production planning and scheduling, and for the distribution network management; all of these constitute core SC capabilities (Chow, et al., 2008). Distribution management practices are structured and the processes are defined. Demand starts to be evaluated in more detail. The future demand for a certain product is the basis for the respective replenishment systems (Aburto & Weber, 2007). Forecasts are frequently updated and measured for accuracy. The processes of production planning and scheduling are structured taking the demand management and forecast as inputs; the greater coordination between manufacturing and marketing also increases the positive impact of adopting information system (Gattiker, 2007). Information system starts to support the operations and integrates with organizational processes. This enables the use of mathematical and statistical methods for distribution planning and demand forecasting (see e.g. (Peidro, Mula, Poler, & Lario, 2009) for an overview of such methods). The impact of future process changes is evaluated in detail before being implemented.

When organizations reach Level 3 – Vision – the key processes of distribution, planning of the SC network, demand planning, procurement and operations have formal process owners; this importantly influences the performance of the SC (Lockamy & McCormack, 2004b). The cross-functional teams that oversee all value-added activities from product conceptualization
to customer relationship management significantly improve governance (Fawcett, et al., 2006). Companies positioned at the Vision level have a formally designated procurement team which meets periodically with other organizational functions such as marketing and operations. The team needs to communicate the benefits of efficient procurement (Tassabehji & Moorhouse, 2008).

At Level 4 – Integration – companies seek to build a collaborative environment with their SC business partners through the sharing of risk and rewards and long-term shared commitment and goals (Awa, Awara, & Emcheta, 2010). The forecasts are developed in detail, considering the demands of each customer individually, thus enabling the management of a whole supply network. Integrated planning and a scheduling model encompass the entire SC and support both pull- and push-based environments (Malik & Qiu, 2008). Information about customer planning starts to be considered as an input for the company’s planning. Forecasts are developed for each customer, individually. Critical suppliers are seen as partners and have broad access to company’s information about production; companies work with them much more closely than in traditional contract-based relationships (McCutcheon & Stuart, 2000). The strategic planning team is involved in the process to select new members and partners for the SC and actively participates in the relationships with suppliers and customers.

Level 5 – Dynamics – is characterized by the strategic integration of the SC, when processes support collaborative practices between partners and enable the SC to be responsive to market changes. Companies attend to the short-term demands of customers and act in a responsive way. The SC starts to behave dynamically, continually improving its processes considering its key performance indicators and reacting fast to the changes in the competitive environment. Companies establish a close relationship with customers and have control over demand and capacity constraints. Buyer-dependence, supplier human asset investments, and trust are all positively associated with improved SC responsiveness (Handfield & Bechtel, 2002).

2.5. Influence of process maturity on information processing needs

Since companies at different maturity levels may have considerably different needs a further study of the necessary focus on different maturity levels is needed. There is namely no single best way of organizing that is effective in all situations (Cadez & Guilding, 2008; Fiedler, 1964) and there is no universal set of choices that is optimal for all businesses (Gingsberg & Venkatraman, 1985). This lack of generalizability precludes organizations from applying a universal strategy (Fredericks, 2005). In our case, there is no optimal strategy for an investment in BA with universal recommendations that would be valid for all companies. Further, there is no single organizational model for organizing BA that suits every company (Harris, et al., 2009).

Therefore, the implication is that when organizations implement systems they must prioritize the outcome they want to focus on (Hartono, Santhanam, & Holsapple, 2007); in our case, which of the SCOR areas needs to be improved. Organizations should examine which mechanism offers greater strategic value and to what extent do IT-enabled business processes affect performance (Qu, et al., 2010; Trkman, 2010). Within an organization, both
management factors in general, and IT factors more specifically, are expected to influence the extent to which value is gained from using IT (Gregor, et al., 2006). This holds true both for the in-house development of BA capabilities and for the external acquisition of technology – the “fit” is very important in both cases (Stock & Tatikonda, 2008).

