QUALITY PAPER

An innovative maturity model to assess supply chain quality management

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Abstract

Purpose – This paper aims to present and discuss an innovative maturity model (MM) to assess supply chain quality management (SCQM). The SCQM MM can be used to guide organizations in the development and improvement of quality in their supply chains (SCs). Additionally, this paper intends to better understand that integration and its impacts on organizational performance.

Design/methodology/approach – The proposed MM was developed based on an exhaustive literature review of the most relevant MMs developed in the areas of quality management, supply chain management and other relevant domains.

Findings – The proposed MM consists of a matrix with 100 criteria organized in five organizational dimensions and five maturity levels, embracing the most relevant SC issues and describing a progressive path towards a state of full maturity.

Originality/value – It is an innovative tool useful for both academic experts and practitioners to integrate quality management across the SC, thus promoting and improving organizational performance from an integrated and sustainable perspective.

Keywords Supply chain quality management (SCQM), Supply chain management (SCM), Quality management (QM), Maturity model, Integration

Paper type Research paper

1. Introduction

In recent years, the market has been characterized by a globalization trend and a dynamic competitive environment. To face the new challenges arising, companies are led to establish strategic partnerships with customers, suppliers and other business partners in order to guarantee their competitiveness and sustainability. In this scenario, business competition is gradually passing from the company level to the supply chain (SC) level, and issues related to quality performance and integration of processes are becoming more and more important in the SC context (Fish, 2011; Zhong *et al.*, 2016; Mahdiraji *et al.*, 2012; Mellat-Parast, 2013; Zhang *et al.*, 2017).

Indeed, the growing competition, globalization of economies and the need to increase the competitiveness of organizations through operational efficiency, promote new opportunities and challenges in the management and organization of the entire SC. Thus, supply chain management (SCM) appears as an essential tool for competitive advantage in the market, since it allows the development of a link between the market, the distribution network, the production process and procurement activities and offering customers a service of excellence at a low cost.

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As companies' SC integrate more and more stakeholders from several suppliers, partnerships, customers, internal suppliers and internal customers, among others, this leads to more information and material flows all along the SC. The SCM extends the concept of integrated management to all organizations involved in the process, both upstream and downstream, i.e. from suppliers of raw materials to end customers.

Furthermore, considering that customers are becoming more demanding, they are increasingly looking for companies that meet their needs in terms of products/services, and companies that can indeed outweigh their expectations. Thus, quality management (QM) influences the performance of companies and customer satisfaction and other stakeholders.

The understanding of how SCM and QM are related in a particular organization and the impact that this integration has on the organizational performance is still very limited (Arawati, 2011; Dellana and Kros, 2015; Huo *et al.*, 2014; Mahdiraji *et al.*, 2012; Ramos *et al.*, 2007; Zeng *et al.*, 2013). In this way, and concerning all business partners' competitiveness involved, SCM and QM have an important role, since both are complementary approaches aiming to enhance customer satisfaction and organizations' competitiveness (Mahdiraji *et al.*, 2012; Talib and Rahman, 2010).

Some authors have been exploring the relationship between SCM and QM approaches, investigating their conceptual similarities, potential synergies and the positive effects that their integration can bring regarding the competitiveness of the SC partners (Chibba, 2017; Soares *et al.*, 2017; Talib and Rahman, 2010; Zhang *et al.*, 2017). This integration can be translated by the concept of supply chain quality management (SCQM), which has become an emergent research field during the last few years (Foster, 2008; Soares *et al.*, 2017).

The research on SCQM has embraced three main broad strands: the definition of the SCQM concept, SCQM practices and its impact on organizational performance (Soares *et al.*, 2017). However, no framework has been found yet to assess the implementation of the SCQM concept. To fill out this gap in the literature, this paper intends to use the concept of maturity in this field by proposing a model to assess the maturity level of SCQM in the organization and, at the same time, by providing guidelines to know which practices must be implemented in order to reach higher levels of maturity.

Maturity models (MM) can be used to highlight the best practices and identify areas for improvement. In addition, maturity levels can help the process of development representing objectives and giving guidelines to what the organization must do to achieve such objectives. Thus, MM are particularly useful and relevant to assess processes that are new in the organizations.

The SCQM maturity model (SCQM-MM) presented and discussed in this paper is based on the conceptual model developed by Fernandes *et al.* (2017a), and it was developed after and based on a research and development partnership with a multinational company from the automotive industry with the intention to develop and implement the SCQM concept. The main goal of this model was the integration of QM along with the SC, as none was found in the literature. Another goal was developing a tool for evaluating processes efficiency and maturity in a clear and efficient perspective. Thus, the research aim of this study was focused on designing the dimensions, criteria, structure and architecture of a MM regarding the interrelated perspective of SCQM.

The SCQM-MM proposed in this paper is a self-assessment framework, to be used by an organization in order to position itself according to five levels of maturity. Besides this SCQM-MM is a theoretical development, this paper also presents some practical implications as a tool to help improvement areas definition, considering both concepts of SCM and QM and their integration.

The remaining of the paper is organized as follows. After this introductory section, Section 2 presents the literature review carried out to support the model developed, exploring the SCQM concept and the existing MMs developed in QM, SCM, information management and other

relevant areas. Then, Section 3 presents the SCQM-MM that was developed. Finally, Section 4 summarizes the main conclusions of this paper and highlights opportunities for further research.

2. Literature review

2.1 The supply chain quality management concept

In today's market, one can state that "*it is no longer business versus business, but rather supply chain versus supply chain*" (Fish, 2011), and in the same line, the term "*my quality*" must be replaced by "*our quality*" (Mahdiraji *et al.*, 2012). This means that, while organizations are facing new challenges, their survival depends on how they expand their vision outside their internal boundaries and see suppliers, customers and the other parties of the SC as strategic business partners. In this way, SCM and QM have become two of the most important strategies to achieve competitive advantage in the global market (Sila *et al.*, 2006; Talib *et al.*, 2011).

