Supply chain maturity and performance in Brazil

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Abstract

Purpose – The purpose of the paper is to investigate the relationship between supply chain maturity and performance, with specific references both to the business process orientation maturity model and to the supply chain operation reference model.

Design/methodology/approach – Quantitative, survey based research was carried out with 478 Brazilian companies. Statistical analysis combined the use of descriptive statistics and structural equation modeling.

Findings – Empirical results indicate a strong and positive statistical relationship between supply chain maturity and performance. The results also suggest that the deliver process maturity has a higher impact on overall performance than the other supply chain processes.

Research limitations/implications – Quantifying supply chain maturity and performance is an opportunity for a company to align its performance measurements and process improvement actions with its broader policies and strategies. The use of this approach has been validated in several previous research studies in organizational self-assessment and business management.

Practical implications – Maturity models are valuable frameworks for corporate leadership. This study provides solid statistical evidence that a company that has achieved a higher maturity level and implemented the maturity factors also has achieved superior performance. It also validates the application of these specific maturity factors in South America, specifically Brazil.

Originality/value – This paper confirms and expands upon earlier research suggesting higher levels of process maturity were related to superior performance. This paper also examines the evolution of performance measurement systems, moving from a traditional approach to a more process oriented perspective by reporting on the origins of maturity models and presenting the main empirical contributions through the use of the business process maturity model and supply chain operation reference model.

Keywords Supply chain management, Performance management, Brazil

Paper type Research paper

Introduction

In order to meet the performance levels demanded by today's customers in terms of quantitative and qualitative flexibility of service in demand fulfillment, delivery consistency and reduction of lead times related to fulfilling orders, firms have developed repertoires of abilities and knowledge that are used in their organizational process (Day, 1994; Lockamy and McCormack, 2004). In the past two decades, supply chain (including logistical) processes have evolved because of these new demands from a departmental perspective, extremely functional and vertical, to an organic arrangement of integrated horizontal processes, oriented to providing value to intermediate and final customers (Mentzer *et al.*, 2001). This new pattern of supply chain process management has focused on the development and application of different maturity models and performance metrics useful in helping define a strategy and face trade-offs as well as identifying items that are critical to improvement of supply chain processes.

In recent years, a growing amount of research, much of which is anecdotal, has been dedicated to investigating maturity model development and performance measurements for the strategic management of supply chain processes (Chan and Qi, 2003; Gunasekaran *et al.*, 2001; Coyle *et al.*, 2003).

The concept of process maturity, including supply chain processes, derives from the understanding that processes have life cycles or developmental stages that can be clearly defined, managed, measured and controlled throughout time. Higher levels of maturity in any business process result in:

- better control of results;
- improved forecasting of goals, costs and performance;
- greater effectiveness in reaching defined goals; and

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- improving managements' ability to propose new and higher targets for performance (Lockamy and McCormack, 2004; Poirier and Quinn, 2004).

This article presents the results from quantitative research that investigated the supply chain process maturity levels of several Brazilian companies and the relationship between supply chain process maturity and performance. This research confirms and expands upon earlier research suggesting higher levels of process maturity were related to superior performance. The question of whether implementing these maturity factors relates to performance improvements has been mostly anecdotal and statistical studies have been lacking, especially in South America. This research not only validates the components of a widely used maturity model but also tests the entire model using structural equation modeling.

This article is divided into four sections including this brief introduction. In section two, the origin of the Performance Measurement System concept and the leading maturity model are discussed. In section three, methodology and results are analyzed. In section four, conclusions are presented and future research suggested.

Theoretical framework

Performance measurement systems (PMS)

Performance measurement systems are evolving from a system based on measurement and cost control, referred to as traditional PMS, to a system based on the measurement and creation of value using non-cost performance measures, those that are not economic or explicitly financial, referred to as innovative PMS (De Toni and Tonchia, 2001). Table I highlights examples of these two approaches.

This evolution of PMS illustrates the shift to the long-term approach of innovative PMS over the short-term, traditional PMS. In this sense, companies are becoming more aware that value means much more than cost efficiency and being profit oriented. Moreover, evaluating performance on only financial indicators points to results and does not consider its determinants, providing a myopic approach for long-term results.

Within the recent developments of performance measurement systems, mainly related to the processes in the supply chain, supply chain operation reference model (SCOR) has gained increasing visibility in business and academic communities as an approach, which moves toward innovative PMS. By offering a standardize way of viewing the supply chain, the SCOR model has also contributed to the development and evolution of different supply chain maturity models which take an innovative PMS perspective.

Table I Evolution of PMS

Traditional PMS	Innovative PMS
Based on cost/efficiency	Based on value
Trade-off between performances	Compatibility of performances
Profit oriented	Client oriented
Short term orientation	Long term orientation
Individual metrics prevail	Team metrics prevail
Functional metrics prevail	Transversal metrics prevail
Comparison with the standard	Monitoring of improvement
Aimed at evaluation	Aimed at evaluation and involvement

Source: De Toni and Tonchia (2001)

The SCOR model

The SCOR model, created by SCC (Supply Chain Council) with the mission of facilitating supply chain management across industries and benchmarking, contains Plan, Source, Make, Deliver and Return processes and defines the process elements, metrics, best practices and technology used within each area (Bolstorff and Rosenbaum, 2003; SCC, 2007).