First, management is faced with a complex set of operating issues and challenges that often necessitates the making of trade-offs (Klassen & Menor, 2007). This need follows the finding that efforts to improve business processes, whether system-based (e.g., total quality management) or technology-based (e.g., automation), must shift their emphasis over time (Klassen & Menor, 2007). Obviously, companies have limited time/resources and a tension arises between quick/efficient decision-making and the careful analysis of data before decisions are taken. The key to managing this tension is to spend time understanding the critical issues and indicators surrounding a decision context, and to really focus on the few ones that make most of the difference (Carlsson & El Sawy, 2008); in our case, the key IP needs. Both researchers and managers need strong foundational, theory-driven tenets that offer pathways for improving process management policies and practices (Klassen & Menor, 2007). Such foundations can help managers better understand what really makes the difference and draw an improvement roadmap optimizing the use of the firm’s resources.

Hence, the successful implementation of BA must focus first on specific business needs (Sahay & Ranjan, 2008). Although there is wide acceptance of the strategic importance of integrating operations with suppliers and customers in SCs, many questions remain unanswered about which types of integration lead to the greatest overall performance improvements (Frohlich & Westbrook, 2001).

Since SCPM3, by its nature, is a process-oriented model, information is an important driver for success. Consequently, it would be reasonable to assume that process maturity in SCs impacts IP needs and consequently the relationship between BA and performance results. This paper aims to evaluate this relationship using descriptive statistics to illustrate how BA impacts performance considering the different maturity levels and SCOR process areas of Plan, Make, Source and Deliver.

3. Methodology

This present study has both a descriptive and exploratory character since it aims to describe and organize information about the influence of process maturity and BA on SC performance. The main research questions are whether there is a relationship between process analytics and performance results and whether the impact of BA in each distinct SCOR area on performance differs between the five process maturity levels.

Based upon earlier research that gathered global data on SCM maturity (Lockamy & McCormack, 2004a), the survey included questions about the utilization of key decision practices in the supply chain. The survey questions were developed after a literature review, along with discussions and interviews with supply chain experts and practitioners. Since the SCOR Model was used as reference to structure the discussions and interviews, with a
preliminary set of questions, experts and practitioners selected from the Supply Chain Council’s member list were invited to validate it. This list spanned multiple industries and contained individuals working within the SC domain.

The survey instrument was developed using a five-point Likert scale measuring the frequency of practices consisting of: 1 – never, or does not exist; 2 – sometimes; 3 – frequently; 4 – mostly; and 5 – always or definitely exists. The initial survey was tested within a major electronic equipment manufacturer and with several SC experts. Based on these tests, improvements in wording and format were made to the instrument and several items were eliminated.

For this research, specific measures representing only analytics practices within each SCOR decision area were identified. Those measures were validated by circulating the list among SCM experts and asking them to accept or reject the measure as representing a BA practice. The SC performance construct is a self-assessed performance rating for each of the SCOR decision areas. The construct is based on perceived performance, as determined by the survey respondents. It is represented as a single item for each decision area. The specific item statement on the supply chain performance for each of the SCOR decision areas is: “Overall, this decision process area performs very well.” The participants were asked to either agree or disagree with the item statement using a five-point Likert scale (1=strongly disagree; 5=strongly agree).

The maturity construct and measures were based upon earlier research (Oliveira, et al., 2009). The measures evaluated the level of supply chain process maturity based on SCPM3.

3.1. Sample

This survey used an electronic form in a webpage, the link for which was sent by email and pre-tested with a small sample of 30 respondents. The sample data were collected from 2002 to 2008 with respondents whose functions are directly related to SCM processes from 788 different companies with headquarters in the USA, Europe, Canada, Brazil and China. The sample deliberately included companies from different industries since various industry settings need to be investigated in the context of global supply chains (Meixell & Gargeya, 2005).

The study participants were selected from:

1. The membership list of the Supply Chain Council. The "user" or practitioner portion of the list was used as the final selection, representing members whose firms supplied a product, rather than a service, and were thought to be generally representative of SC practitioners rather than consultants. An email solicitation was sent out, seeking to recruit participants for a global research project on SC maturity. The responses represent 39.3% of the sample composition with 310 cases.