The SC is defined as the global network of firms, activities, material and information, which are used to deliver products and services, from the extraction of raw materials until the end-user (Seuring and Müller, 2008). In turn, SCM consists of integrating and synchronizing all the internal and external operations of the SC, in order to deliver the right product, in the right quantities, at the right time, to the right location, seeking to fulfil the end customer demands (Fish, 2011; Mellat-Parast, 2013; Xu, 2011). According to the Supply Chain Operations Research model (SCOR), SCM activities can be summarized in six main processes – *Plan, Source, Make, Deliver, Return* and *Enable* (APICS, 2017). SCM has been regarded as a major inter-organizational practice for gaining competitive advantage as it intends to improve the efficiency of the SC activities, putting SC partners working together in order to reduce costs, improve flexibility, enhance quality and ensure customer satisfaction (Fish, 2011; Mellat-Parast, 2013).

Besides delivering the right product, the organization must ensure that it is in conformity with the customer needs and expectations and with the design requirements. For that reason, quality is becoming an issue of greater importance in the SC context (Zhong *et al.*, 2016).

QM involves a set of practices whose core task is to assure that the organization has the capacity to provide high-quality products, i.e. products able to fulfil (and exceed) the customer needs and expectations. As a management philosophy, QM has known great developments since the beginning of the 20th century, with the appearance of mass production. While it was firstly focused on the final product, quality now addresses the whole organization as a complex system with many processes and mutual relationships that have to be managed and continuously improved (Weckenmann *et al.*, 2015). Following the International Organization for Standardization (ISO) survey of 2016, the ISO 9001 (requirements for a Quality Management System) is by far the most implemented ISO standard around the world (ISO, 2017), which reflects the recognition by organizations from all sectors of activity, that quality has become a relevant strategic factor concerning sustainability and competitiveness.

As can be verified, QM and SCM are two management approaches that, despite being based on different methodologies, pursue the same goals: enhancing customer satisfaction and promote the organization competitiveness (Mahdiraji *et al.*, 2012; Talib and Rahman, 2010). Furthermore, the establishment of QM practices allows to reduce process variability, directly impacting on the SC performance and resulting in better product quality and customer service (Chibba, 2017; Fish, 2011; Talib *et al.*, 2011).

Following this line of thought, several authors argued about the integration between SCM and QM approaches as a natural evolution process, in order to take advantage of the synergies and improve the overall competitiveness of the SC parties (Fish, 2011; Zhong *et al.*, 2016; Mellat-Parast, 2013; Talib and Rahman, 2010). Such integration can be translated by the

concept of SCQM, which can be understood as an extension of the SCM approach through the application of QM practices and tools in order to improve quality aspects on the entire SC (Quang *et al.*, 2016; Soares *et al.*, 2017).

Some studies related to the integration of SCM and QM have been published, where researchers study differences and similarities between both concepts and proposed various frameworks related to SCM and QM integration (Fernandes *et al.*, 2017a; Rashid and Haris Aslam, 2012; Robinson and Malhotra, 2005; Sharma *et al.*, 2012; Vanichchinchai, 2019; Vanichchinchai and Igel, 2009). In an attempt to explore the integration between QM and SCM, Fernandes *et al.* (2017a) identified the key SCM and QM dimensions that have a relevant impact on organizational performance, considering the Balanced Scorecard perspectives. The work developed in this paper is based on Fernandes *et al.* (2017a). Thus, as shown in Figure 1, a conceptual model was proposed where five dimensions were identified as common dimensions to both SCM and QM, supporting the integration concept of SCQM. Moreover, other specific dimensions were also identified related to SCM and QM, respectively.

Based on this model, it is possible to understand that collaboration and information sharing are key pillars for the success of the SCQM concept. Plus, for a successful and long-lasting integration concept, the achievement of a sustainable performance is required. Therefore, on both SCM and QM, sustainability is crucial to ensure long-term profitability and performance, by promoting robust collaborations between suppliers and customers, reducing costs and environmental impacts (Fernandes *et al.*, 2017a; Seuring and Gold, 2013).

2.2 Maturity models

Maturity can be defined as the current state of a specific process, area or domain of an organization, as it passes through an evolutional path with several stages of learning, being related to the extent to which the process is explicitly defined, managed and controlled (Archie and McCormack, 2004). As the level of maturity increases, the knowledge and capacity of solving problems about the process increase as well (Dale and Lascelles, 1997; Domingues *et al.*, 2016; Fraser *et al.*, 2002). According to McCormack *et al.* (2009), higher levels