The SCOR model also provides a "scorecard" framework for development of performance measures and goals. Figure 1 provides a simplified example of a scorecard that is constructed from SCOR performance metrics. The scorecard is used to help define an enterprise business strategy, align the activities of the partners and to identify the business value that is obtained through the improvement in operations efficiency.

For each metric the scorecard can focus managers on being responsible for not only current performance but the amount of improvement needed to attain the company's goal for that metric and the projected financial gain that could be obtained in case of achievement of the desired improvement.

The SCOR model emphasizes process orientation (a horizontal focus) and deemphasizes organizational or functional orientation (vertical focus). This means that the model focuses on the activities involved in the process and not on the professional group or organizational element that may execute such activity. This process orientation is a critical element of process maturity and is reflected in the maturity model used in this study.

Maturity models and supply chain process management

A maturity model represents a methodology with components related to definition, measurement, management and business processes control. These have been shown to be very similar to management approaches/concepts of BPR (Business Process Reengineering), thus attracting a growing interest not only by companies but also by researchers involved in this area (Chan and Qi, 2003; Gunasekaran *et al.*, 2001). Although its origins are not directly linked to supply chain processes, there has been a growing amount of research in recent years that represent the use of maturity models based on KPI (Key Performance Indicators) to analyze the activities of supply chains (Chan and Qi, 2003; Gunasekaran *et al.*, 2001).

In the following section, a leading maturity model currently used by companies to analyze the performance of their supply chain processes is presented. Specifically, the Business Process Orientation Maturity Model, developed by DRK Research (a group associated with Samford University and North Carolina State University). This self-assessment model has been used since 1998 to evaluate over 1,000 companies in Europe, North America, China, and Australia. This model is also the only SCOR based, comprehensive model whose components, but not the model as a whole, have been statistically examined and their relationship to performance established.

The business process orientation maturity model

The concept of Business Process Orientation suggests that companies may increase their overall performance by adopting a strategic view of their processes. According to Lockamy and McCormack (2004), companies that strategically focus on their business processes reach greater

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Figure 1 SCOR card – metrics approach

Scorecard				
Overview Metrics	SCOR Level 1 Metrics	Actual	Goal	Value from Improvement
Delivery Performance/ Quality	Delivery Performance to Commit Date	50%	85%	$20M
	Fill Rates	63%	94%	$10M

Source: Adapted from the Supply Chain Council – www.supply-chain.org

levels of performance and have a better work environment based on high levels of cooperation and less conflict.

A very important aspect of this model as applied to the supply chain is the use of SCOR to organize and classify the processes within a supply chain (Lockamy and McCormack, 2004; SCC, 2007). The SCOR model was utilized because of its process orientation and growing use among professionals and academics who are directly involved with supply chains. SCOR is also becoming the common language for benchmarking and comparing supply chains and supply chain management practices.

The five stages of the maturity model, as indicated in Figure 2, depict groups of practices that are employed at different levels of process maturity, building upon each other and producing increasing levels of supply chain performance. With each level of maturity come increasing levels of predictability, capability, control, effectiveness and efficiency.

Ad Hoc, the model's first level, is characterized by poorly defined and un-structured practices. Process measurements are not applied and organizational structures are not based on horizontal process at the supply chain. Performance is unpredictable and costs are high. Functional cooperation and customer satisfaction levels are low.

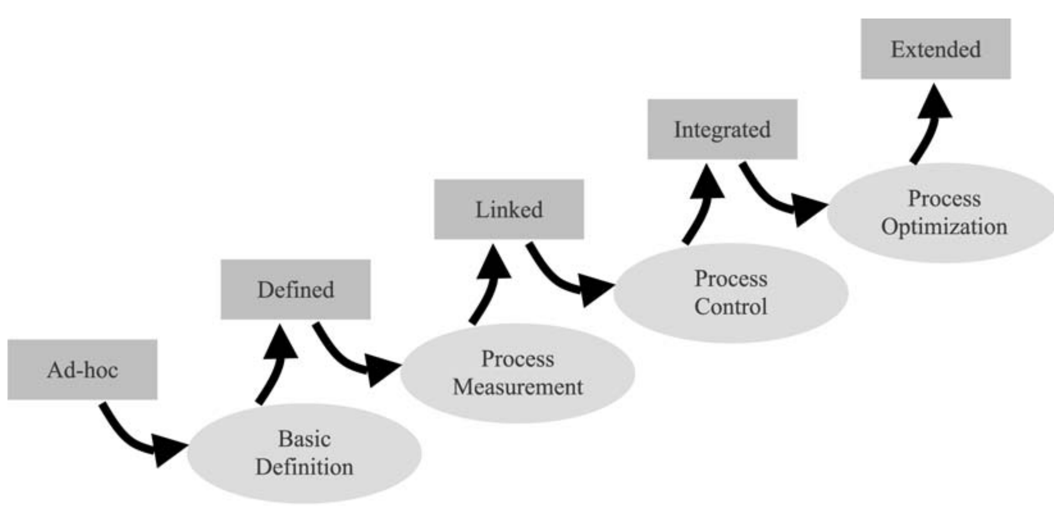
At the second level, defined, the supply chain's basic processes are defined and documented. There are very few organizational changes. Performance is more predictable. In order to overcome inter-functional problems, considerable effort is required, and costs remain high. Customer satisfaction levels improve but still remain low.