2. Companies formally associated with IMAM, which is a recognized logistics education and consultancy institution in São Paulo, Brazil. The sample composition included: manufacturing firms; construction firms; retail businesses; graphic industries; mining;
communication and IT providers; gas, water and electricity productive facilities and distribution services. From a total of 2,500 companies, 534 surveys were received, thus yielding a response rate of 21.4%. After data preparation, there were 478 respondents representing 60.7% of the total sample.

The respondents came from nine positions (sales, information systems, planning and scheduling, marketing, manufacturing, engineering, finance, distribution, and purchasing). Approximately 20% of the respondents work in other positions mainly in new supply chain oriented jobs such as “Global Supply Chain Manager” or “Supply Chain Team Member”. The share of senior leaders/executives, managers and consultants/individual contributors is approximately the same. 49% of the companies came from the manufacturing industry, 18.9% from logistics and communication services, 7.2% from the food industry, 5.2% from the auto industry and home utilities and 19.3% from other industries.

3.2. Data analysis

In order to support the analysis, the variables for each construct were aggregated by summing its scores and computing in new variables. In this sense, for example, all variables for Plan analytics were computed in a single variable representing the score for analytics in the Plan area. At the end, five new variables were generated by the sum of the indicators of the constructs of “Plan Analytics”, “Source Analytics”, “Make Analytics”, “Deliver Analytics” and Performance considering the sum of the performance scores for the Plan, Source, Make and Deliver process areas.

Table 1: Descriptive statistics

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>Min</th>
<th>Max</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>Ref. Mean</th>
<th>Cronbach’s Alpha</th>
</tr>
</thead>
<tbody>
<tr>
<td>Performance</td>
<td>788</td>
<td>4</td>
<td>20</td>
<td>12.91</td>
<td>3.12</td>
<td>3.23</td>
<td>0.805</td>
</tr>
<tr>
<td>Analytics Score</td>
<td>788</td>
<td>26</td>
<td>115</td>
<td>72.56</td>
<td>17.67</td>
<td>3.15</td>
<td>0.728</td>
</tr>
<tr>
<td>Plan Analytics</td>
<td>788</td>
<td>11</td>
<td>55</td>
<td>34.91</td>
<td>9.87</td>
<td>3.17</td>
<td>0.886</td>
</tr>
<tr>
<td>Source Analytics</td>
<td>788</td>
<td>4</td>
<td>20</td>
<td>12.26</td>
<td>3.55</td>
<td>3.07</td>
<td>0.795</td>
</tr>
<tr>
<td>Make Analytics</td>
<td>788</td>
<td>2</td>
<td>10</td>
<td>6.18</td>
<td>2.26</td>
<td>3.09</td>
<td>0.709</td>
</tr>
<tr>
<td>Deliver Analytics</td>
<td>788</td>
<td>6</td>
<td>30</td>
<td>19.20</td>
<td>5.15</td>
<td>3.20</td>
<td>0.788</td>
</tr>
<tr>
<td>Maturity Score</td>
<td>788</td>
<td>113</td>
<td>444</td>
<td>295.26</td>
<td>60.38</td>
<td>3.28</td>
<td>-</td>
</tr>
</tbody>
</table>

Table 1 presents descriptive statistics about the latent variables. Ref. Mean was calculated dividing the mean by the number of questions for each variable. A scales reliability and internal consistency test for each construct showed that all the Cronbach Alphas were proven acceptable with values above the cutting value of 0.7.
Then, a Pearson’s correlation test was conducted taking the sum of the business analytics indicators and the sum of the overall performance in each of the SCOR areas of Plan, Make, Source and Deliver. Based on the results from the correlation test shown in Table 2, the correlation was proven to be positive, strong and highly significant.

**Table 2: Correlation between Analytics score and performance**

<table>
<thead>
<tr>
<th>Performance</th>
<th>Pearson’s correlation</th>
<th>Sig. (2-tailed)</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>.806</td>
<td>.000</td>
<td>788</td>
</tr>
</tbody>
</table>

In addition, the sample was divided by considering the companies’ maturity levels based on the scores obtained when using the SCPM3 classification. After pre-processing the sample, generating the new variables and identifying the five sets, one for each maturity level, 52 companies were identified as belonging to maturity level 1, 156 to level 2, 206 to level 3, 233 to level 4, and 141 to level 5. For the aims of this research, different, yet complementary, approaches were adopted and later combined.

