**PONTIFICAL CATHOLIC UNIVERSITY OF PARANA**

**POLITECHNICAL SCHOOL**

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**CARLA GONÇALVES MACHADO**

# DEVELOPING A MATURITY FRAMEWORK FOR SUSTAINABLE OPERATIONS MANAGEMENT

**CURITIBA**

**2015**

**CARLA GONÇALVES MACHADO**

# DEVELOPING A MATURITY FRAMEWORK FOR SUSTAINABLE OPERATIONS MANAGEMENT

Thesis dissertation presented to the Industrial and Systems Engineering Graduate Program (PPGEPS) of the Pontifical Catholic University of Parana, as requirement to obtain the degree of Doctor in Industrial Engineering.

Supervisor: Prof. Dr. Edson Pinheiro de Lima
Co-supervisor: Prof. Dr. Sergio E. Gouvea da Costa

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# APPROVAL TERM

## Carla Gonçalves Machado

### DEVELOPING A MATURITY FRAMEWORK FOR SUSTAINABLE OPERATIONS MANAGEMENT

Thesis submitted in partial fulfilment of the requirements for the degree of Doctor of Industrial and Systems Engineering in the Industrial and Systems Engineering Graduate Program of the Polytechnic School, Pontifical Catholic University of Parana.

Prof. Dr. Edson Pinheiro de Lima
Chair - Supervisor (PPGEPS/PUCPR)

Prof. Dr. Sergio Eduardo Gouvêa da Costa
Supervisor (PPGEPS/PUCPR)

Prof. Dr. Jannis Jan Angelis
External Member (KTH/Sweden)

Prof. Dra. Lucila Maria de Souza Campos
External Member (EPS/CTC-UFSC)

Prof. Dr. Dr. Wesley Vieira da Silva
External Member (PPAD/PUCPR)

Dr. Ângela Cristiane Santos Póvoa
External Member (PPAD/PUCPR)

**Curitiba, 15 de Maio de 2015.**

This thesis dissertation is dedicated to my family, especially
my parents, Antonio Carlos and Fátima Machado, for their
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Effective sustainable operations management could become a core competence of the organization, and as such a driver of business strategy rather than merely the vehicle for its implementation.

(Bettley and Burnley, 2008, p.884)

# RESUMO

MACHADO, Carla G. Developing a maturity framework for sustainable operations management. Curitiba, 2015, 334f. Tese de doutorado (Doutorado em Engenharia de Produção e Sistemas) – Programa de Pós-Graduação em Engenharia de Produção e Sistemas, PUCPR, 2015.

As empresas estão enfrentando problemas para integração e plena implementação da sustentabilidade. Esta é uma questão complexa e multidisciplinar, que exige que as empresas sejam confrontadas com dilemas e decisões com diferentes objetivos e valores. Estratégias de operações sustentáveis podem ajudar nesta questão, porque representam a integração das dimensões do triple tripé da sustentabilidade nas operações. No entanto, há lacunas de modelos ou estruturas que apoiem estratégias de operações sustentáveis. Modelos de maturidade são indicados para cenários complexos e estão sendo aplicadas em diferentes campos. Este estudo considera que competências relacionadas com a gestão operações de operações sustentáveis podem ser agrupadas e associadas à um *framework* de maturidade, representando um caminho evolutivo que apoia as empresas no processo de integração da sustentabilidade. Assim, o principal objetivo desta pesquisa é compilar uma estrutura de maturidade para operações sustentáveis, indicado para empresas de manufatura, que podem utilizá-lo para evoluir na implementação e integração da sustentabilidade nos negócios. Questões de sustentabilidade exigem múltiplas abordagens para um entendimento amplo. Esta pesquisa busca estender o conceito de triangulação, onde o modelo proposto está baseado em quatro fontes principais: literatura (acadêmica e profissional); estudos de casos, painéis de especialistas, e levantamento de dados via pesquisa *survey*. A pesquisa foi desenvolvida em três fases, que envolvem um conjunto de métodos qualitativos e quantitativos a fim de: (1) Identificar o estado da arte relacionado com a sustentabilidade e a gestão de operações; (2) desenvolver um *framework* teórico-prático de maturidade para a gestão de operações sustentáveis; e, (3) aperfeiçoar o framework e aplicar o conceito de maturidade em um estudo prático. Esta pesquisa contribui e soma esforços para o desenvolvimento de estudos sobre a gestão de operações sustentável. A contribuição global da pesquisa é a organização de competências em dimensões de operações sustentáveis, que podem ser geridas de maneira integrada e evoluir de forma a permitir que as empresa atinjam níveis mais elevados de integração da sustentabilidade. Contribui também ao mitigar a lacuna de *frameworks* que promovam o alinhamento entre as decisões operacionais e as metas de desempenho com as questões de sustentabilidade, e também auxilia as empresas a se tornarem mais sustentáveis, ajudando a orientar a estratégia, a auditar o nível de integração de sustentabilidade e a desenvolver um sistema de gestão de desempenho de sustentabilidade.



**Palavras-chave**: Sustentabilidade. Operações sustentáveis. Modelo de maturidade. Gestão de desempenho.

**ABSTRACT**

MACHADO, Carla G. Developing a maturity framework for sustainable operations management. Curitiba, 2015, 334p. Thesis Dissertation – Industrial and System Engineering Graduate Program, PUCPR, 2015.

Companies are facing a problem in fully implementing and integrating sustainability. This is a complex and multidisciplinary issue and requires companies to confront dilemmas and decisions with different objectives and values. Sustainable operations strategies can help in this matter because they represent the integration of triple bottom line dimension into the companies' operations. However, there is a lack of models or frameworks that support sustainable OM strategies. Maturity models are indicated to complex scenarios and are been applied in different fields. The study considers that the capabilities related to sustainable operations management can be grouped together and associated with a maturity framework, representing an evolutionary path that supports companies in the process of integrating sustainability. Thus, the main purpose of this research is to compile a maturity framework for sustainable operations indicated for manufacturing companies that can use it to evolve in the implementation and integration of business sustainability. Sustainability issues require multiple approaches for a broad understanding. This research seeks to broaden the concept of triangulation, where the proposed model is based on four main sources: literature (academic and professional); case studies, panel studies, and survey data collection. The research was developed in three main phases, which encompass a set of qualitative and quantitative methods in order to: (1) Identify the state of the art related to sustainability and operations management in the field; (2) develop a theoretical-practical framework of maturity in sustainable operations management; (3) refine the framework, and apply the concept of maturity in a practical study. This research contributes and adds efforts to the development of studies related to sustainable operations management. The overall contribution of the research is the organization of capabilities into dimensions of sustainable operations, which can be managed in an integrated manner and evolve in ways that permit the company to reach higher levels of sustainability integration. It contributes by mitigating the lack of frameworks that seek alignment between operations decisions and performance goals with sustainability issues, and assists businesses in becoming more sustainable, helping to guide the strategy, to audit the level of sustainability integration, and developing a sustainability performance management system.