At the third level, linked, broad application of supply chain management (SCM) principles occurs. The organizational structures become more horizontally oriented through the assignment of authority over multiple functional units to "process owners". Cooperation among intra-organizational functions, suppliers and clients, are represented by teams that share measures and common objectives within the supply chain. These teams work on continuous improvement and root cause analysis resulting in performance improvements. Efficiency improves and customers become directly involved in improvement efforts focused on intra-organizational processes.

At the fourth level, integrated, the company, suppliers, and clients strategically cooperate at the process level. Organizational structures and activities are based on SCM principles and traditional tasks start to disappear and are replaced with broad activities in the expanded supply chain. Performance measurements for the supply chain are broadly deployed and collaboration is used in most activities. The process improvement objectives are assigned to teams and costs are drastically reduced. Client satisfaction, as well as team spirit, becomes a competitive advantage.

At the final level, extended, competition is based in multi-organizational supply chains. Multi-organizational SCM teams appear with expanded processes, recognized authority

Figure 2 Process maturity development stages



Source: Adapted from Lockamy and McCormack (2004) and objectives throughout the supply chain. Trust and interdependence build the support base of the extended supply chain. Process performance and trust in the extended system are measured. The supply chain is dominated by a client-focused horizontal culture. Investments in system improvements are shared, as well as the investment returns.

In summary, the model identifies the supply chain management activities that could improve a company's competitive supply chain performance.

In Figure 3, the maturity measurement questions are grouped into maturity variables, which have precedence (basic components not shaded and advanced components shaded) (Lockamy and McCormack, 2004). These variables, described in the call outs in Figure 3, are tactics and practices that have been shown, through earlier research, to lead to improved supply chain performance. The *X*-axis represents two major groupings of components: chassis and engine. Chassis Groupings, as with automobiles, provide the foundation for achieving process capability and predictability. Engine Groupings provide the power and control mechanisms for achieving higher performance levels and efficiency. Both are required in order to achieve sustainable maturity levels.

For example, the assignment of basic cross-functional process ownership in the Chassis Grouping sets the stage for the establishment of basic supply chain process measures in the Engine Grouping. This is the basic level of an innovative PMS system and its components have shown strong relationships to higher levels of performance (Lockamy and McCormack, 2004).

The scores at *Y*-axis in Figure 3 can reach a maximum value of 470 points, which comes from summing the scores gathered from the 94 questions in a five-point Likert scale (94 times 5 = 470).

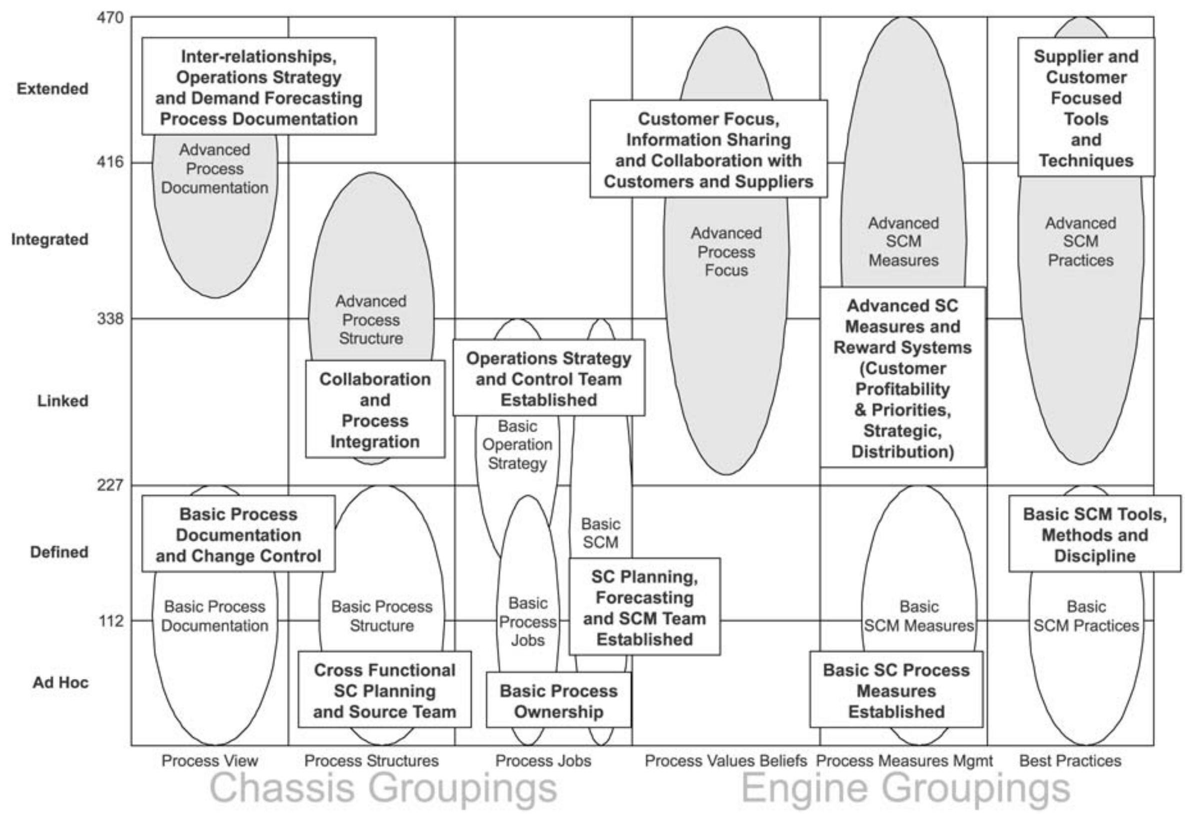
This self assessment model, using tools similar to Figure 3, provides a method for determining the maturity of an organization's supply chain processes and practices and suggests appropriate next steps to progress to the next maturity level.