Initially, a Pearson’s correlation test was conducted for Analytics Score and Performance for each sample set, corresponding to the five maturity levels. Based on the results (Table 3) correlations to overall performance were proven significant just for those companies belonging to level 3 or above.

**Table 3: Correlations between analytics score and performance at each maturity level**

<table>
<thead>
<tr>
<th>Performance</th>
<th>Analytics Score Level 1</th>
<th>Analytics Score Level 2</th>
<th>Analytics Score Level 3</th>
<th>Analytics Score Level 4</th>
<th>Analytics Score Level 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pearson’s correlation</td>
<td>.252</td>
<td>.119</td>
<td>.144</td>
<td>.231</td>
<td>.359</td>
</tr>
<tr>
<td>Sig. (2-tailed)</td>
<td>.071</td>
<td>.138</td>
<td>.038</td>
<td>.000</td>
<td>.000</td>
</tr>
<tr>
<td>N</td>
<td>52</td>
<td>156</td>
<td>206</td>
<td>233</td>
<td>141</td>
</tr>
</tbody>
</table>

In order to explore the dataset and extract signs showing the impact of BA on performance at each maturity level, the first approach took scatter plots drawn with linear trend lines. Scatter plots can suggest various kinds of correlations between variables. The pattern of dots that slopes from the lower left to the upper right suggests the existence of a positive correlation between the variables and vice versa. A line of best fit (alternatively called a “trend line”) can
be drawn in order to better identify the correlation between the variables. This method was used due to the simplicity and intuitiveness of the analyses, making it easy to use even by those managers who do not have advanced statistical skills. Based on the analysis of the scatter plots and the respective trend lines, the score areas that emerge to more expressively impact on the performance for each maturity level were identified (see Figure 3).

Figure 3: Scatter plots of the relationship between BA in each SCOR area and performance at each maturity level

The trend lines for each SCOR area extracted from the scatter plots reveal distinctive behavior when comparing the different maturity levels.

Pearson's correlation tests were then conducted in order to measure the impact and direction of the relationships between BA in each SCOR area and performance at each maturity level. The results are presented in Table 4.

Table 4: Correlations between BA in each SCOR area and performance at each maturity level

<table>
<thead>
<tr>
<th>Maturity Level</th>
<th>Plan Analytics</th>
<th>Source Analytics</th>
<th>Make Analytics</th>
<th>Deliver Analytics</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Pearson’s correlation</td>
<td>.192</td>
<td>.276</td>
<td>.287</td>
</tr>
<tr>
<td></td>
<td>Sig. (2-tailed)</td>
<td>.086</td>
<td>.024</td>
<td>.020</td>
</tr>
<tr>
<td></td>
<td>N</td>
<td>52</td>
<td>52</td>
<td>52</td>
</tr>
</tbody>
</table>

Analytics Performance Impact by Level
Level 1 – Plan and Source
Level 2 – Plan and Delivery
Level 3 – Make and Delivery
Level 4 – Source, Make and Delivery
Level 5 – Source
The last step was stepwise regression statistics. The stepwise regression is based on a loop procedure in which for each step the independent variable not in the equation that has the smallest probability of F is entered, if that probability is sufficiently small. Variables already in the regression equation are removed if their probability of F becomes sufficiently large. The method terminates when no more variables are eligible for either inclusion or removal. The Overall Performance variable was considered as a dependent variable in the equation and the BA variables for Plan, Make, Source and Deliver were considered as independents. After conducting a stepwise regression for each maturity level, the resulting equations were taken into consideration to identify in which SCOR areas an analytics improvement could be considered to impact on performance for each maturity level. The results of the stepwise regression are shown in Table 5, while a summary of the identified impacts with different methods is presented in Table 6.