**Keywords:** Sustainability. Sustainable Operations. Maturity Model. Performance Management.

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## ABBREVIATIONS

| | |
|---|---|
| APQC | American Productivity & Quality Center |
| BCG | Boston Consulting Group |
| CEOs | Chief executive officers |
| CLSCs | Closed-loop Supply Chains |
| CMM | Capability Maturity Model |
| CMMI | Capability Maturity Model Integration |
| CSR | Corporate Social Responsibility |
| D4S | Design for sustainability |
| EMS | Environmental Management System |
| GSCM | Green Supply Chain Management |
| IFC | International Finance Corporation |
| LCA | Life Cycle Assessment |
| LCM | Life Cycle Management |
| MIT | Massachusetts Institute of Technology |
| OM | Operations Management |
| OH&S | Occupational Healthy and Safe |
| PLS | Partial least squares |
| QMS | Quality Management System |
| RL | Reverse Logistics |
| RQ | Research question |
| SD | Sustainable Development |
| SEI | Software Enginnering Institute |
| SLR | Systematic Literature Review |
| SO | Specific objetives |
| SOM | Sustainable Operations Management |
| TBL | Triple Bottom Line |
| UN | United Nations |
| UNEP | United Nations Environmental Programme |
| WCED | World Commission on Environment and Development |

## CONTENTS

# 1. INTRODUCTION

This PhD dissertation considers that sustainable operations management capabilities are associated with a maturity framework that can represent a structure for companies to evolve in their implementation of sustainability.

Since the publication of the Club of Rome's (1972) *The Limits to Growth*, governments, private and non-profit organizations, and society have all been seeking more sustainable ways to conduct their activities while meeting the critical challenges that face the planet and humanity: population growth, environmental degradation, global warming, the depletion of natural resources, market globalization, and social and political issues (MEADOWS et al., 1972).

Elkington (2004) stated that sustainability brings seven main revolutions, which are listed in Exhibit 1. This author highlighted four areas in which the challenges of integrating sustainability will increasingly appear:

> […] balance sheets (transparency, accountability, reporting and assurance), boards (ultimate accountability, corporate governance and strategy), brands (engaging investors, customers and consumers directly in sustainability issues) and business models (moving beyond corporate hearts and minds to the very DNA of business) (ELKINGTON, 2004, p.15).

To Porter and Kramer (2006), organizations must guarantee good economic performance in the long term while at the same time investing in integrated environmental and social strategies that permit compliance with a variety of regulatory demands, operating licenses, business transparency, and other demands from their stakeholders.

Elkington (2004) and Lubin and Esty (2010) identify sustainability as a megatrend similar to “quality” and “information technology”. Megatrends require companies to create a new agenda, innovate and adapt their businesses, and integrate new business priorities in order to not be excluded from the market.

The "Down to Business Report" indicated that the private sector is considered the second most responsible actor for sustainable development (SD). Companies must strive to accurately achieve sustainability performance and contribute to SD in the following areas: contributing to technological development and innovation, working with governments to establish a regulatory environment that supports sustainable development, improving internal sustainability performance, influencing customers to make positive behavior changes, participating in multi-sectorial partnerships, mobilizing suppliers on sustainable initiatives, and engaging employees on sustainability initiatives (CLINTON, 2012).

Exhibit 1 - Elkington's seven sustainability revolutions

| | Old Paradigm | New Paradigm | Focus | Companies' approach |
|---|---|---|---|---|
| Markets | Compliance | Competition | Business will operate in markets that are more open to competition; customers' and financial markets' demands about commitments to TBL aspects and performance; | TBL thinking and accounting to build the business case for action and investment. |
| Values | Hard | Soft | New human and societal values | Decisions need to be not only based on economic aspects, but need to consider socio-environment ones. |
| Transparency | Closed | Open | Business will find its thinking, priorities, commitments and activities under increasingly intense scrutiny worldwide. | Provide information, e.g. sustainability reports (GRI) |
| Life-cycle technology | Product | Function | Companies are being challenged about the TBL implications of either industrial or agricultural activities far back down the supply chain, or about the implications of their products in transit, in use and – increasingly – after their useful life has ended. | Managing the life cycles of technologies and products |
| Partnerships | Subversion | Symbiosis | New forms of partnership spring up between companies; new forms of relating with opponents who are seen to hold some of the keys to success in the new order. | Campaigning groups will need to work out ways of simultaneously challenging and working with the same industry – or even the same company |
| Time | Wider | Longer | Sustainability agenda is pushing us in the other direction –towards 'long' term | The need to build a stronger 'long time' dimension into business thinking and planning will become ever-more pressing. The use of scenarios, or alternative visions of the future, is one way we can expand our time horizons and spur our creativity. |
| Corporate Governance | Exclusive | Inclusive | What is business for? Who should have a say in how companies are run? What is the appropriate balance between shareholders and other stakeholders? What balance should be struck at the level of the triple bottom line? | Build the relevant requirements into its corporate DNA from the very outset – and into the parameters of the markets that it seeks to serve. |

