Business Analytics, Process Maturity and Supply Chain Performance

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Abstract. The paper investigates the relationship between analytical capabilities in the plan, source, make and deliver area of the supply chain and its performance. The effects of analytics on different maturity levels are analyzed with various statistical techniques. A sample of 788 companies from the USA, Europe, Canada, Brazil and China was 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: BPM Maturity, business analytics, Supply Chain Management, Performance, SCOR.

1 Introduction

Business analytics ("BA") can be an important tool to improve the organization's efficiency. 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 [1]. 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 [2], 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

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depends on the supply chain process maturity of the organization. Accordingly, the main contribution of our paper is the statistical analysis of the impact of the use of BA in different areas of the SC (based on the Supply Chain Operations Reference ('SCOR') model) on the performance of the SC. Further, the mediating effects of two important constructs, namely information systems ('IS') support and business processes orientation ('BPO'), are examined. The first part of the statistical analysis [2] used a sample 310 companies from different industries from the USA, Europe, Canada, Brazil and China, while further 478 companies were surveyed for the second part of our study.

The structure of the paper is as follows: first, the importance of BA and its influence on the SC performance is established. The moderating effect of BPO maturity is discussed. The research model is presented. Then the methodology and results obtained are presented. The findings are thoroughly discussed along with the limitations of our research and potentially interesting topics for further research.

2 The Influence of BA on Performance

The use of BA can have a profound influence on performance on operational, tactical and even strategic levels [3]. The professional press has thus quickly touted BA as an approach to achieve faster cycle times, greater flexibility and a higher "metabolism" for processing information [4]. 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 [5]. Properly implemented and used, BA can increase performance in each of these processes [2].

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 [6]. Companies or individual decision makers are not necessarily able to derive value from the growing amount of information [7].

A compelling and specific vision for how an organization will use information to improve their performance is needed [8]. This further increases the need to analyze in which area the impact of BA may be most beneficial. 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 [9]. An improper investment in an early stage of implementing BA may 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 [10].

2.1 Ways of Business Analytics Influence

As shown, the potential positive impact of BA on SC performance is well established; however, the potential ways and moderating influences of this impact are not so well-understood. Most previous research papers have used SCM as an umbrella term to

analyze this impact. Yet it should not be forgotten that SCM is quite a broad term and encompasses the integration of organizational units and business processes along a SC to coordinate materials, information and financial flows in order to fulfil customer demands [11]. SCM is therefore still largely eclectic with little consensus on its conceptualization [12] and can basically encompass every business activity in a company. In this sense, a more precise reference is needed to analyze the impact of BA.

Since SCOR has been widely employed for SC optimization in recent years (see e.g. [5]), it was used as a framework for our study. SCOR has often been recognized as a systematic approach to identifying, evaluating and monitoring supply chain performance [5, 13]. In the SCOR model, a balanced performance measurement system at multiple levels, covering four core SC processes (Plan, Source, Make, Deliver, later Return was also added), was developed [5]. SCOR is supposed to be the most promising model for SC strategic decision-making [14]. It provides a common SC framework, standard terminology and metrics that can be used for evaluating, positioning and implementing SC processes [14].

Several examples of BA use in various areas were previously reported [2]. In general, improvements in any of the four areas can considerably increase the SC performance [13]. However, the influence of BA in each of these four areas on different process maturity levels has not been analyzed.

The positive impact of BA is however not self-assured but has to be moderated by IS support and by the BPO. Modern BA tools have namely not only been successfully incorporated into existing organizational ISs but have also become an integral part of organizational business processes [15]. The link between IT use and the simultaneous design of business processes is a vital ingredient to bring a benefit from such development efforts. In fact, in practice it is often difficult to separate the origin of the benefit, whether it has derived from IT, a process change, or both [16].

Although both effects are obviously connected, it may still be important to identify which are the moderating effects of each of them separately. The moderating effect of BPO is discussed in the next section while the effect of IS support is described in [2].

2.2 Moderating Effect of Business Process Orientation

The main question is how to assure that BA will indeed be used to improve the operation of a SC. Our hypothesis is that the BPO [17] has a moderating effect between BA use and SC performance. Therefore, both BPO and BA maturity have to increase in order to lead to improved business performance. This could mean that companies that are more process-oriented are in a better position to utilize BA to improve their performance. This is in line with the previous finding that BA systems have to be process-oriented to link across functions/break the functional perspective at both the strategic and tactical levels [18].