<table>
<thead>
<tr>
<th>Maturity Level</th>
<th>Variables Entered</th>
<th>Standardized Coefficients</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Make Analytics</td>
<td>0.287</td>
<td>0.039</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Deliver Analytics</td>
<td>0.216</td>
<td>0.007</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Make Analytics</td>
<td>0.166</td>
<td>0.017</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Source Analytics</td>
<td>0.283</td>
<td>0.000</td>
</tr>
<tr>
<td></td>
<td>Make Analytics</td>
<td>0.189</td>
<td>0.002</td>
</tr>
<tr>
<td></td>
<td>Deliver Analytics</td>
<td>0.181</td>
<td>0.004</td>
</tr>
<tr>
<td>5</td>
<td>Source Analytics</td>
<td>0.466</td>
<td>0.000</td>
</tr>
<tr>
<td></td>
<td>Deliver Analytics</td>
<td>0.180</td>
<td>0.180</td>
</tr>
</tbody>
</table>

Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100. Dependent Variable = Performance
Table 6: Overview of results

<table>
<thead>
<tr>
<th>level</th>
<th>scatter plot</th>
<th>significant correlations&lt;sup&gt;1&lt;/sup&gt;</th>
<th>multiple regression</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Plan, Source</td>
<td>Source, Make; Plan&lt;sup&gt;2&lt;/sup&gt;</td>
<td>Make</td>
</tr>
<tr>
<td>2</td>
<td>Plan, Deliver</td>
<td>Deliver</td>
<td>Deliver</td>
</tr>
<tr>
<td>3</td>
<td>Make, Deliver</td>
<td>Make</td>
<td>Make</td>
</tr>
<tr>
<td>4</td>
<td>Source, Make, Deliver</td>
<td>Source, Make, Deliver</td>
<td>Source, Make, Deliver</td>
</tr>
<tr>
<td>5</td>
<td>Source</td>
<td>Source, Make</td>
<td>Source, Deliver</td>
</tr>
</tbody>
</table>

<sup>1</sup> At the 0.05 level  
<sup>2</sup> At the 0.10 level

4. Discussion

An investment in BA may be beneficial for the performance of companies at all maturity levels as conceptualized in our model. Thus (similarly to the finding in (Trkman, et al., 2010)), a relatively low level of process maturity does not preclude a company from generating the benefits of BA. However, the impact at lower levels of maturity is much weaker; further, the area of the BA impact varies considerably.

Interestingly, the results of the analysis with different approaches see the greatest variations for companies at level 1. This shows that at a low level of maturity it is hard to predict if BA will have a positive effect and in which SCOR area the investment would be most beneficial. Based on our results we can stipulate that companies at low maturity levels may benefit from an investment into Plan, Source and partly Make. This is understandable since companies at level 1 have poorly defined (ad hoc) processes and a better approach to and analysis of planning processes can bring substantial benefits to determine to which areas and when to dedicate the company's resources. Other processes may also improve through planning since they have measurable goals.

Further, the development of supplier evaluations in sourcing can bring considerable benefits in the reduction of lead times, an increase in quality and a decrease in inventory (Cormican & Cunningham, 2007). It is well known that relatively small investments in supplier evaluation can considerably improve the quality/lead times/reliability of the supplier and that performance measurement systems directly affect information sharing, problem solving and the willingness to adapt to changes (Mahama, 2006).

These impacts are closely related to the »order management« component of SCPM3 that is in use at maturity level 1. Companies are scrambling to ensure the better control of their processes in order to be able to handle orders from their customers. A typical example of such a company at a low maturity level is reported in Erjavec et al. (2009). Each order was processed separately regardless of other orders and this led to inefficient resource planning.
The company did not have exact data about stocks, leading to multiple production orders trying to use the same materials. It had unconnected information systems and was unable to even calculate the production costs of each product. An improvement in any of these areas would obviously be beneficial, especially to prepare the basic structure for developing process capabilities. However, in such cases the effects are sporadic and it is quite possible that the prepared analyses would be either inaccurate due to missing/wrong data and/or not even used by decision-makers in the processes.