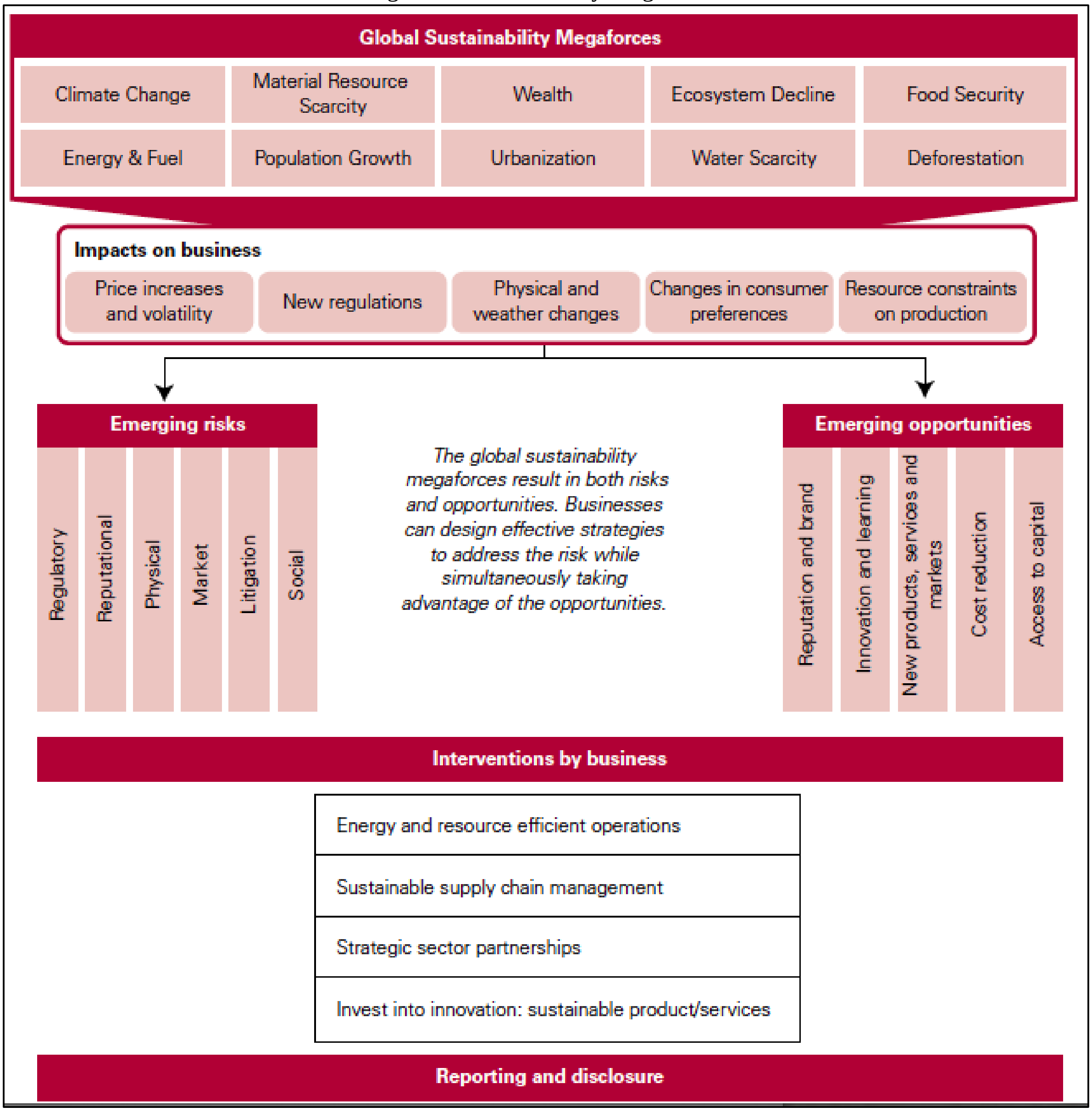
Source: adapted from Elkington, 2004, p.3-6.

According to Elkington (2004), the process of changing to a sustainable model is one of the most complex in history, and not all organizations will be able to succeed in this transition.

KPMG's report "Expect the Unexpected: Building business value in a changing world" presents ten global sustainability megaforces (Figure 1).

These megaforces will have a significant impact on business activities over the next twenty years. The report states that business strategies need to consider these megaforces, because they represent constraints, complexity, and risks that companies can turn into opportunities or innovation (KPMG, 2012).

Figure 1 - Sustainability Megaforces




Source: adapted from KPMG, 2012, p.133.

The megaforces can have impacts on companies of all types and sizes, and five main operational capabilities can support strategies in this complex scenario: energy and resource efficient operations, sustainable supply chain management, strategic sector partnerships, and sustainable product/services, reporting and disclosure (KPMG, 2012).

The findings in both reports are directly related to the OM context. Bayraktar et al. (2007) and Drake and Spiler (2013) affirm that the OM field fits and also "[…] offers a vital sustainability perspective". The sustainable operations management (SOM) approach represents the sustainability perspective applied to OM.

Based on the WECD (1987) definition of sustainable development "[…] to ensure that it meets the needs of the present without compromising the ability of future generations to meet their own needs", Kleindorfer et al. (2005, p.490) define SOM as:

> [...] the set of skills and concepts that allow a company to structure and manage its business processes to obtain competitive returns on its capital assets without sacrificing the legitimate needs of internal and external stakeholders and with due regard for the impact of its operations on people and the environment.

According to Bakshi and Fiksel (2003) sustainability encompasses the entire system, extending 'process' limits beyond the plant and even beyond the company's boundaries. This means that sustainability cannot be achieved by a single firm's actions; in other words, the entire supply chain, not just individual partners, must operate in a sustainable manner (CARTER; ROGERS, 2008; KLEINDORFER et al., 2005).

To Ueda et al. (2009) the sustainability problem is complex and requires the company to confront dilemmas and decisions with different objectives and values. Consequently, decisions related to sustainable operations take place in a complex and uncertain environment, because they expand the scope of operations beyond manufacturing in order to comply with multiple demands from different stakeholders: legislation, customer requirements, competition, external communities, etc. (NUNES et al., 2013).

The UN/Accenture report "A New Era of Sustainability" identified that a major contemporary challenge is how to transform sustainability strategy into action; "[…] 49% of CEOs cite complexity of implementation across functions as the most significant barrier to implementing an integrated, company-wide approach to sustainability" (LACY et al., 2010, p.11-14).

To Silvius and Schipper (2010) "[…] maturity models are a practical way to 'translate' complex concepts into organizational capabilities and to raise awareness for potential development".

Merriam-Webster's dictionary (2015) defines maturity as "full development". As for processes, the capability maturity model (CMM), created by Carnegie Mellon University, defines maturity as the extent to which a process is explicitly managed, defined, controlled and effective (SEI, 1995).

To Fraser et al. (2002), maturity represents the evolution from an initial state to a more advanced one, passing through intermediate stages. They also suggested that the maturity of a process may also be defined as effective and institutionalized (repeatable).

According to the American Productivity & Quality Center (APQC), companies achieve a high level of maturity "[…] when they respond to circumstances or their environment in an appropriate and adaptive manner […]" (TESMER et al., 2011).

Since the 1970s, maturity models have been used as an improvement tool (van Looy et al., 2013). Fraser et al. (2002) presented some examples of maturity models applied in different areas: quality management (Crosby, 1979, 1996), software development (Paulk et al., 1993), supplier relationships (Macbeth; Ferguson, 1994), R&D effectiveness (Swkonyi, 1994a,b), product development (Mcgrath, 1996), innovation (Chiesa et al., 1996), product design (Fraser et al., 2002), collaboration (Fraser; Gregory, 2002), and product reliability (Sander; Brombacher, 2000).

According to CMM, a maturity model contributes to a company's improvement in many ways: (1) providing a place to start; (2) presenting orientation based on best practices; (3) providing a common language and a shared vision; (4) presenting a framework that helps companies to prioritize actions; (5) helping to define what improvement or 'maturity' means for the organization (SEI, 1995, 2010).

For APQC,

> […] frameworks and reference models help support process analysis, design, and modeling activities […] Starting with a process framework or reference model accelerates these activities by giving a professionals a basis on which to build" (TESMER et al., 2011).

In this area, maturity models or frameworks based on process improvement can be used as a base for building an evolutionary path to improve sustainable business management.

**Thus, this thesis argues that joining the structure of maturity models with the SOM approach can result in an evolutionary framework to integrate sustainability into business, based on the sustainability maturity of operations management.**

## 1.1. DESCRIPTION OF THE PROBLEM AND RESEARCH GAPS

For Ueda et al. (2009) an appropriate approach to sustainability issues is important in designing, implementing, and running enterprise systems. According to Singh et al. (2009) and Bititci et al. (2012), there is a demand for people, organizations, and society to find the models, metrics, and tools needed to operationalize sustainability, because progress and gaps need to be measured and monitored for sustainability to have more optimized and efficient stages.