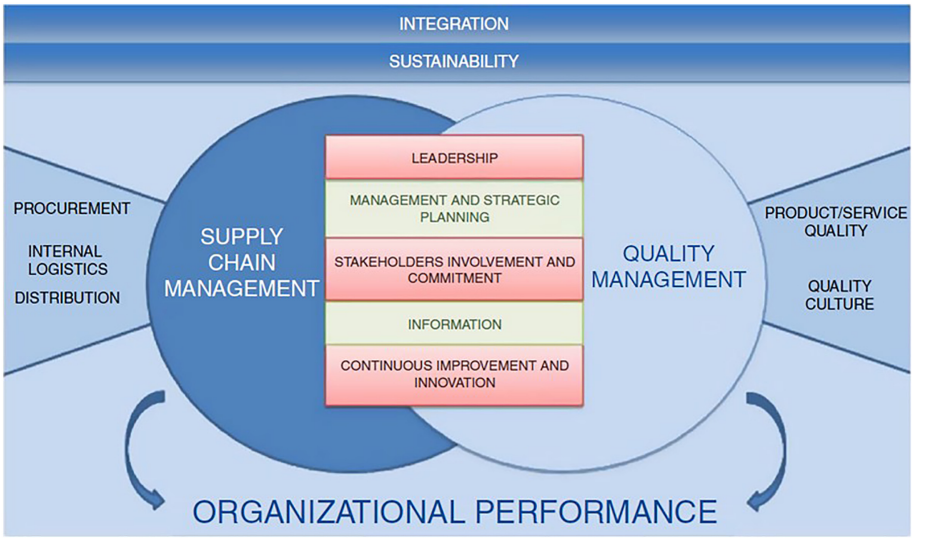


Figure 1.
SCQM conceptual model

Source(s): Fernandes *et al.*, 2017a

of maturity in any business process allows to achieve greater effectiveness and better control of results, to improve the forecast of goals, costs and performance and to improve the managers' ability to propose more ambitious targets of performance.

The maturity can be assessed through the systematic use of a MM, positioning the company's current practices against a maturity scale (Bititci *et al.*, 2015). A MM consists of a matrix that describes the typical behaviours and practices that should be implemented to reach a certain maturity level (Bititci *et al.*, 2015), and its essential components can be enumerated as: (1) maturity levels; (2) organizational dimensions/domains; (3) attributes/criteria; (4) appraisal and scoring methods; and (5) improvement roadmaps (Caralli *et al.*, 2012).

These can also be divided into different groups according to the followed approach:

(1) Maturity grids encompass a brief description of each maturity level of an activity. In this case, the higher the number of maturity levels, the more difficult it is to describe each activity at each level (Fraser *et al.*, 2002). A simple description with the typical behaviour and features related to each maturity level are presented, explaining what is expected in each one (Domingues, 2013; Fraser *et al.*, 2002; Lahti *et al.*, 2009).

(2) CMM-like models are characterized by a formal and particular architecture, and each process area has common features to reach defined goals. In this case, there are no individual descriptions for each activity at each maturity level but only global descriptions of maturity for each level focusing on the improvement of processes (Fraser *et al.*, 2002).

(3) Situational MMs consider the organizations' design giving a static view of the organization (Mettler and Rohner, 2009).

(4) The Likert-type questionnaire is a tool to assess the maturity level in which a set of good practices, questions or achievements are listed and divided into several areas aiming to characterize the current status of a firm or organization. The respondent scores each statement according to the performance of the organization through a Likert scale, in which the "strongly agree" answer in the Likert scale corresponds to the high maturity level (Fraser *et al.*, 2002). In these cases, threshold values or turning points should be determined to easily find the maturity level (de Oliveira *et al.*, 2011; Kwak and Ibbs, 2002; Oliveira *et al.*, 2012).

(5) Hybrids models are a mix of questionnaire and maturity definitions. They describe the maturity levels but not the activities that should be performed (Fraser *et al.*, 2002).

In a simple way, the general purpose of a MM is to provide guidelines to be followed by an organization through a progressive and evolutional path, in order to reach a desired level of maturity. These models have been developed in several domains in order to help organizations to gain and retain competitive advantage, providing an evaluative and comparative basis for improvement, and helping an organization to increase its capabilities to operate in a specific area (de Bruin *et al.*, 2005). Table 1 presents a summary of some known MMs available in the literature, in terms of the number of levels that each model has and how they are designated, and some brief notes regarding each.

Considering the objectives the present research work, most relevant MMs and assessment frameworks were selected regarding the following subjects for the target domains: QM (Crosby, 1979), SCM (de Oliveira *et al.*, 2011; Lahti *et al.*, 2009), Sustainability (Baumgartner and Ebner, 2010; Cagnin *et al.*, 2005; Carter and Rogers, 2008; Seuring and Müller, 2008), and Information and Technology Management (Geissbauer *et al.*, 2016; Lichtblau *et al.*, 2015). However, as no MM was found only regarding the specific area of SCQM, the mentioned MM allowed the design and supported the structure of the model proposed in this paper.

Maturity model	Authors	Levels	Notes
Quality grid	Crosby (1979)	(1) Uncertainty (2) Awakening (3) Enlightenment (4) Wisdom (5) Certainty	First MM; six measurement categories
Total quality management (TQM)	Dale and Lascelles (1997)	(1) Uncommitted (2) Drifters (3) Tool pushers (4) Improvers (5) Award winners (6) World class	Evaluation of the level of commitment and efforts on the implementation of TQM throughout six levels. Qualitative and quantitative general characteristics on each level
Capability maturity model for Software (CMM^{SM})	Paulk *et al.* (1993)	(1) Initial (2) Managed (3) Defined (4) Quantitatively managed (5) Optimizing	Utilization to improve processes through continuous representation (evaluation of process areas individually) or staged representation (measurement of the entire organization)
Project management	Kwak and Ibbs (2002)	(1) *Ad hoc* (2) Planned (3) Managed at project (4) Managed at corporate (5) Continuous learning	Process maturity evaluation through nine knowledge areas. Utilization of questionnaire divided into three main sectors
Business process orientation	Archie and McCormack (2004)	(1) *Ad hoc* (2) Defined (3) Linked (4) Integrated	Strategic view of the processes. Characteristics for each level
Supply chain management	Lahti *et al.* (2009)	(1) *Ad hoc* (2) Defined (3) Linked (4) Integrated (5) Extended	Quantitative evaluation using a questionnaire and a Likert-point scale to evaluate one hundred twenty-eight questions
Supply chain process management	de Oliveira *et al.* (2011)	(1) Foundation (2) Structure (3) Vision (4) Integration (5) dynamics	Dendrogram with thirteen groups spread by the five maturity levels. Utilization of statistical analysis in order to evaluate ninety capability process indicators
Integrated management systems	Domingues (2013)	(1) Uncertainty (2) Awakening (3) Enlightenment (4) Wisdom (5) Certainty	Relationship between the variables and statistical analysis. Preliminary model based on Crosby's maturity grid and a pyramidal model version taking into account the key process agents, maturity levels and weighting

Table 1.
Known maturity models

(*continued*)

Maturity model	Authors	Levels	Notes
Logistics	Battista and Schiraldi (2013)	(1) Start up (2) Managed (3) Defined (4) Measured (5) Optimized	Four pillars and logistics areas to evaluate each area/sub-area/process in comparison with some expected achievements giving a maturity score for each one
Reverse logistics	"Waste not, Want not. Capturing the value of the circular economy through reverse logistics" (2016)	(1) Initial (2) Managed (3) Defined (4) Quantitatively managed (5) Optimizing	Maturity grid with dimensions and key components describing each level following a holistic approach

Table 1.