Several reasons make BPO especially important. Since most firms offer similar products and use comparable technologies, business processes are among the last remaining points of differentiation with BA optimizing their value [19]. Further, in order to fully use BA companies need to undergo thorough business process changes,

apply change management practices and focus on changing downstream decision-making and business processes [20]. Thus a proper level of maturity of business processes (see e.g. [17, 21]) may be determine a proper focus of investment of BA; in our case, which of the SCOR areas needs to be improved.

Management is thus faced with a complex set of operating issues and challenges that often necessitates the making of trade-offs [22]. Even further: efforts to improve business processes must shift their emphasis over time [22]. 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 [23]. Managers need to 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 [6]. These business needs may change with the change in BPO. 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.

For the purpose of this research, the Supply Chain Process Management Maturity Model – SCPM3 [24] 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 [25].

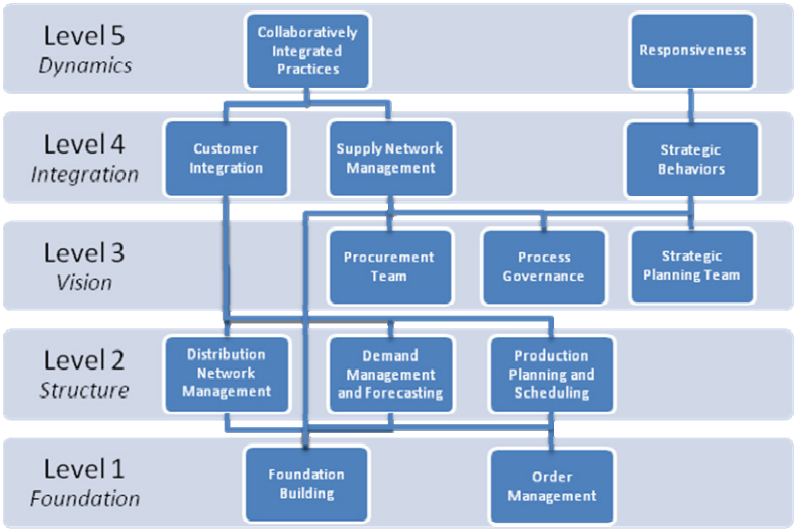

Fig. 1. SCPM3 – Supply Chain Process Management Maturity Model [24]

The SCPM3 model (shown in Figure 1) 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 [26]) are built on anecdotal evidence or consulting practice SCPM3 was derived from a statistical analysis. As illustrated in Figure 1, the model is composed of 13 groups of capabilities hierarchically interrelated and classified on five levels of maturity.

Squared boxes (fig. 1) are groups of capabilities that are configured under hierarchical relationships that are represented by the links between the boxes. For example a firm that wants capabilities related with "Collaboratively Integrated Practices" need to develop "Customer Integration" and "Supply Network Management" capabilities. Those hierarchical relationships are not a necessary condition but firms that develop such capabilities at previous levels are able to get a better return of investment from higher level capabilities.

3 Methodology

3.1 Data Collection

The survey instrument was developed using a 5-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 upon these tests, improvements in wording and format were made to the instrument and several items were eliminated.

The Supply Chain Council board of directors also reviewed the initial survey instrument. Based on this review, the survey was slightly reorganized to better match the SCOR model. The whole questionnaire is provided in [2]. The questions focus on decision-making in the key SCM decision categories for each of the four SCOR decision areas. The whole data set can be obtained from the authors by email.

3.2 Sample

The sample for the first part of the study was composed of respondents whose functions are directly related to SCM processes from 310 different companies with headquarters in the USA, Europe, Canada 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 [27].

The study participants were selected from several sources:

1. The membership list of the Supply Chain Council. The "user" or practitioner portion of the list was used as the final selection since this represented members whose firms supplied a product, rather than a service, and were thought to be generally representative of supply chain practitioners rather than consultants.

2. Firms that were interested in measuring their supply chain maturity and developing an improvement plan. These firms responded to an email solicitation recruiting participants for a global research project on Supply Chain Maturity.