Over the last decade, surveys of companies and managers have been conducted around the world in an attempt to understand how companies are dealing with sustainability demands. Lubin and Esty (2010) stated that companies need to tackle two issues simultaneously: develop a strategic sustainability vision for value creation, and determine how to carry out this vision.

Epstein and Buhovac (2010) identified that even with a formal strategy and a commitment to improving sustainability, companies still are unsuccessful in implementation. Their findings showed that is necessary to combine leadership, mission (commitment) strategy, structure, organizational culture, management control, performance measurement, and reward systems.

Sustainability has been placed squarely into the strategic agenda of companies that are seeking guidance in order to develop sustainability competences and integrate these within a complex, global, distributed, and dynamic operations network (GUNASEKARAN; NGAI, 2012).

In an analysis of data from 2009 to 2014, MIT and BCG found that even with a majority of companies considering sustainability as relevant to competitiveness and addressing significant sustainability issues, a significant number indicated the presence of a gap between sustainability vision and action. As barriers to integrating sustainability, the companies cited a "lack of a model for incorporating sustainability" and "difficulty quantifying intangible effects" (KIRON et al., 2013b).

Eccles and Serafelm (2013) identified gaps related to the formulation of sustainably business strategies by companies, indicating that strategies and their implementation are being adapted as the companies' business models evolve.

Traditionally, operations strategy has been directly associated with the competitive environment, linking the corporative strategy, market requirements, and operational resources. However, Slack et al. (2004) declared that theory and practice in the field of OM are not synchronized.

The evolution of SOM research is more focused on environmental issues; social issues or studies dedicated to integrated the economic with the environmental and social perspectives are still rare (SEURING; MÜLLER, 2008; BETTLEY; BURNLEY, 2008).

To Bayrakatar et al. (2007) the field of OM naturally calls for sustainability, which brings more complexity to operations strategy decisions. According to Drake and Spinler (2013, p.11) "[…] Many decisions that determine a firm's sustainability impact also naturally intersect with established OM streams". They affirm that SOM research needs to create incentives to develop more efficient production models that consider socio-environmental impacts, and to integrate the multidisciplinary aspects of sustainability.

However, there is an absence of specifications, norms, and/or frameworks to describe how operational performance can be effectively tied to models of sustainability (LIYANAGE, 2007).

To Bettley and Burnley (2008), the integration of sustainability should be guided by trade-offs and decisions that sustainably combine processes and technologies, which need to be continuously improved. To Ferrer (2008, p.5) it is necessary to provide integrated operations model. According to this author, "[…] it's important to introduce a framework that converts business strategies focused on the economy-environment-community triad into implementable operational decisions".

To Lubin and Esty (2010), most sustainability initiatives are implemented in an isolated manner, without a vision or plan. They affirm that managers consider the integration of sustainability to be an "unprecedented journey" without an itinerary. Park and Pavlovsky (2010) said that companies that take an *ad hoc* approach to sustainability or use isolated initiatives may not achieve better results than companies using an integrated approach.

In his master's thesis, Kamperman (2012) identified five gaps related to the need to develop models to manage sustainability in companies: (1) the development of tools and models based on scientific knowledge; (2) the lack of a comprehensive, linked, system-based framework; (3) the fact that many frameworks only take into account performance management within the boundaries of the company; (4) the lack of understanding and agreement about the definition of SD; (5) need for the adopted practices to reflect the intrinsic values of the company.

To Nunes et al. (2013), there are relevant frameworks to support sustainable manufacturing strategies, but in the literature, these authors identified a gap in the application of these frameworks; due the complexity of this new context, a system approach seems necessary.

According to Parisi (2013), studies about how companies adopt sustainability performance measurement systems, including for those used for social and environmental goals are not explicitly addressed, and research needs to investigate the strategic and operational levels.

For Gunasekaran et al. (2014) "[…] sustainable development remains a major challenge and opportunity for global firms. However, the role of operations research (OR) and operations management (OM) is yet to be studied in depth".

In the editorial of the Special Issue "Sustainable Operations Management: design, modeling and analysis", Gunasekaran and Irani (2014, p.1-2) highlighted relevant aspects related to the evolution in SOM research:

> […] most of the research on SOM has been limited to literature reviews […] there are not many articles that deal with modeling and analysis of SOM decision making at strategic, tactical and operational levels that are important for implementation of SOM decisions.

As a result, companies are facing a problem in fully implementing and integrating sustainability. SOM strategies can help in this matter because they represent the integration of TBL into the companies' operations. However, there is a lack of models or frameworks that support sustainable OM strategies in an integrated way and are guided by a performance management system, which permits assessment of the level of sustainability integration.

Besides the research gaps, in the studied maturity models it was not possible to identify a model or framework that considers the capabilities of SOM from an integrated management perspective based on TBL.

The framework proposed by Veleva et al. (2001) primarily encompasses the environmental, health, and safety aspects of sustainable production. The PREST Model, presents the relationship between the six dimensions of value, including operations (CAGNIN, 2005). The model traces the evolution of the maturity of operations based on sustainability, but does not describe the capabilities of SOM with regard to maturity level. Labuschagne et al. (2005) proposed a set of criteria and indicators for evaluating the sustainability of operational initiatives, but the framework do not specify the organization and application of the capabilities of SOM to accomplish criteria.

Other models and frameworks focused on specific development of SOM capabilities.

Kleindorfer et al. (2005) presented an evolutionary framework for sustainable operations based on three main SOM capabilities: green product and process development, lean and green OM, and remanufacturing and closed-loop supply chains. Reefke et al. (2010) and Porteous et al. (2012) presented a maturity model for sustainable supply chain management. The model proposed by Swarr et al. (2011) is related to lifecycle management. The maturity of corporate responsibility is explored by Ainsbury and Grayson (2014), and Life Cycle Management by Mani et al. (2010).

Summarizing, this research contributes in three areas: (1) sustainability management; (2) models or frameworks for sustainability implementation and management; (3) SOM research.