3. Supply chain quality management maturity model

3.1 Development of the maturity model

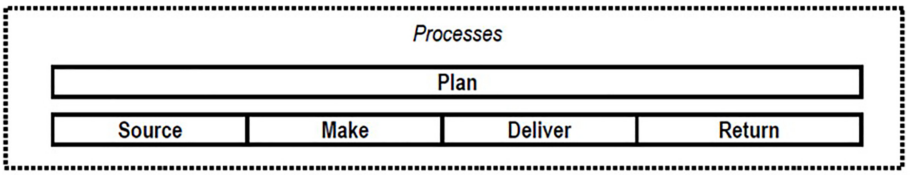
Based on the theoretical background given by the conceptual model of Fernandes *et al.* (2017a), a literature review was carried out focusing on SCQM topic and MMs research papers in order to identify the dimensions, criteria, the structure and architecture of a MM regarding the SCQM concept. To the best of the authors' knowledge, no MM in the literature was found specifically to assess the integration of QM along with the SC. This paper aims to present the MM developed, which is named Supply Chain Quality Management Maturity Model (SCQM-MM). The SCQM-MM was built based on different existing MMs from the areas of QM and SCM, and it also took into consideration the conceptual model developed by Fernandes *et al.* (2017a) and its dimensions. Fernandes *et al.* (2017b) show a first attempt to evaluate the maturity of SCM and QM integration.

The architecture of the SCQM-MM is represented in Figure 2. Summarily, the SCQM-MM is a matrix composed of 100 criteria (describing organizational characteristics, typical practices and behaviours), divided into 5 organizational dimensions and 5 maturity levels, which are described and explained in more detail in Sections 3.2 and 3.3, respectively. Each organizational dimension is divided into four sub-dimensions, related to a more specific set of characteristics assessed in the respective dimension. Each sub-dimension has five criteria associated, each one demonstrating a higher maturity level than the previous one. As can be seen in Figure 2, taking "OP1" as a sub-dimension of the "Organizational Performance" dimension, there will be criteria related to OP1 sub-dimension on Level 1 (*Ad Hoc*), a more mature criteria on Level 2 (Basic), and so on, until Level 5 (Mature). In this way, each sub-dimension describes a specific evolutional path across the five maturity levels, which is the basis for the assessment and scoring method (described in Section 3.4).

Furthermore, the mentioned evolutional path across the maturity levels also provides guidance on the how and what should be the following developments regarding both the sub-dimensions and the overall dimension itself. The developed SCQM-MM is presented in Appendix.

3.2 Organizational dimensions

Regarding the organizational dimensions of the model, the main dimensions of the SCQM-MM are (1) Organizational Performance, (2) Quality Management, (3) Information Management, (4) Supply Chain Integration, and (5) Sustainability. In the next paragraphs, a brief description of each dimension is presented.



Dimension / Level	Organizational Performance	Quality Management	Information Management	Supply Chain Integration	Sustainability
Ad Hoc	- OP1 - OP2 - OP3 - OP4	- QM1 - QM2 - QM3 - QM4	- IM1 - IM2 - IM3 - IM4	- SCI1 - SCI2 - SCI3 - SCI4	- S1 - S2 - S3 - S4
Basic	- OP1 - OP2 - OP3 - OP4	- QM1 - (...)	- IM1 - (...)	- SCI1 - (...)	- S1 - (...)
Intermediate	- OP1 - (...)				
Advanced	- OP1 - (...)				
Mature	- OP1 - (...)				

Characteristics to be achieved on each dimension for each level

Figure 2.
Proposed architecture for the SCQM-MM

Organizational Performance (OP): In this dimension, it is required that the organization has its processes defined and documented and assure proper cost management practices, being fundamental the use of Key Performance Indicators (KPIs) to measure the efficiency and effectiveness of the processes (Archie and McCormack, 2004; ul Hassan *et al.*, 2012). Higher maturity levels in this dimension gradually require evidence that the organization keeps a deep and controlled performance monitoring process and has the capacity to improve the processes performance. Also, the organization must identify close relationships between the processes, its performance and the business results. The sub-dimensions considered in this dimension are: OP1 – Process Definition; OP2 – Performance Measurement; OP3 – Processes Flexibility; and OP4 –Costs Management.

Quality Management (QM): This dimension assigns the importance of establishing a culture of quality and the use of quality and continuous improvement practices and tools (Talib *et al.*, 2011; Zeng *et al.*, 2013). Higher levels of maturity gradually require evidence that the quality culture is spread across all processes and levels of the SC, as well as the quality tools, are used on a regular and daily basis and there are high and sustainable levels of customer satisfaction. The sub-dimensions on the QM dimension are: QM1 – Quality and Continuous Improvement Practices; QM2 – Problems Management; QM3 – Quality Culture; and QM4 – Customer Satisfaction.