For the second part of the research a larger sample was needed since the companies in the sample had to be divided according to their maturity level. Thus the survey was repeated with additional questions added using the companies formally associated with IMAM. IMAM is a recognized logistics education and consultancy institution in São Paulo, Brazil. By accessing the mailing list of this institution, the sample composition evolved: manufacturing firms; construction firms; retail businesses; graphic industries; extractive firms; communication and IT providers; gas, water and electricity productive facilities and distribution services. 478 additional cases were thus included in the sample.

3.3 Data Analysis

The whole 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.

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. Overall performance is the average of the performance from the four SCOR areas.

To analyze the different BA impact on different maturity levels three complementary, approaches were adopted and later combined. Firstly scatter plots were examined 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. Secondly 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. Thirdly 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.

4 Results

4.1 Different Impacts of BA on Different Maturity Levels

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. 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 (table 1).

Table 1. Correlations between analytics score and performance at each maturity level

		Analytics Score Level 1	Analytics Score Level 2	Analytics Score Level 3	Analytics Score Level 4	Analytics Score Level 5
Performance	Pearson's correlation	.252	.119	.144	.231	.359
	Sig. (2-tailed)	.071	.138	.038	.000	.000
	N	52	156	206	233	141

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. The results of the stepwise regression are shown in Table 2.

Table 2. Regression Table – Stepwise method by maturity level

Maturity Level	Variables Entered	Standardized Coefficients	Sig.
1	Make Analytics	0.287	0.039
2	Deliver Analytics	0.216	0.007
3	Make Analytics	0.166	0.017
4	Source Analytics	0.283	0.000
	Make Analytics	0.189	0.002
	Deliver Analytics	0.181	0.004
5	Source Analytics	0.466	0.000
	Deliver Analytics	0.180	0.180

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

Table 3 summarizes the results from the three used approaches to data analysis. For example, on level 1 scatter plots suggest that BA in Plan and Source have the effect on performance. The correlation analysis suggests that also BA in Make influences performance while multiple regression indicates only the latter. Results are less ambiguous for higher maturity levels.

Table 3. Overview of the impact of BA on various maturity level

level	scatter plot	significant correlations[1]	multiple regression
1	Plan, Source	Source, Make; Plan[2]	Make
2	Plan, Deliver	Deliver	Deliver
3	Make, Deliver	Make	Make
4	Source, Make, Deliver	Source, Make, Deliver	Source, Make, Deliver
5	Source	Source, Make	Source, Deliver

1 At the 0.05 level unless otherwise noted

2 At the 0.10 level

4.2 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 [2]), 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 show 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 [28]. 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 [29].

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. This supports the commonly held belief that firms need a strong logistics capability to perform well in traditional and e-commerce markets [30]. 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 [31]. 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 [32]. 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.

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. At level 3, planning is already integral in different processes. An investment in BA 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.

Companies at level 4 have obviously taken cooperation with their customers and suppliers to the process level. Companies need to increase their BPO to build stronger relationships with their trading partners through integrating complex and cross-enterprise processes governed by business logic and rules [33]. 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 [34]. 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 [35].

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 [36].

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 [37-39]. The effect on lower levels of maturity indicates that planning may be a surrogate for BPO but on higher levels of maturity planning is integral in other processes.

5 Conclusion

The paper has several practical implications. It shows companies on different maturity levels in which areas they should they focus on. It also provides a general roadmap for development of BA capabilities on different maturity levels. Since validated questionnaires for measuring SCPM exist [24, 40], 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 some limitations. The selection of companies in the sample may not be completely random since companies that were more aware of the importance of BA/process improvement might have been more inclined to participate. A refinement of the measurement of BA use in each of the four SCOR areas would also be beneficial. Further, the users' evaluation may not always accurately reflect the real quality of IS [41]. 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. 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.

Future research should investigate whether the different kinds of IS (e.g. enterprise resource planning, web services/service-oriented architecture) have a different moderating effect on the impact of BA in various areas of SCM on performance. Since performance was treated as a single construct in this paper, a much needed further investigation is how BA in various areas of SC impact different performance metrics, e.g. on-time delivery, quality, costs, reliability and flexibility.

A closely connected topic is an investigation of the development of performance measurement systems and the need for target analytical capabilities in specific areas. The development of analytic capabilities outside a focal company (in e.g. a customer-supplier dyad) could be studied to analyze how value is created in interorganizational networks.

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