## 1.2. RESEARCH QUESTIONS

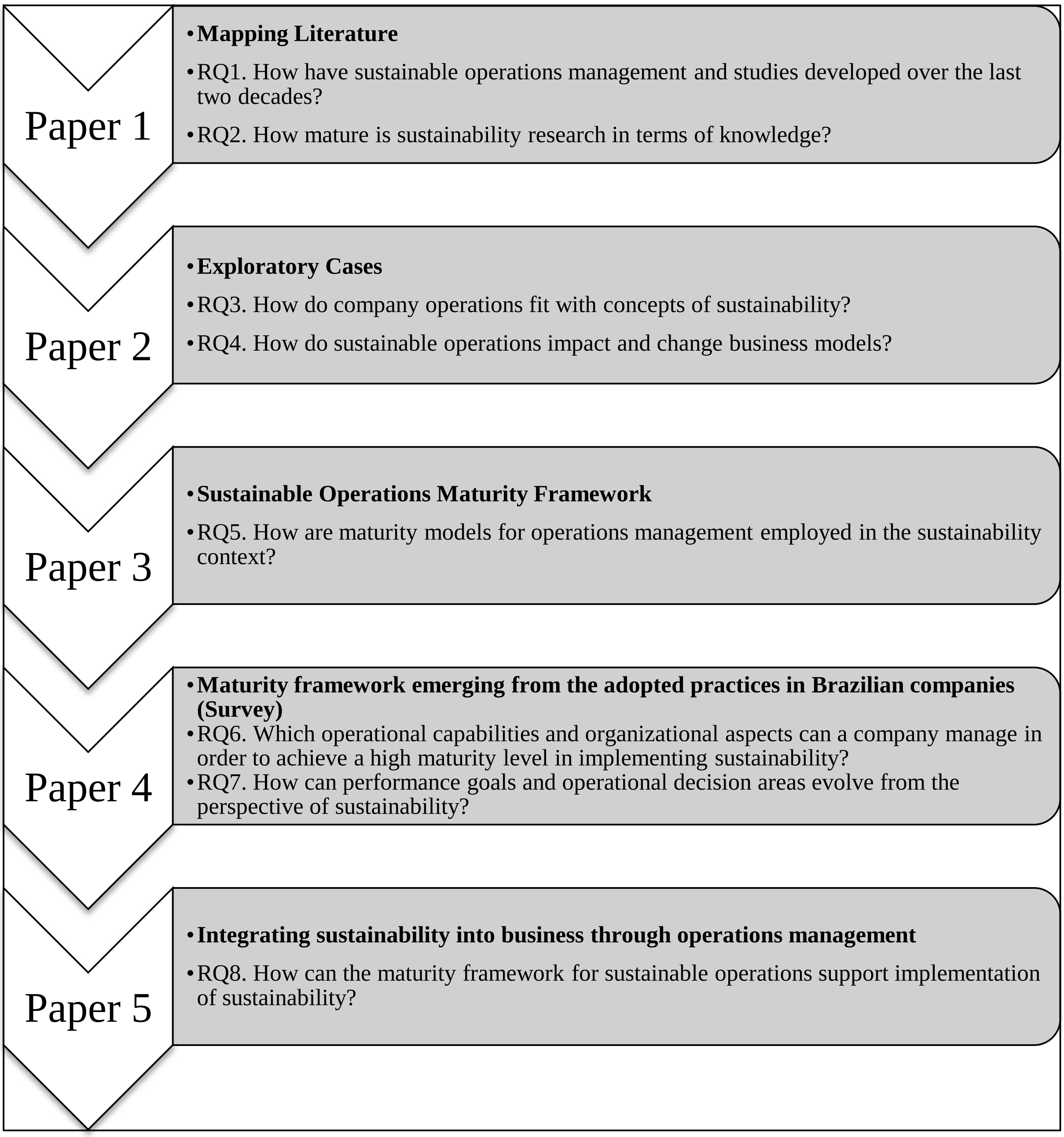
Based on the concepts presented, the main research question emerges: how can the capabilities of sustainable operations evolve and be managed in order to provide support for companies to improve and carry out sustainability integration processes?

This research aims to identify a pathway for sustainability implementation based on SOM maturity. In order to achieve this purpose and objective, eight research questions (RQ) have been formulated (Exhibit 2).

The complementary RQs were first defined based on the fact that companies are struggling to implement sustainability and how OM is related to a firm's sustainability performance. Second, they were based on the use of maturity models or frameworks to help companies achieve full sustainability development.

To answer these RQs, a review of the literature was conducted and empirical data was collected from companies recognized for their practices, through case studies and survey research.

Exhibit 2 - Research Questions




Source: the author, 2015.

Research questions 1, 2, and 5 are important because they contribute to the positioning of the thesis from the viewpoint of contribution to the field of OM, and because they are innovative in nature. Questions 3 and 4 are relevant for the development of the conceptual model, as the exploratory study indicates practices, evolution, and other strategic directives for implementing sustainability. Question 5 not only contributes to the positioning of the study, but also helps to identify how the capabilities of SOM evolve and can be grouped into maturity levels. Questions 6 and 7 seek to validate, adjust, and verify the feasibility of the conceptual model based on the empirical data from companies. Finally, research question 8 is important to answer the main question proposed in this study, because it permits the verification of the utility and applicability of the model, which was constructed based on the literature and company practices, in a real-world application.

## 1.3. RESEARCH OBJECTIVES

The main purpose of this research is to compile a SOM maturity framework for manufacturing companies, so that these companies can use to evolve in the implementation and integration of business sustainability.

To meet this objective, Specific Objectives (SO) were established, representing important steps in the development of the study. These objectives were elaborated within the research questions:

- SO1 - Describe the evolution and maturity of the research around sustainable operations management;
- SO2 - Analyze how the companies' operations management is related to the principles of sustainability;
- SO3 - Identify how sustainable operations impact the business models;
- SO4 Describe the use of maturity models in the context of sustainable operations management;
- SO5 - Structure a maturity framework for sustainable operations which considers the evolution of SOM capacities, the performance objectives, and the areas of decision within the operations;
- SO6 - Test the structure and maturity framework content based on the practices decided by and emerging from the companies;
- SO7 - Verify the applicability of the maturity model as an instrument for supporting sustainability implementation.

The aim of this research is to contribute to the evolution of the field of OM by analyzing empirical data and by assisting in the development of the theory of SOM by identifying the main capabilities that can lead sustainability integration toward maturity.

The thesis takes the approach that integration of sustainability requires the value chain perspective to integrate more sustainably into operations, and can be implemented via the maturity of SOM capabilities.

## 1.4. RESEARCH FOCUS AND LIMITS

This thesis is based on the compilation of a maturity framework for sustainable operations management in manufacturing and infrastructure companies, and is mainly concerned with integrating sustainability throughout the value chain.

There is no intention to presenting a “sustainable business model”. It is understood that companies are looking for new ways to operate, to understand, and to respond to internal and external environments. In this sense, we believe that the maturity of SOM capabilities must be considered as an essential competence for a sustainable business model.

The framework is limited to manufacturing companies, but is not related to a specific industry. According to the SustainAbility an IFC report (2002), the general business environment can be applied to different industries, although there may be variations in some specific elements.

The empirical data was collected from companies with operations in Brazil. According to international surveys, companies located in emergent countries such as Brazil have been developing robust strategies and obtaining successful results in turning sustainability issues into actions (KIRON et al., 2013b; SUSTAINABILITY; IFC, 2002).