Methodology and research results

This research used a self-administered survey based quantitative study using a sample of cross industry supply chain professionals from Brazilian companies. Brazil, with a population of 170 million and the fifth largest country after Russia, the USA, Canada and China, is a country with continental dimensions and with very dynamic manufacturing and services industry. Although Brazil is not a leader in the area of supply chain management, the country is significant in terms of internal markets and international trade. Therefore, there are many international world class supply chain service providers participating in different Brazilian economic sectors.

To reach the respondents, an electronic self-administered survey was conducted between January and February 2006 using a diversified sample composed of companies from

Figure 3 BPO maturity model and components (as applied to the supply chain)



Source: Lockamy and McCormack (2004)

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different economic sectors. This included manufacturing, construction, retail, graphics, mining, communication, information technology, utilities (gas, water and electricity) and distribution industries.

Instrument development

For the purpose of the development of the research instrument, a literature review on the subject of "performance management systems and maturity models" was first completed. Next, the model proposed by Lockamy and McCormack (2004) was used as a basis for the development of 85 variables. The model of Lockamy and McCormack used the SCOR model for the purpose of evaluation of four areas (Plan, Source, Make, Deliver), on a scale of 1 (poor) to 5 (excellent). Considering that in many companies the processes for return or reverse logistics are not a significant factor in their supply chain, this model does not include the "Return" area of the SCOR model in the assessment. For the purpose of the present research, the model of Lockamy and McCormack weights nine variables differently due to their appearance in different constructs, reaching a final set of 94 questions using a Likert five-point scale. Moreover, all variables means were normalized before running data analysis. Samples of the survey instrument are shown in the Appendix.

This maturity model was selected because it already contained detailed measures that had been tested and validated (Lockamy and McCormack, 2004; McCormack and Johnson, 2002). In addition, this self-assessment model has been used since 1998 to evaluate over one thousand companies in Europe, North America, China, and Australia. This model is also the only SCOR based, comprehensive model whose components' relationship to supply chain performance has been quantitatively tested, although not the model as a whole.

Since actual performance data is difficult to gather and compare between companies, this research used self-reported performance measures as the dependent performance variable. The use of this approach has been validated in several previous research studies in organizational self-assessment and business management and has been shown to be a reasonably accurate measure of comparative performance (Gupta *et al.*, 2000; Teo and Dale, 1997; Kumar *et al.*, 1993; Kumar and Stern, 1993; Seidler, 1974).

The questions were translated into Portuguese by the researchers and the translations were tested using various test subjects. Adjustments were made as needed until the translations were deemed valid.

The survey was conducted using the internet. The data collection instrument was constructed using PHP language and MySQL database. The instrument displayed answer choices using a selection box, radio buttons and free text fields.

Pre-test and sample

Since this was the first use of the model in Brazil, the first phase of data collection was a pre-test used to validate the translated instrument and to calculate the recommended sample size for final data collection. For a pre-test sample, the questionnaire was given to a group of 30 respondents representing companies from diverse segments. Translated questions were adjusted as needed based upon feedback from this group. The basic relationships predicted by earlier research (Lockamy and McCormack, 2004) were examined in the pre-test sample. These relationships were validated both in direction and magnitude.

Using the data from this pilot sample, an estimate of the population variance was calculated using the maturity levels of each respondent. The calculation of the final sample used a reliability level of 95 per cent and an error "E = 9,4". The pre-test standard deviation was 77,40. The recommended size for the final sample was then determined by using the formula below (Anderson *et al.*, 2002):

$$n = \frac{(z_\alpha)^2 \sigma^2}{E^2} = \frac{(1,96)^2 77,4^2}{9,4^2} = 261 \text{ respondents}$$

With the recommend sample size of 261 respondents and the instrument validated, the final sample was collected. This consisted of professionals from companies associated with IMAM at the time in which the research was held. IMAM, with a membership of 2500, is a highly recognized logistics education and consultancy institution in São Paulo, Brazil. The IMAM mailing list included the following industries: manufacturing firms; construction firms; retail businesses; graphic industries; extractive firms; communication and IT providers; gas, water and electricity productive facilities and distribution services.

Data preparation

A total of 534 surveys were received for a response rate of 21.4 per cent. The first step in data preparation was analysis and treatment of the missing data within the returned surveys. As Hair *et al.* (2005) suggests for the first level of purification, all the questionnaires that had more than 15 per cent missing data were excluded from the sample. This resulted in 479 remaining surveys of the initial 534.