Information Management (IM): Information Systems and Technology plays a crucial role in an efficient SC, allowing the collection of relevant data and the information sharing between the SC partners, promoting a real-time collaboration and a sophisticated integration between the internal and external processes that can substantially improve the overall SC

performance (Kache and Seuring, 2017; Xu, 2011). In this way, the assessment of this dimension lies on the means (infrastructure and procedures) used by the organization and the SC to collect, treat and share information, generating value from it. Higher levels of maturity in this dimension gradually impose the use of updated technology and integrated information systems to support the decision-making process, enabling the automatic collection and treatment of relevant data and the easy access to that information by all the interested parties of the SC, always assuring the quality, accuracy and reliability of the data. In the IM dimension, the sub-dimensions defined are: IM1 – Support Infrastructure to Information Management; IM2 – Data Collection and Treatment; IM3 – Support to the Decision-Making Process; and IM4 - Share of Information.

Supply Chain Integration (SCI): This dimension assesses the type of relationship established between the different parties of the SC, how they cooperate and how they are involved in the strategic thinking of the SC (Huo *et al.*, 2016; Vanpoucke *et al.*, 2017). Higher maturity levels in this dimension gradually require the regular involvement of suppliers and customers in more strategic levels, besides the information sharing and the existence of higher levels of confidence, partnerships and cooperation between business partners. Therefore, this dimension is divided into the following sub-dimensions: SCI1 – Cooperation between Stakeholders; SCI2 – Relationship with Stakeholders; SCI3 – Involvement of Stakeholders within the Overall SC; and SCI4 – Business alignment with Stakeholders.

Sustainability (S): As the economy is one of the society's pillar, businesses that are managed for longer longevity are managed sustainably. Therefore, this dimension assesses how the organization strategy reflects a concern with its long-term survival and its own impact on the society, environment and on the local and national economy (Bastas and Liyanage, 2019; Wang and Dai, 2018). Higher levels of maturity in this dimension are related to higher levels of compliance with the principles of the three bottom-line dimensions: Economic, Environmental and Social (Carter and Liane Easton, 2011), which must be reflected from the top management to the operational levels of the organization, on a regular daily practice and in the relationships established between the different business partners of the SC. The sub-dimensions defined for this dimension are: S1 – Sustainability as a Dimension of the Organizational Culture; S2 – Sustainability Practices; S3 – Sustainability Strategic Focus; and S4 – Sustainability of the Business Partners.

The chosen dimensions' result from the intersection of the conceptual model developed by Fernandes *et al.* (2017a) with the literature review performed regarding MMs on the QM and SCM domains. They also reflect the contributions that both underlying management philosophies present and how both impact positively on organizational performance in a sustainable manner. Although all dimensions can be considered to have equal relevance for the presented MM and managing concept, one must recognize the important role of the IM dimension as its performance is key for the relationship between all internal and external stakeholders for matters related to both SCM and QM, expecting that sharing information contributes to creating added value. Further details regarding each dimension criteria can be seen in Appendix.

3.3 Supply chain quality management maturity levels

The maturity levels were defined as (from the lowest to the highest): (1) *Ad hoc*; (2) Basic; (3) Intermediate; (4) Advanced; and (5) Mature. Each maturity level of the SCQM-MM represents a set of organizational characteristics, practices and behaviours, in a progressive evolutional path to a plain maturity state. The following paragraphs present a brief description of each maturity level.

Ad hoc: Being this the lowest level, it is recognized that the company has not started yet to take the first steps to reach higher maturity levels. For example, processes are not

documented or defined, and the performance measurement is very scarce, as well as the usage of quality tools and practices. A reactive attitude prevails in the company, as there are no prevention actions, no knowledge of quality costs and the customer satisfaction level remains low. Further, there is low cooperation along with the SC with only basic relationships between the company and the stakeholders. Sustainability is not a concern to the company.

Basic: It is recognized that the company starts to make their first efforts towards achieving maturity in processes and business. For example, the main processes are defined, some data collection is done by non-automatic ways, and historical data records are gathered and kept informally. Some metrics are used to characterize the main processes but without a regular monitoring. On a broader overview, some cooperation along the SC can be seen although there is no share of information, since each process has its own information system. Continuous improvement starts to exist due to some corrective actions implementation. Customer satisfaction shows some increase, but no significant improvements are achieved. Sustainability issues start to be a concern and some practices are implemented.

Intermediate: It is recognized that the company already shows some significant management and control practices about the processes, although in a non-balanced way, denoting that some business areas/processes are more mature than others. Customer satisfaction shows significant improvements, representing a competitive advantage, although it remains with inconsistent performance. Sustainability issues are managed in order to promote the company's reputation towards society and stakeholders.

Advanced: It is recognized that the company's processes are already completely defined and measured, and the information is shared with suppliers and customers. KPIs translate the efficiency and effectiveness of the processes. There is a high level of cooperation and involvement of the stakeholders in the company strategic decisions. Quality tools and continuous improvement practices are used on a regular basis, as well as preventive actions, which are translated into known costs and improvement of customer satisfaction. Sustainability is a big concern for the organization, although it is not completely integrated with company's goals.

Mature: In this last level, it is recognized that the company and SC processes are well defined and documented, and there is an integrated information system that allows the management of the overall performance. There is a global translation of the efficiency and effectiveness of each main process in terms of evolution and costs. At this level, continuous improvement is part of the company culture, with regular use of quality practices. Close cooperation between all the different SC areas can be identified. Stakeholders, including customers, are actively involved in strategic planning. Sustainability is integrated with company's policy and vision and translated into goals and practices.

3.4 Maturity assessment and scoring method

The SCQM-MM is only focused on the assessment of the SC processes, namely, Source, Make, Deliver and Return. The maturity criteria are the same, independently of the SC process, but each process must be assessed separately. In this way, the following procedure must be replicated to each process that the organization intends to maintain under evaluation.