This is a transversal study, which means that the findings are limited by the data collection period and may not include more recent issues. According to the SustainAbility report and the IFC (2002, p.6):

> […] while the trajectory of sustainable development’s profile is likely to continue rising, the subject will continue to be volatile. New issues are likely to emerge, often unpredictably. The challenges of three years hence will be very different from those three years ago.

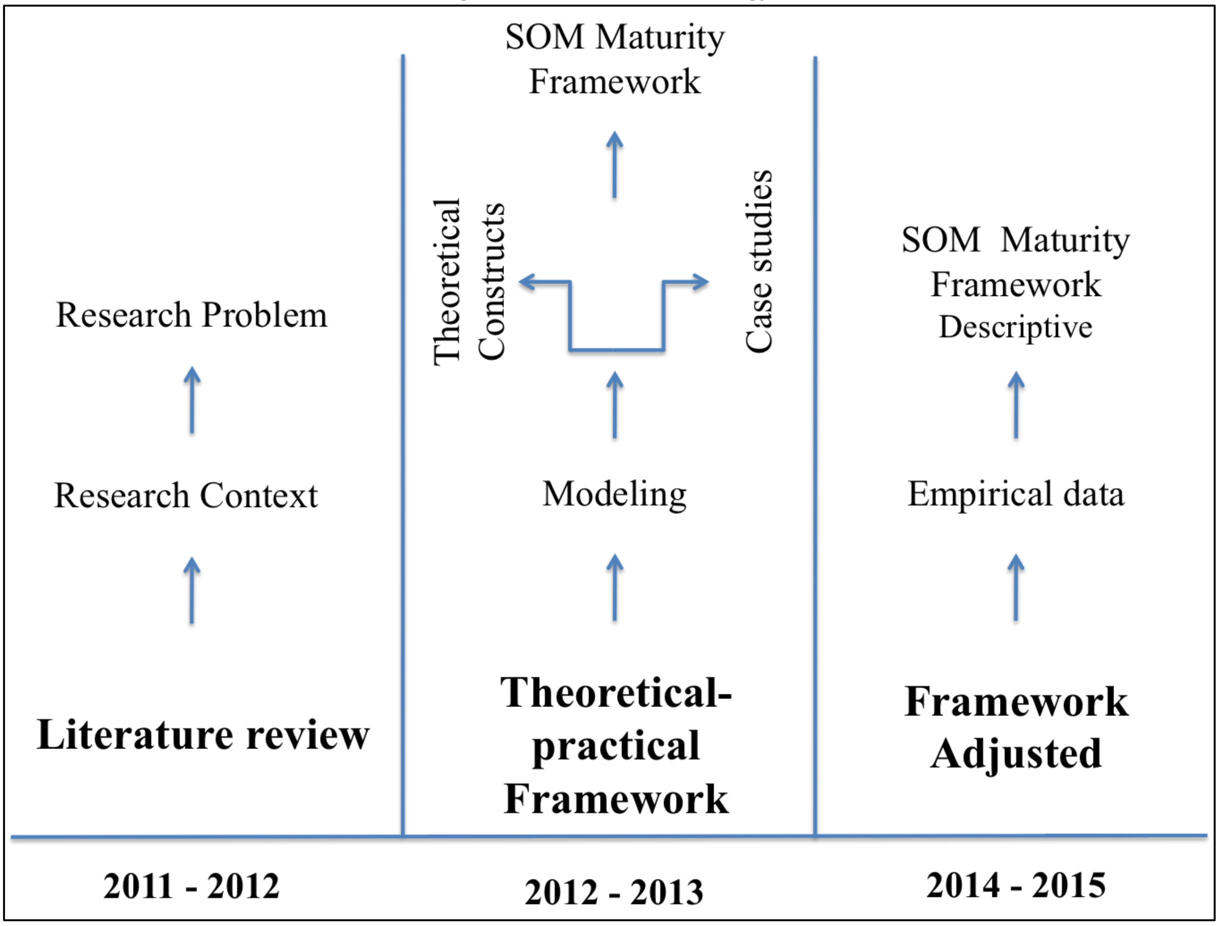
The framework considers a company’s point of view for its value chain, which means that the framework is not limited to focal companies.

Although the overall objective is to develop a maturity framework for sustainable operations, the research identifies characteristics and strategies to help companies in the implementation process. To do so, managerial orientations were identified in the literature and in the companies’ practices. However, this is an exploratory study, intended to be the first of a series of studies related to sustainable operations management. In this sense, the research is limited to proposing the framework based on the literature, the experts’ comments, and the collected empirical data.

## 1.5. RESEARCH CHRONOLOGY AND STRUCTURE

The research was conducted in three main phases, which are illustrated in Figure 2. During the research phase, the design and findings of the study were presented to other researchers. The contributors to the research project: Miguel Selitto, PhD, UNISINOS (December 2011); Ken Platts, PhD, University of Cambridge (March 2012); Geert Letens, PhD, Royal Military Academy, Belgium (October 2012); Lucila Campos, PhD, UFSC (May 2013); Wesley V. da Silva, PhD, PUCPR (May 2013); Jannis Angelis, PhD and Indek research group, KTH, Sweden (September, 2014); Mats Winroth, PhD and Naghmeh Taghavi, MSc, Chalmers University (September, 2014).

Figure 2 - Research chronology




Source: the author, 2015.

The other strategy adopted was to submit research findings to international conferences in order to receive comments and suggestions provided by qualified referees. The full set of articles and papers published during the research phases are listed in Exhibit 3.