Of the 479 remaining cases, only 17 still had missing data. More than 50 per cent of these had up to three variables missing out of the 94 questions used on the analysis. In accordance with Hair *et al.* (2005), a *t*-test was executed. This test evaluates the difference of the means between two groups in order to determine if the missing data patterns are random. The conclusion was that the occurrences were completely random making it possible to use substitution methods for the missing data (Hair *et al.*, 2005). The final sample size was 478 valid surveys, excluding one response that was considered as an outlier.

Next, variables for the constructs were generated. The maturity construct variables (McCormack *et al.*, 2003), M_Maturity, were generated using the sum of the 94 questions for each case. The M_Maturity variable was then used to evaluate the level of maturity for the sampled companies and test the relationships to performance.

Data analysis

Frequency distribution profiles of the respondents were then examined. As shown in Table II, 62.6 per cent of the respondents in the sample held, at the time of this research, managerial or executive positions in their respective companies. This was found to be representative of the positions within supply chain management and no position bias was indicated.

In total, 20.7 per cent of the respondents were in Distribution followed by Planning and Scheduling, Sales, Manufacturing and others.

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Table II Position by the respondents

	Position	Frequency Abs.	(%)	Valid percent	Cumulative percent
Valid	President	17	3.6	3.6	3.6
	Director	72	15.1	15.1	18.6
	Manager	210	43.9	44.9	62.6
	Consultant	59	12.3	12.3	74.9
	Practitioner	115	24.1	24.1	99.0
	Not informed	5	1.0	1.0	100.0
	Total	478	99.0	100.0	
Total		478	100.0	100.0	

Source: Research data

A total of 49.2 per cent of the respondents were from transformation industries, followed by transport, storage and communications, each with approximately 16 per cent.

In total, 50.4 per cent were located in São Paulo. The rest were from the states of Minas Gerais, Rio Grande do Sul, Paraná, Rio de Janeiro and Santa Catarina. This geographic concentration in the response set reflects the import/export, manufacturing and supply chain centers of Brazil and therefore no geographic bias was evident.

The maturity of the companies, M_Maturity, was then examined. The sample had a mean of 323, with a standard deviation of 72 points (Table III).

The distribution of maturity scores by maturity level, using the McCormack *et al.* (2003) model, is shown in Table IV. The participants were mainly levels 3 and 4 maturity but all levels were represented and were consistent with the earlier research using the model.

Table III Descriptive statistics for costs, services, overall performance and maturity

Statistics	**Variable M_Maturity**
N	478
Mean	323.66
SD	72.085
Skewness	-0.680
Skewness std. error	0.112
Kurtosis	0.549
Kurtosis std. error	0.223
95 per cent confidence interval for mean	317.19-330.14

Source: Research data

Table IV Frequency distribution by maturity levels

Maturity level	**Minimum score required (points)**	**Frequency (%)**
Level 5 extended	416	6.1
Level 4 integrated	338	40.8
Level 3 linked	227	44.4
Level 2 defined	112	7.5
Level 1 ad hoc	94	1.3

Source: Research data

Performance scores for the main areas of the SCOR (Plan, Source, Make and Deliver) were examined next. This variable used a Likert scale of five-points ranging from 1 = completely disagree to 5 = completely agree. The respondents were asked if their performance in each SCOR process area could be considered superior when compared to its competitors. These results are reported in Table V.

Although all performance means in the main areas of the SCOR were located between 3 and 4, when comparing the statistical difference between means by using t-test (using the superior value of Overall Make Performance as reference – 3.59), the only mean that had a statistical difference was the Plan area (Table VI). This could indicate less of a focus of the companies on the planning function, compared to Source, Make and Deliver.

As shown at the Table VII, 84.7 per cent of the companies had rated their performance equal or superior to that of their main competitors.

Based on the survey responses, the mean of the sum of the scores in each grouping (Figure 4) was calculated and converted into the percentage of fulfillment. For example, if the basic process documentation component has a total possible score of 25 (five questions × five points maximum per question), and the calculated score mean for the respondents under study is 18,69, then the oval shown for this component would be 74,76 per cent filled (Figure 4). This technique provides the powerful visual score card of the current situation and areas of opportunity.

Each of the 12 groupings of maturity model structural components (McCormack *et al.*, 2003), as shown in Figure 4, had an average score that ranged between 58.67 per cent for Advanced SCM Practices and 74.76 per cent for Basic SCM Practices.

Considering the visual positioning of each grouping of components within each maturity level of the model, it is possible to conclude that, normally, the groupings of components located at the lower levels of maturity (Ad Hoc and Defined) will have slightly higher averages than those located in higher levels of maturity. This suggests precedence or a tendency for the companies to focus on its basic practices before the advance practices. This conforms to the structure of the BPO maturity model in regards to basic and advance practices.

Correlation analysis between the performance and maturity constructs

In order to answer the research question, "What is the relationship between supply chain processes maturity and performance?", as illustrated in Figure 5, test were run using the Spearman correlation coefficient.

Table VIII shows the results of examining the relationship between performance of the main areas of the SCOR – Plan, Source, Make and Deliver – with M_Maturity by using the Spearman Correlation Coefficient. Results indicated a positive, strong and highly significant correlation in all cases.