The SCQM-MM intends to be used as a self-evaluation tool to help any organization implement and assess how the SCQM concept is currently implemented and how to reach a more advanced state. The assessment procedure consists in indicating, for each sub-dimension, the maturity criteria that better describes the status of the organization. However, it is important to point out that this type of assessment is a snapshot in time that is applied to capture highly dynamic variables such as markets, customer needs and technology. All the information used to answer the maturity criteria must be well supported by evidence to minimize the subjectivity linked to the evaluator. Each sub-dimension is then scored from 1 to 5, according to the maturity level corresponding to the selected criterion.

An example of this procedure applied to the "Organizational Performance" dimension is provided in Table 2, using random fictitious values.

After addressing a score to each sub-dimension, it is possible to calculate the Global Maturity Score of the organization's SC, which is ranked from 20 to 100 points, and the assignment of the maturity level obeys the scale presented in Table 3. Thus, in the scoring process, all the dimensions and SC processes have equal weights.

The minimum of 20 points represents that all the assessment criteria were ranked on the lowest level of the MM. To be classified on the Basic level, for example, it means that at least 16 criteria need to be graded on a higher level, this is, for the same assessment to be considered on the Basic level, it means that at least 16 of the criteria need to be on the Basic level or higher. The same happens to the other maturity levels until the highest one, this is, for an organization or SC process to be ranked at a given level, 80% of the criteria need to be at that level or higher. This scoring method not only allows a better assessment and placement within each level but also facilitates the measurement of the efforts made to reach a higher maturity level.

Furthermore, it is possible to present the results in a graphic way, as exemplified with random fictitious values in Figure 3.

In Figure 3, one can observe which organizational dimensions and SC processes contribute more significantly to the global score, and at the same time in which areas, improvement actions must be addressed. In the example provided in Figure 3, the following analysis can be made.

(1) The organization is positioned at the *Advanced* level;

(2) None of the SC processes is especially influencing the global maturity score;

(3) Improvement efforts must be oriented to the *Sustainability* dimension because it is the dimension with the lowest average score.

Furthermore, as important as determining the level of maturity, it is also important to understand the contributions and the weakness that either a company or the SC under subject has for the achieved level of maturity. On the example presented previously, one can conclude that there are no significant differences regarding maturity and their development between SC processes, meaning that the system is well balanced and an overall attention to all involved processes is being given. However, when analyzing the same system from a

Table 2. SCQM-MM assessment procedure (example for the organizational performance dimension)

Sub-dimension		Score	Criteria description
OP1	Processes definition	4	Processes are completely defined and measured
OP2	Performance measurement	5	Consolidated performance measurement system that evaluates the efficiency and effectiveness of the macro processes
OP3	Processes flexibility	2	Limited flexibility regarding the implementation of process changes
OP4	Costs management	4	Known costs are close to the real ones

Table 3. SCQM maturity levels scale

Global maturity score	Maturity level
Ad hoc	20 to 35 points
Basic	36 to 51 points
Intermediate	52 to 67 points
Advanced	68 to 83 points
Mature	84 to 100 points

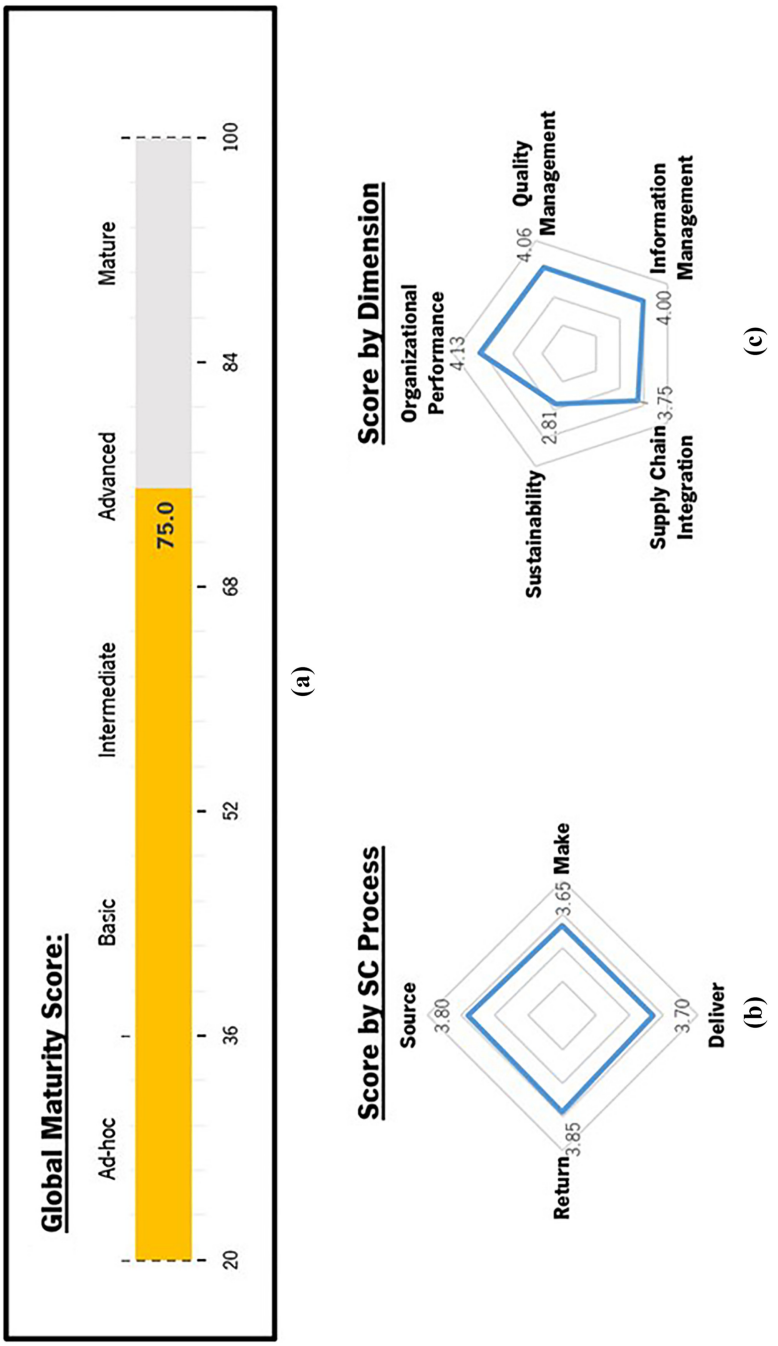


Figure 3.
SCQM-MM – representation of results (example)