Exhibit 3 - Research outputs

| Phase | | Outputs | |
|---|---|---|---|
| Literature Review | 2012 | 'Sustainability operations management: an overview of research trends' - Proceedings of the 2012 Industrial and Systems Engineering Research Conference, ISERC 2012 – Finalist Best Paper. | International conference |
| | 2012 | 'Industrial Engineering, Operations Management and Sustainability: an overview' - Proceedings of the International Conference on Engineering and Operations Management, ICIEOM 2012. | International conference |
| | 2013 | 'Gestão de Operações e Sustentabilidade: mapeamento intelectual do campo de estudo' - *Produto & Produção* – 2013. | Qualis B4 |
| | 2012 | 'Industrial Engineering, Operations Management and Sustainability: an overview' - *Brazilian Journal of Operations and Production Management* (BJO&PM) – 2012. | Qualis B4 |
| | 2014 | 'Operations management and sustainability: evolution, trends and opportunities' - paper submitted to *Journal of Cleaner Production* (under review). | Qualis A2<br>*Impact Factor: 3.844 |
| Theoretical-practical framework | 2012 | 'Sustainable operations strategy: theoretical frameworks evolution' - Proceedings of 19th International Annual EurOMA Conference, Euroma 2012. | International conference |
| | 2012 | 'Indicators formulation process for sustainable operations management' - Proceedings of International Conference on Production Research - ICPR America 2012. | International conference |
| | 2013 | 'Developing a sustainable operations maturity model (SOMM)' - Proceedings of the 22nd International Conference on Production Research, ICPR 22. Best Paper Award for a Young Researcher | International conference |
| | 2013 | 'Correlation process in content analysis for BPM modeling project' - Article accepted to the 22nd International Conference on Production Research, ICPR 22. | International conference |
| | 2013 | 'Sustainability Standards and guidelines requirements for integrated management' - Proceedings of the 22nd International Conference on Production Research, ICPR 22. | International conference |
| | 2013 | 'Sustainable operations maturity models characterization' – Proceedings of the 20th International Annual EurOMA Conference - Euroma 2013 | International conference |
| | 2015 | ‘Sustainability integration through an operations management lens’ - paper will be submitted to *Business Strategy and the Environment* (may 2015). | Impact Factor: 2.542 |
| Adjusted Framework | 2014 | ‘Studying sustainability process implementation through an operations management lens’ - Proceedings of 21st International Annual EurOMA Conference, Euroma 2014. | International conference |
| | 2014 | ‘Developing and testing a design process for sustainable indicators’ - Proceedings of the 2014 Industrial and Systems Engineering Research Conference, ISERC 2014 – Finalist Best Paper. | International conference |
| | 2015 | ‘Developing a maturity framework for sustainable operations management’ - paper submitted to *International Journal of Production Economics,* IJPE (under review). | Qualis A1<br>Impact Factor: 2.752 |
| | 2015 | ‘Capabilities’ organization for sustainable production’ - paper submitted to *International Journal of Operations & Production Management,* IJOPM (under review). | Qualis B1<br>Impact Factor: 1.736 |
| | 2015 | ‘Implementing a Sustainability Indicators Design Process Framework’ - paper submitted to *Computers in Industry* (under review) | Qualis A2<br>Impact Factor: 1.287 |

Source: the author, 2015.

### 1.5.1. Structure of the Remainder of the Report

This thesis consists of six chapters. Following the introduction in Section 1, Section 2 introduces the theoretical foundations on which the research has been based. The theoretical sections of the papers have been developed to support the specific research questions of each paper.

Section 3 examines and provides details about the methods and research strategies applied in each phase of the research.

Section 4 presents the conclusions and main outputs of the attached papers, and as a complement, Section 5 presents the discussion about the empirical and theoretical findings.

The analysis and discussion were conducted from the perspective of the scope and RQs, which are presented in Exhibit 4.

Exhibit 4 – Relationship between the research questions and specific objectives

<table>
<tr><th>Main RQ</th><th>Deployed RQs</th><th>SO</th><th>Papers</th></tr>
<tr><td rowspan="8">How can the capabilities of sustainable operations evolve and be managed in order to provide support for companies to improve and carry out sustainability implementation processes?</td><td>RQ1</td><td rowspan="2">SO1</td><td rowspan="2">I</td></tr>
<tr><td>RQ2</td></tr>
<tr><td>RQ3</td><td rowspan="2">SO2<br>SO3</td><td rowspan="2">II</td></tr>
<tr><td>RQ4</td></tr>
<tr><td>RQ5</td><td>SO4<br>SO5</td><td>III</td></tr>
<tr><td>RQ6</td><td rowspan="2">SO6</td><td rowspan="2">IV</td></tr>
<tr><td>RQ7</td></tr>
<tr><td>RQ8</td><td>SO7</td><td>V</td></tr>
</table>

Source: the author, 2015.

Finally, Section 6 presents conclusion, research contributions, and recommendations. The papers are included in the **APPENDIX 1**.

# 2. THEORETICAL FOUNDATIONS

This chapter presents the main theoretical concepts that underlie this research. Some of these topics can be found in the papers, such as sustainable operations and maturity models. However, in order to facilitate standalone readability, a broader conceptual background is provided herein.

Initially, some definitions of sustainability and sustainable development are presented, and definitions that fit the research scope are highlighted. Next follow the context and evolution of sustainable operations management, and the characteristics and use of maturity models in the sustainable operations area.

Sustainability integration demands changes in business and organizational culture, and so in this sense it was considered relevant to identify models and concepts which assist in processes of implementation.

## 2.1. SUSTAINABILITY AND SUSTAINABLE DEVELOPMENT

Hasna (2010) states that the definition of sustainability is complex, and that not only has the term been defined differently within and between cultures, but also changes over time.

In 1987, the WCED published a definition of sustainable development definition which is considered to be the most widespread: “Humanity has the ability to make development sustainable to ensure that it meets the needs of the present without compromising the ability of future generations to meet their own needs” (WCED, 1987, p.15).

Because of its comprehensive character, the WCED definition has been used as a reference for establishing other definitions related to sustainable development, and is often used to mean the word 'sustainability'. Mebratu (1998) presented interpretations of the term "sustainable development" in institutional, ideological and academic perspectives. This author identified that different definitions cite the WCED definition as a source of inspiration.

The BS8900 (2006) guide to sustainable development defines sustainability as "[...] an enduring, balanced approach to economic activity, environmental responsibility and social progress". According to BS8900, sustainable development is a journey, and the destination is hard to see or imagine for many organizations (WANG, 2008).

Sartori et al. (2014) presented two different approaches to defining sustainability and SD. The first, based on the definition by Dovers and Handmer (1992), stated that sustainability is the ability to endure, resist, or adapt, and SD represents “how” to achieve this long-term goal. In the second perspective, proposed by Elkington (1997), the triple bottom line balance (economic/environmental/social) represents sustainability; consequently, from this perspective SD is the long-term goal and sustainability represents "how" to achieve it.

The TBL has been a reference for how sustainability should be practiced. It combines social and environmental values with the traditional economic vision of the company (ELKINGTON, 1997; WILKINSON et al., 2001; PORTER; KRAMER, 2006; HUTCHINS; SUTHERLAND, 2008; UEDA et al., 2009).

Based on Elkington's definitions of TBL, Gimenez et al. (2012) provided some definitions related to manufacturing aspects:

- Economic sustainability: at the plant level, this has been operationalized as production or manufacturing costs;
- Environmental sustainability: the use of energy and other resources, the footprint companies leave behind as a result of their operations, waste and emissions reduction, pollution reduction, and energy efficiency;
- Social sustainability: focus on both internal communities (i.e., employees) and external ones (equal opportunities, encouraging diversity, promoting connectedness within and outside the community, ensuring quality of life and providing democratic processes and accountable governance structure).

Survey reports indicated that there still does not appear to be a single, widely accepted definition of sustainability for companies; in general, the term is used to refer to the integration of environmental, economic, and societal topics (BERNS et al., 2009; HANNAES et al., 2011).

In 2012, Brandlogic and the Institute for Supply Chain Management reported similar results. For the surveyed companies, sustainability represents the integration of TBL with the corporative governance dimension (BRIDWELL; CERRUTI, 2012).

Although the sustainability concepts are intuitively understood, expressing these in concrete and operational terms remains a challenge, especially implementing them into existing business models in a practical manner. Moreover, it is still possible to identify resistance to adopting more sustainable practices among businesses and society (LABUSCHAGNE et al., 2003; MISRA, 2008; KIRON et al., 2013a).