As the correlations between constructs indicates, the null hypothesis, an absence of a statistically significant association between the levels of maturity and performance, can be rejected. The supply chain processes maturity of the companies in the study and performance has a strong and

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Table V Performance descriptive statistics of SCOR areas

Statistics	Data	Overall plan performance	Overall source performance	Overall make performance	Overall deliver performance
N	Valid	478	478	478	478
	Missing	0	0	0	0
Mean	3.45	3.58	3.59	3.56	
SD	0.999	0.947	1.016	1.042	
Skewness	−0.561	−0.567	−0.610	−0.566	
Skewness std. error	0.112	0.112	0.112	0.112	
Kurtosis	0.048	0.276	0.093	−0.103	
Kurtosis std. error	0.223	0.223	0.223	0.223	

Source: Research data

Table VI *T*-test for mean comparison

	Test value = 3.59				95 per cent confidence interval of the difference	
Performance	*T*	df	Sig. (two-tailed)	Mean difference	Lower	Upper
Plan	−3.094	477	0.002	−0.141	−0.23	−0.05
Source	−0.166	477	0.868	−0.007	−0.09	0.08
Make	−0.083	477	0.934	−0.004	−0.09	0.09
Deliver	−0.643	477	0.521	−0.031	−0.12	0.06

Source: Research data

Table VII Frequency distribution of performance by SCOR areas

Performance score from Likert scale	Plan (%)	Source (%)	Make (%)	Deliver (%)
1 = very poor	5	3.3	4.4	4.6
2 = poor	10.3	7.5	8.6	10.3
3 = equal	31.8	31.8	28.9	28.5
4 = superior	40.8	42.3	40.6	38.7
5 = very superior	12.1	15.1	17.6	18.0

Source: Research data

positive relationship thus confirming the hypothetical model purposed in this study.

Interrelationship analysis with structural equation modeling

In order to better understand the relationship of the model as a whole between performance and maturity, the PLS algorithm was used. Partial Least Squares (PLS) regression is a multivariate data analysis technique, which can be used to relate several response (*Y*) variables to several explanatory (*X*) variables. The method aims to identify the underlying factors, or linear combination of the *X* variables, which best model the *Y* dependent variables. PLS can deal efficiently with data sets where there are very many variables that are highly correlated and involving substantial random noise. PLS is primarily intended for causal-predictive analysis in situations of high complexity but low theoretical information (Jöreskog and Wold, 1982)

The test was applied according to SCOR areas using maturity as a formative construct composed of the sum of the indicators of maturity for Plan, Source, Make and Deliver impacting the performance construct which was created by summing the overall performance indicators of Plan, Source, Make and Deliver areas.

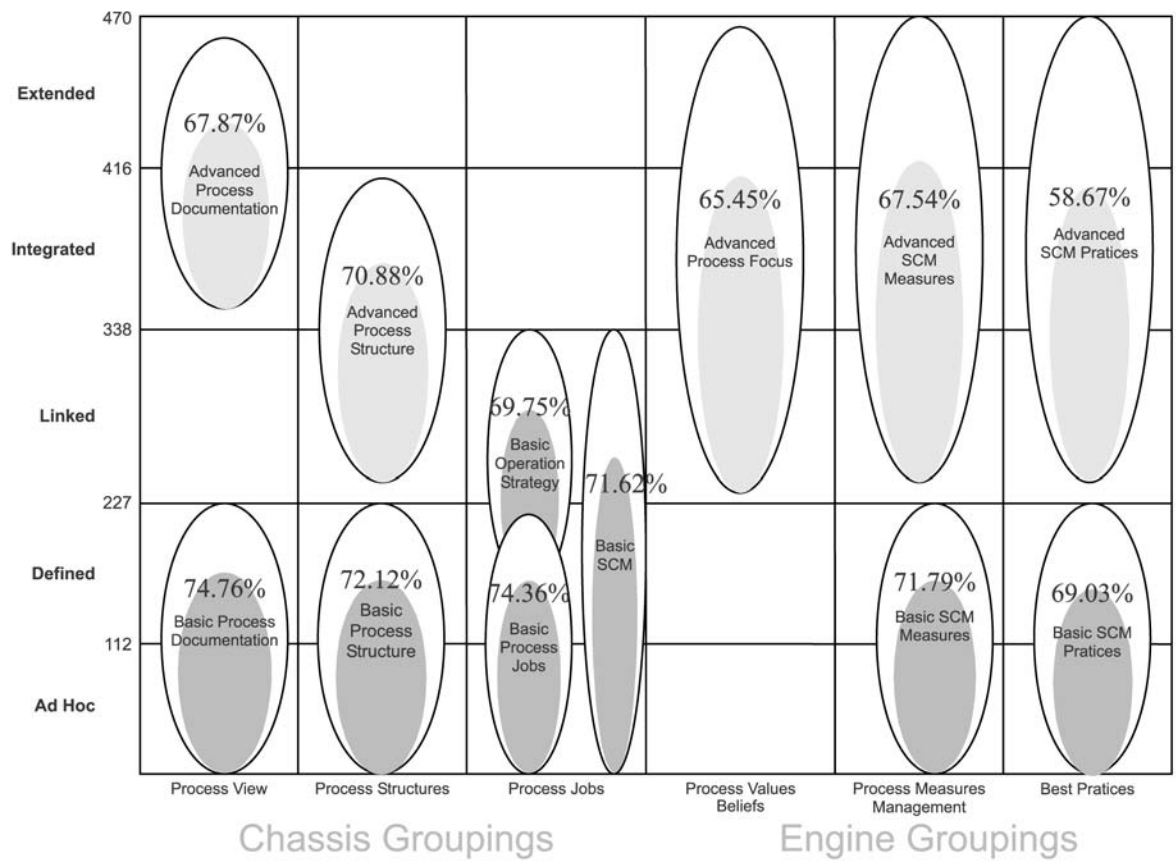
After running the PLS algorithm, the following model converged at the eighth iteration cycle resulting in the weights and loadings shown in Figure 6. Additionally, the result of analyzing the path coefficient, the correlation between the maturity and performance variables, was an expressive value of 0.8592. This value corroborates previous research results showing a strong relationship between maturity and performance of the supply chain processes (Lockamy and McCormack, 2004).