dimensional overview, it is possible to conclude that the Sustainability dimension and its criteria are being disregarded, meaning that the following improvement actions to implement could give greater focus on this domain.

4. Conclusions

Today's market has brought the need to develop more sophisticated tools to improve the competitiveness of SCs, and the concept of SCQM has become one of the most emergent research topics in this context.

Aiming to go further on this subject, the main purpose of this research work was to develop and present a self-evaluation tool that would allow any organization to implement and assess how the SCQM concept is currently implemented and know what to do next to reach a more advanced state of SCQM integration. Similar frameworks were identified in the literature covering some important areas linked to SCQM, but none of them was specifically related to the assessment of the SCQM integration. In this way, and based on those frameworks, the SCQM-MM was created to fill this gap.

The presented SCQM-MM covers five organizational dimensions and relevant aspects regarding the SCQM integration, describing an evolutional and progressive path with five maturity levels. It is based on 100 criteria, organized in a matrix of five maturity levels and five organizational dimensions. With this structure, the MM aims to be progressive and comprehensive, embracing most relevant aspects concerning the SCQM concept.

As this is an innovative and pioneer MM to assess the integration of quality through the organizational SC, this paper has both theoretical and practical implications. Concerning the theoretical implications, a new MM was developed specifically for the SCQM research area. To the best of the authors' knowledge, there is not a MM available to assess this concept. Furthermore, based on literature's MMs, it is not common to see a tool that assesses management concepts (or their integration) in one specific framework. On the other side, the practical implications are several, namely, the proposed MM can support a better integration of the stakeholders in the strategic definition process, it can be used as a decision-making tool and, additionally it will help companies to identify improvement areas in their processes regarding both concepts of SCM and QM and their integration. Furthermore, the model is built to promote the internal and external development of an organization and its SC, whose benefits will not only be collected by a single agent in the SC, but eventually, the remaining SC partners as cooperation, flexibility and collaboration are the key concepts behind the model. Nevertheless, it is important to remind that MMs assessment task is a snapshot in time.

As a multi-dimensional framework that focuses on several domains that usually are managed and developed separately, the implementation of such a concept will lead an organization (in a first instance and later on the remaining business partners in the SC) to develop such systems in a more integrated and sustainable manner, with a clear focus on the performance of the organization itself and the SC. Also, the inclusion of a sustainability dimension provides the model with a balanced business development assessment in terms of the three pillars of the sustainability concept.

Furthermore, future work is needed to complement the current research. Namely, it will be important to validate and implement the SCQM-MM in a larger range of organizational contexts, providing new ways to guarantee its fitness to any type of organization. Also, the development of a more detailed layer of information regarding each dimension and each level is required. Some criteria or indicators could be added to the model as guidelines for evidence, supporting the criteria chosen by each organization. This additional layer should provide guidance on a more tactical overview by demonstrating what can be expected and implemented in each maturity level; however, flexible enough to allow each SC to design its

tactical framework according to their needs. Furthermore, each organization should define the period and recurrence of its maturity assessment and evaluation.

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Appendix

Table A1.
Supply chain quality management maturity model – full criteria description

Level	Organizational performance	Quality management	Information management	Supply chain (internal and external) integration	Sustainability
Ad-hoc	- Processes are not completely defined - No measurements about processes performance - Processes changes are very difficult - Unknown QM and SCM costs	- No quality tools or practices are used leading to no evidence of continuous improvement - Company is only prepared to solve problems using short-term solutions - No problems prevention and quality is only related to a specific department - Low/non-evaluated customer satisfaction level	- Company resources are few and only some processes are supported by IT systems - Non-documented system and lack of documented processes definition - Poor and scarce monitoring and control of the processes - Use of inadequate and imprecise information (e.g. demand) associated with insufficient documented records, leading to miscommunication and waste of resources	- Low cooperation - Basic relationship between the company and the suppliers and/or customers - Low knowledge about the customers and the suppliers - No information is shared across all the SC	- Non-importance as a priority or a concern is given to sustainability, as it does not make part of the company culture - There are no sustainability data, processes, practices, benefits and goals available or managed by the company - Only regulation and compulsory requirements are fulfilled - Business partners are selected by cost criteria because the focus is on economic performance
Basic	- Few processes are defined - Few KPIs are used in the processes and targets are defined but are not achieved - Limited flexibility regarding the implementation of processes changes - Some known costs, but still with no accuracy	- Some quality tools and practices are used due to obligatory requirements leading to scarce continuous improvement evidence - Company is not prepared to face new or non-predetermined requirements, only to the major problems - Lack of preventive actions to face unexpected problems due to the weak link of QM to the departments directly related to production - Customer satisfaction is a concern, but without significant improvements	- IT infrastructures are available but there is no connection between all of them neither a capacity to later expansion regarding technology evolution - Non-automatically data collection - Each process has its own information, historical data, data collection, extraction, manipulation, treatment and analysis, however through a semi-manual process - As information becomes more accurate (e.g. demand), this starts to be evaluated in more detail, serving as an input for planning and scheduling processes of the internal SC	- Cooperation exists between different areas inside the SC - Project development made with stakeholders from different areas of the company - Focus on improving business performance, knowledge about the customers' orders and requests starts to be more detailed - Information sharing within the company and first steps to future information sharing with business partners start to appear	- Some sustainability costs and activities are shared within the company - Sustainability practices and goals depend on control and analysis of past data, mainly economic and quality information - Awareness and concerns regarding to sustainability practices, with impact on business performance, start to appear, mainly the ones related to environmental and work conditions issues - Besides costs, business partner's performance is also evaluated regarding quality and delivery