The companies on level 2 have defined processes and are able to “operate” relatively well and achieve basic cooperation between different functions in an organization. The BA impact now partly shifts from Source to Deliver. The main question is whether the company is able to fulfill the orders of its customers. The supply chain now needs an improvement in the SCPM3 practice “Distribution Network Management” and the use of BA can help achieve this. This supports the commonly held belief that firms need a strong logistics capability to perform well in traditional and e-commerce markets (Cho, Ozment, & Sink, 2008). Companies on level 2 may focus on approaches such as just-in-time and vendor-managed inventories that derive a competitive advantage from accurate and reliable delivery and from an increase in the flexibility of the distribution processes. This follows the finding that the process view improves the reliability of delivery (Armistead & Machin, 1997). Further, an investment in Source on level 1 may pay off as supply management (supplier selection and the reduction of the supplier base) is the core prerequisite of just-in-time and similar concepts (Kannan & Tan, 2005). Suppliers are now performing efficiently (not necessarily successfully, e.g. companies are probably not cooperating in product development) so a further investment in BA in Source may have a limited effect. The chart also visually suggests a possible relationship between performance and BA in Plan, although this could not be confirmed by the other statistical techniques. We can assert that an investment in BA in Plan still has a sporadic effect which is contingent on several other variables not included in the model.

A typical example of a company at level 2 is a British pharmaceutical firm which initiated a national project to implement Collaborative Planning, Forecasting and Replenishment for its major customers. This included significant analytical models and control systems to improve the process performance of the finished goods storage and delivery processes such as detailed forecasting calculations, restocking suggestions and performance dashboards (Danese, 2006).

The alignment of production and other processes to produce the goods at prices and quality that customers want is crucial at level 3. Various practices such as make-to-order (instead of make-to-stock); a rapid response, flexibility, and lean manufacturing are being used. For each of these practices IP needs are high and improved BA capabilities are thus needed. At level 3, planning is already integral in different processes. An investment so as to increase IP capabilities in Plan was important at lower levels where this was the only way to at least partly align the business functions. At level 3 specific investments in planning might be unjustified and would lead to analysis-paralysis.
A typical example of such use is Procter and Gamble which used network (manufacturing, sales and warehousing), inventory and order visibility systems and BA to remove several days in the cycle and gain these days on the shelf, leading to increasing sales, less inventory and less spoilage (Fliedner, 2003).

Companies at level 4 have obviously taken cooperation with their customers and suppliers to the process level. Companies need to increase their BP maturity to build stronger relationships with their trading partners through integrating complex and cross-enterprise processes governed by business logic and rules (Chen, Zhang, & Zhou, 2007). Therefore, the shift of the impact on higher levels of maturity (on both the 4th and 5th levels) back to BA in the Source area is logical. Those companies that went after »low hanging fruit« on level 1 by investing in supplier evaluation now take their cooperation with suppliers at the process level and from the supplying of materials to developing final products or services. The basis of the relationship changes from the parts to be supplied to the programs to be developed and marketed (Mayer & Teece, 2008). The increase in performance is thus no longer derived from efficient, reliable and high-quality supplies but from strategic cooperation with suppliers, whereby product development, joint projects or even the outsourcing of whole business processes take place. Suppliers gradually receive and share more information and schedules with a focal company and become a co-maker of a product and not just a supplier (Bechtel & Jayaram, 1997).

However, developing and maintaining a successful alliance is a very daunting task and goal clarification, communication, and performance evaluation is of the utmost importance (Whipple & Frankel, 2000). Alliance contracts are namely designed to share risk, facilitate learning and joint decision-making and the exchange of knowledge (Mayer & Teece, 2008). Accordingly, the increase in IP capabilities with BA in all SCOR areas (except Plan) was proven to positively affect performance.

The impact of BA on level 4 corresponds well with the importance of the »supply network management« component of SCPM3 at that level. A typical case of the use of BA in supply network management is a medical devices company which built a network of strategic suppliers. This included a shared sourcing, production planning, inventory management and order release system complete with a network analytical model that reduced the network inventory by 50% and improved delivery performance by 25%. Shared process and quality key performance indicators were highly visible and viewed as network team goals and objectives. Suppliers in the network took on the responsibility of managing and replenishing the work in process inventory and had a detailed, real-time view of manufacturing.