When the construct of maturity was examined, the Deliver area had a significantly higher coefficient than the others areas (0.574). These results suggest that maturity indicators for Deliver have a greater impact on performance than the other SCOR areas. This might be explained by the emphasis normally given by supply chain practitioners and academics in Brazil to logistics and transportation compared with other activities in the supply chain. The strong influence of Deliver activities can also be seen in the resulting equation for performance using the indicators for the maturity model construction:

$$\text{Performance} = \text{Deliver}(0.5741) + \text{Make}(0.1936) + \text{Plan}(0.2653) + \text{Source}(0.0535) + \zeta$$

It is important to mention that, in spite the fact that this equation explains about 73.83 per cent of the performance results, it is proposed only to illustrate the weights of each SCOR area over the performance results.

Figure 4 Mean percentage of total component scores



Source: Research data

Figure 5 Relational model of performance and maturity

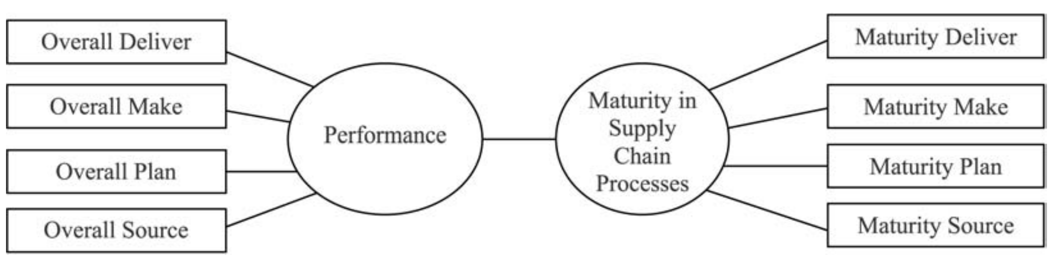


Table VIII Spearman correlation coefficient – SCOR area Performance vs M_Maturity

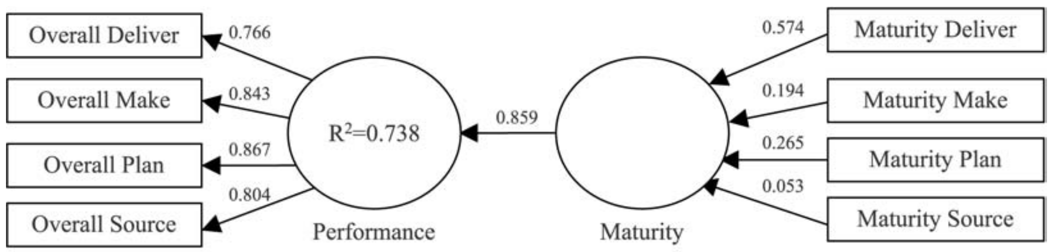
Pair of variables	Spearman correlation coefficient
Plan performance vs M_Maturity	0.733(**)
Source performance vs M_Maturity	0.639(**)
Make performance vs M_Maturity	0.718(**)
Deliver performance vs M_Maturity	0.595(**)
Sample size = 478	

Note: ** Correlation is significant at the 0.01 (two-tailed)
Source: Research data

Analyzing the quality indicators of the model (Table IX), it is possible to conclude that all results showed good scale adequacy, i.e. the model was well adjusted, providing a good representation of the performance variables.

In summary, these results suggest that there is a strong and positive correlation between maturity and performance of the supply chain processes. Additionally, 73.83 per cent of the performance results can be explained by using maturity indicators. This means that if companies use maturity indicators in order to direct and measure improvement in its processes, it will most likely generate a positive impact on performance. This result also contributes to the use of maturity models in research on supply chain processes by

Figure 6 Maturity and performance results



Source: Research data

Table IX Scale quality indicators for the performance construct

AVE	0.6741
Composite reliability	0.892
***R*-square**	0.7383
Cronbach's alpha	0.8381
Redundancy	0.4971

Source: Research data

confirming the practical performance results acquired from its implementation and use.

Conclusions

Supply chain processes, as well as other kinds of processes, demand assessment and management models geared towards actions resulting in improvement and measurement of results or impacts of these actions. Quantifying its supply chain maturity and performance levels using a maturity model, clearly an innovative PMS, represents an opportunity for a company to solidify and align its performance measurements and process improvement actions with its competitive strategies.