(*continued*)

Level	Organizational performance	Quality management	Information management	Supply chain (internal and external) integration	Sustainability
Intermediate	- Some processes are defined - Some KPIs are used in some processes and targets are defined but are not achieved - Some flexibility regarding processes changes and their implementation - Some known costs and others only estimated	- Some continuous improvement practices are used to achieve company goals (e.g. PDCA cycle, lean tools, FMEA . . .) - Corrective actions are used to face quality problems - Company quality control depends on the top management involvement and proactivity - Customer satisfaction shows some improvements due to the customers' involvement in process improvement	- Further IT system expansion is possible, since the equipment already satisfies future integration requirements - Some BI tools and systems are used for analysis in an isolated way and not for the all company or SC, leading to a not standardized decision support system - IT architecture and systems are linked among them, enabling some automatic data collection, supporting production processes - Accurate and detailed information is shared within internal SC and some relevant information is shared with some strategic business partners	- Some involvement, cooperation and collaboration of the stakeholders from different SC areas related to the processes - The company production process uses several interconnected IT-based add-on functionalities, however, there is no integration with customers systems - Customers and suppliers start to being engaged on the process improvement - Internal information is shared and integrated into the system with limited access to external stakeholders' information	- Initial investments are being made regarding the development of professional skills, promoting the implementation of new technologies and work methods to increase SC sustainable performance - Sustainability data and processes are planned, controlled and managed (e.g. KPIs for emissions control and waste production), but goals remain unknown although some people in the company are dealing with those questions - Sustainability is associated with company image towards the society, displaying compliance to regulations, standards and good practices - SC business partners are evaluated concerning economic, environmental, social and quality matters

(*continued*)

Table A1.

Table A1.

Level	Organizational performance	Quality management	Information management	Supply chain (internal and external) integration	Sustainability
Advanced	- Processes are completely defined and measured - Relevant KPIs translate processes' efficiency and effectiveness, and the majority of targets are achieved - Changes in processes are implemented following a documented guideline - Known costs are close to the real ones	- Preventive actions related to product quality are common practices - Company faces unexpected problems through problems prevention and quick problems identification - Quality management involves and depends on the customer requirements - Customer satisfaction is a business priority as a competitive advantage	- Standardized decision support exists due to the compilation of internal and external information sources through a BI system (data analytics) - Integrated information system collects, treats, analyses and evaluates the company performance - Some information is shared with suppliers and customers through several communication processes because there is interconnected data - Information is widely shared between all business partners, seeking a more collaborative and strategic environment regarding the business performance	- Company aligned with stakeholders in terms of measures and goals - Development of confidence relationships to share confidential data with suppliers and customers - Customers and suppliers play an active role in the process improvement - Integration of shared information across the SC with intensive data exchange between stakeholders	- Regular investments are made in the relevant areas of the SC regarding professional skills, new technologies and work methods to increase overall SC sustainable performance - On the operational level, sustainability data, processes and goals are defined and managed in all SC processes - There is a concern related to business risk management along the SC regarding sustainability regulations, standards and good practices - Supply chain business partners are required to perform according to international standards regarding integrated management systems (e.g. ISO 9001, ISO 14001 and SA 8000)

(*continued*)

Table A1.

Level	Organizational performance	Quality management	Information management	Supply chain (internal and external) integration	Sustainability
Mature	- Close relationship between the documented processes - Consolidated PMS that evaluates the efficiency and effectiveness of the macro processes - Processes are dynamic and continuous improvement turns the processes sustainable - Relationship between KPIs and costs with an evaluation of the evolution	- Continuous improvement and advanced practices are well established in the company as a normal activity - Problems prevention is a concern - Improvements opportunities are measured, evaluated, and prioritized according to their business impact - Customer satisfaction is high and a collaborative culture exists	- IT system automatically collects all the relevant (internal and external) data due to the implemented infrastructures and equipment with the integration and communication' requirements fulfilled - Advanced information system (big data warehouse) supports the production processes and collects large amounts of data that can be used and shared by all SC areas - Integrated information system such as machine learning and predictive analytics tools are used for real-time events handling optimization, helping the decision making support - Business partners have a completely integrated information system, sharing between them relevant data, leading to a dynamic and synchronized behaviour regarding the overall SC competitive environment	- Cooperation and collaboration between different SC areas and partners - Suppliers and customers are involved in the strategy definition, planning, and performance analysis of the company - Integration of stakeholders leads to dynamic and improved processes - Fully integrated information systems (I4.0) to share information across all the SC	- Regarding overall SC performance, the long-term strategy is closely concerned with professional skills and new technologies development - Sustainability measures regarding economic, environmental and social performance are integrated into the SC overall goals, business partners mission, values and practices - Sustainability practices and processes are real concerns as the company manage the economic, environmental and social risks in the SC, leading to a better understanding of the data and a sustained and continuously improved performance - Company develop close confidence relationships and cooperate with business partners to promote the SC sustainable performance

Note(s): BI – Business Intelligence; FMEAs – Failure Mode and Effects Analysis; IT – Information Technology; KPIs – Key Performance Indicators; PDCA – Plan, Do, Check, Act; QM – Quality Management; SCM – Supply Chain Management