Level 5 demonstrates similar impacts of BA as level 4. What is even more visible is that on level 5 the increase in performance is no longer derived from efficient, reliable and high-quality supplies but mainly from strategic partnership/alliances with the use of BA in Source having an undeniable effect well proven by all statistical techniques. The main role of the focal company in the SC is thus to select and coordinate partners. Indeed, if such a network can create a strong identity and coordinating rules, then it will be superior to a firm as an
organizational form (Dyer & Nobeoka, 2000). All of this relates to the “collaboratively integrated practices” from SCPM3.

A typical example of such use of BA is Cisco that needs BA in Source to coordinate a virtual organization that allows Cisco to concentrate on product innovation while outsourcing other functions. Contract manufacturers are closely integrated into Cisco's order fulfillment systems. They ship about half of Cisco's orders directly to the end customer or to a distributor without Cisco ever taking physical possession of the product (Kraemer & Dedrick, 2002). One of the main critical success factors for achieving this is business process improvement, while other CSFs listed in (Lu, Huang, & Heng, 2006) are also closely related to process maturity.

Cisco is also an excellent example of the failure to properly use BA in Source. To lock in supplies of scarce components, Cisco ordered large quantities well in advance, based upon demand projections from the company's sales force. However, many of their forecasts were artificially inflated, which led to double and triple orders. Cisco's SC system did not show that the spike in demand for these components actually represented overlapping orders. Because communication was taking place sequentially from one tier to another, Cisco lacked visibility to demand information at the component level (Sherer, 2005). The final result of this lack of IP capabilities was that Cisco had to scrap around USD 2.5 billion of surplus raw materials inventory (Narayanan & Raman, 2004).

Interestingly, our analysis has also revealed either a limited or even nonexisting effect of the use of BA in planning at all levels of BP maturity. While this finding may be surprising at first glance, it is in fact in line with most of the studies in the last two decades which found inconclusive evidence of the effect of planning on performance. Some found low and others no significant relationship, while some studies even found small negative effects (Boyd, 1991; Falshaw, Glaister, & Tatoglu, 2006; Miller & Cardinal, 1994; Pearce, Freeman, & Robinson, 1987; Powell, 1994; Rogers, Miller, & Judge, 1999; Rudd, Greenley, Beatson, & Lings, 2008). Most of these studies agree that the effect of planning on performance depends on several variables, mainly strategic orientation, turbulence and a firm’s size. Similarly to Rudd et al. (2008), we could summarize that it is not about planning but about strategy. Obviously, a company’s strategy can be better executed with the use of BA in the other three areas of SCOR.

5. Conclusion

The paper’s contribution is that it facilitates a better understanding of the impact of BA on performance. It provides a preliminary confirmation of the need to change the focus on different process maturity levels. This shows that simply following the »best practice« approaches or the well-known cases of other companies may bring little benefit.

Although it is likely that companies in different industries may need quite different focuses, the results of the analysis of the sample from several different industries/countries reveal a strong underlying pattern. This pattern was confirmed with the use of different statistical
The paper has several practical implications. It shows companies on different maturity levels in which areas they should focus on. It also provides a general roadmap for developing IP capabilities on different maturity levels. Since validated questionnaires for measuring SCPM exist (Lockamy & McCormack, 2004a; Oliveira, et al., 2009), it is relatively easy to establish the current process maturity level and consequently the proper focus of BA. There may be a smaller impact of implementing BA if the focus is not in line with the maturity level.

The paper has several limitations. The significant correlation between BA and performance does not necessarily imply a causal relationship or that more investment in that area would further enhance performance. Most of the explanation in the discussion section is not directly substantiated by statistical analysis; additional research is needed to justify the proposed influences.

Further, an important limitation is that the impact of BA on performance does not only depend on the SCPM but also on other contingent variables, e.g. the strategy, the type of SC, the industry in question and turbulence in the SC’s environment (see e.g. (Trkman & McCormack, 2009) for an analysis of the effects of a turbulent environment). Finally, since it is quite possible that the use of BA does not bring immediate results, the performance should be measured with a time lag.

A longitudinal case study that analyzes a single company at different maturity levels, its use/impact of BA and the development of IP capabilities would be valuable to further validate the need for a different focus. Specifically, the way in which companies build their IP capabilities and whether such a road has specific turning points that importantly influence further development should be studied.

References