This research suggests that measurement and performance systems, in the form of maturity models developed from an innovative PMS perspective, can significantly contribute to the theory and practice of supply chain management. As for supply chain processes, use of self administered maturity models, along with the implementation of the changes that lead to the higher levels of maturity prescribed by the models, supported by the use of process frameworks such as SCOR, can be a valuable input into supply chain strategies.

Many maturity models currently applied to the supply chain use SCOR as a way of organizing and classifying the processes and metrics enabling an evaluation system focused on adding value to the customer. These cross-functional process measurements also stress continuous improvement, accountability and commitment resulting in improvements for short and long-term results.

Maturity models, supported by SCOR, enable access to a complete process definition and measurement system that, by implementing the model, can help a company to improve its performance by looking for a superior maturity level in its supply chain processes. In addition, a complete measurement system is essential in improving companies' supply chain process performance and supply chain management practices, including supply chain orientation (Huan *et al.*, 2004; De Toni and Tonchia, 2001).

From the point of view of corporate leadership, maturity models have broad application, in that they emphasize performance measurement and continuous process improvement in whatever process or activities involved. The maturity models are valuable support tools for corporate leadership, specifically the leadership of the supply chain processes, in terms of determining the actual stage of maturity, setting the goals for the next level of maturity and performance and identifying precedence and the items considered more critical to implement so that the companies can focus their resources.

Future research

Following are questions for future research:

- what are the main barriers that must be overcome by companies when they decide to apply any maturity model oriented to the control and improvement of supply chain process?
- is there a precedence of improvement activities in a maturity model beyond the basic and advance categories indicated in this research?
- how can a maturity model be used as a standard to analyze different companies from the same branch or from the same supply chain?
- what are the costs involved in the planning and implementing of maturity models in the supply chain?

Answers to such questions can contribute significantly to the practical use of maturity models. At the present time, there is not a model able to properly synthesize all the complexities typically encountered in the management of supply chain processes in the wider context of supply chains (extended supply chains or supply chain networks), although efforts are being aimed at improving and extending the individual performance evaluation systems of the companies into suppliers, distributors and customers.

Therefore, research is continuing on developing new and improved maturity models that can contribute to the principle of continuous improvement in a supply chain that is truly integrated across company boundaries. In the future, it is predicted that certifying a company's level of maturity, according to the level of their supply chain process maturity, will gain relevance, similar to total quality and certifying professional and services of IT. In addition, as discussed by McCormack and Johnson (2002), evaluating and certifying a supply chain network's maturity level will be a new frontier in the use of cross company maturity models. In this sense, momentum is building for the broad use of benchmarking and other different measurement systems geared towards the continuous improvement of planning, supply, manufacture and distribution processes, translated into more robust and imposing levels of process maturity for firms and supply chains.

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Appendix. A sample of questions used in the survey instrument

Table AI

Please circle your answer concerning this supply chain decision process are using a range of: 1 = never or does not exist; 2 = sometimes; 3 = frequently; 4 = mostly; 5 = always or definitely exists. Please put an "X" on any question you are unable to answer					
Decision process area: PLAN					
Includes P1: Plan supply chain, and P0: Plan infrastructure					
Do you have an operations strategy planning team designated?	1	2	3	4	5
Do you have a documented (written description, flow charts, etc.) operations strategy planning process?	1	2	3	4	5
Does the team have supply chain performance measures established?	1	2	3	4	5
Does the team look at the impact of their strategies on supply chain performance measures?	1	2	3	4	5
Do you have a documented demand forecasting process?	1	2	3	4	5
Decision process area: SOURCE					
Includes P2: Plan source					
Are the supplier inter-relationships (variability, metrics) understood and documented?	1	2	3	4	5
Do you share planning and scheduling information with suppliers?	1	2	3	4	5
Do you "collaborate" with your suppliers to develop a plan?	1	2	3	4	5
Do you measure and feedback supplier performance?	1	2	3	4	5
Decision process area: MAKE					
Includes P3: Plan make					
Are your planning processes integrated and coordinated across divisions?	1	2	3	4	5
Are supplier lead times a major consideration in the planning process?	1	2	3	4	5
Are you using constraint-based planning methodologies?	1	2	3	4	5
Is shop floor scheduling integrated with the overall scheduling process?	1	2	3	4	5
Do you measure "adherence to plan"?	1	2	3	4	5
Does your current process adequately address the needs of the business?	1	2	3	4	5
Is your customer's planning and scheduling information included in yours?	1	2	3	4	5
Decision process area: DELIVER					
Includes P4: Plan deliver					
Do you track the percentage of completed customer orders delivered on time?	1	2	3	4	5
Are the customer's satisfied with the current on time delivery performance?	1	2	3	4	5
Do you meet short-term customer demands from finished goods inventory?	1	2	3	4	5
Do you "build to order"?	1	2	3	4	5
Do you promise orders beyond what can be satisfied by current inventory levels?	1	2	3	4	5
Do you maintain the capability to respond to unplanned, drop-in orders?	1	2	3	4	5
Do you measures "out of stock" situations?	1	2	3	4	5
Can rapid re-planning be done to respond to changes?	1	2	3	4	5

Note: For a full version of the questionnaire, please contact the authors

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