According to Misra (2008) companies' resistance to sustainability can be motivated by less flexible business models and systems, among other factors.

In this sense, Sartori et al. (2013, p.10) defines sustainability from the systemic perspective. According to these authors, sustainability requires

> […] open systems, to interact with society and nature, involving industrial systems (transportation, manufacturing, energy etc.), social systems (urbanization, mobility, communication, etc.) and natural systems (soil, air, water and biotic systems etc.), including flows of information, goods, materials, waste. That is, sustainability involves an interaction with dynamic systems that are constantly changing and require proactive measures (SARTORI et al., 2013, p.10).

For the purposes of this study, sustainability and sustainable development are intrinsically related. We agree with the definitions by Elkington (1994) and BS8900 (WANG, 2006), which maintain that SD is the main goal to be achieved through integrated management of the TBL dimensions.

However, Bettley and Burnley (2008, p.877) present another approach, which states that no business can declare "[…] itself a sustainable operation". They recommend adopting related approaches as "zero defects" and decisions based on trade-offs to achieve "more sustainable" operations.

Despite agreement with Bettley and Burnley (2008), we decided to adopt the expressions 'sustainability', 'sustainable', or 'sustainable development' to express the goal of developing operations to ensure financial returns, while at the same time considering and improving the environmental and social aspects.

## 2.2. SUSTAINABLE OPERATIONS MANAGEMENT

The field of operations management (OM) is recognized for its practical approach. One of its main characteristics is the construction of theories to explain routine managerial phenomena (AMUNDSON, 1998).

To Slack et al. (2004, p.385): "OM is a powerful lens through which it is possible to understand and improve the operational and strategic activities of nearly all organizations […]".

Operational strategy guides technologies, production design, and the system that establishes the degree of efficiency of the materials and the types of energy used. Furthermore, it also determines the type and intensity of wastes generated, and the sustainability of an ecosystem in relation to society. In this context, the field of sustainable operations management takes on a fundamental role in efforts to find solutions to complex sustainability questions (DRAKE; SPILER, 2013).

According to Gunasekaran and Irani (2014, p.1):

> […] both researchers and practitioners recognize the importance of SOM as a key strategic component in the development of cost-effective and sustainable global supply chains to meet the increasing needs of customers in terms of flexibility, responsiveness and cost while safeguarding natural resources for future generations (GUNASEKARAN; IRANI, 2014, p.1).

To Kleindorfer et al. (2005), the evolution of sustainable OM theory is clear in three areas: green product and process development, lean and green OM, and remanufacturing and CLSCs. These authors attribute the expectation to promote business changes to CLSCs.

To Gunasekaran et al. (2014), SOM:

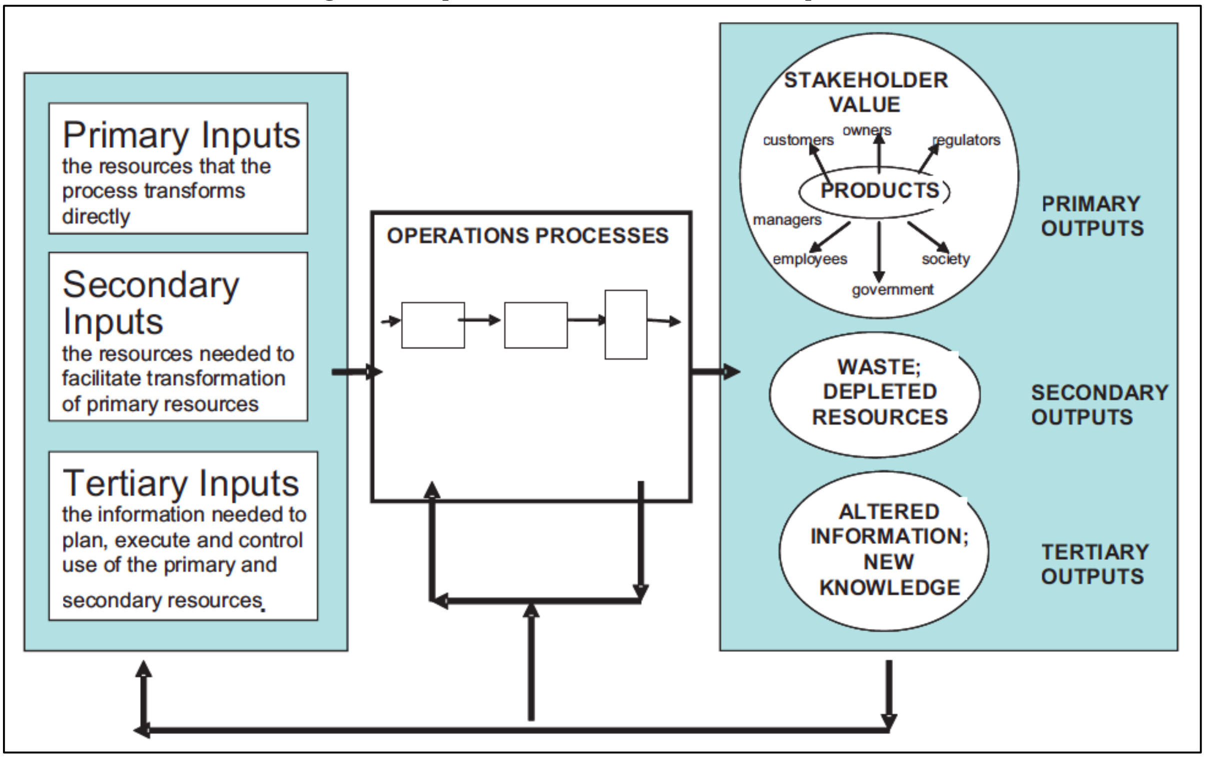
> […] implies that the management of operations should not only have cost reduction or economic interest as an objective, but should also consider and protect the environment through reducing for instance the carbon footprint, the cost of reverse logistics, remanufacturing and GSCM.

Sustainable operations management demands broader systemic vision of the operation, integrating the sustainability objectives into all levels (strategy, design, planning & control, performance measurement & improvement), and requires training for those managing operations (BETTLEY; BURNLEY, 2008).

Figure 3 shows the model expanded by Bettley and Burnley (2008) for sustainable operations. The expanded model proposed by Bettley and Burnley (2008) encompasses: expanded operations model/product/service system, product and process design to optimize life cycle performance, closed loop supply chains (CLSCs), reverse logistics (RL), stakeholder engagement processes, and risk assessment and management.

To Gunasekaran and Spalanzani (2012) SOM is represented by: CLSCs, green supply chain management (GSCM), cradle-to-cradle methodology, green purchasing or procurement, carbon footprint mitigation, quality, environment and social system management, RL and remanufacturing/recycling, lean operations, life cycle assessment (LCA), corporate social responsibility (CSR), and ethics.

Figure 3 - Expanded transformation model of operations

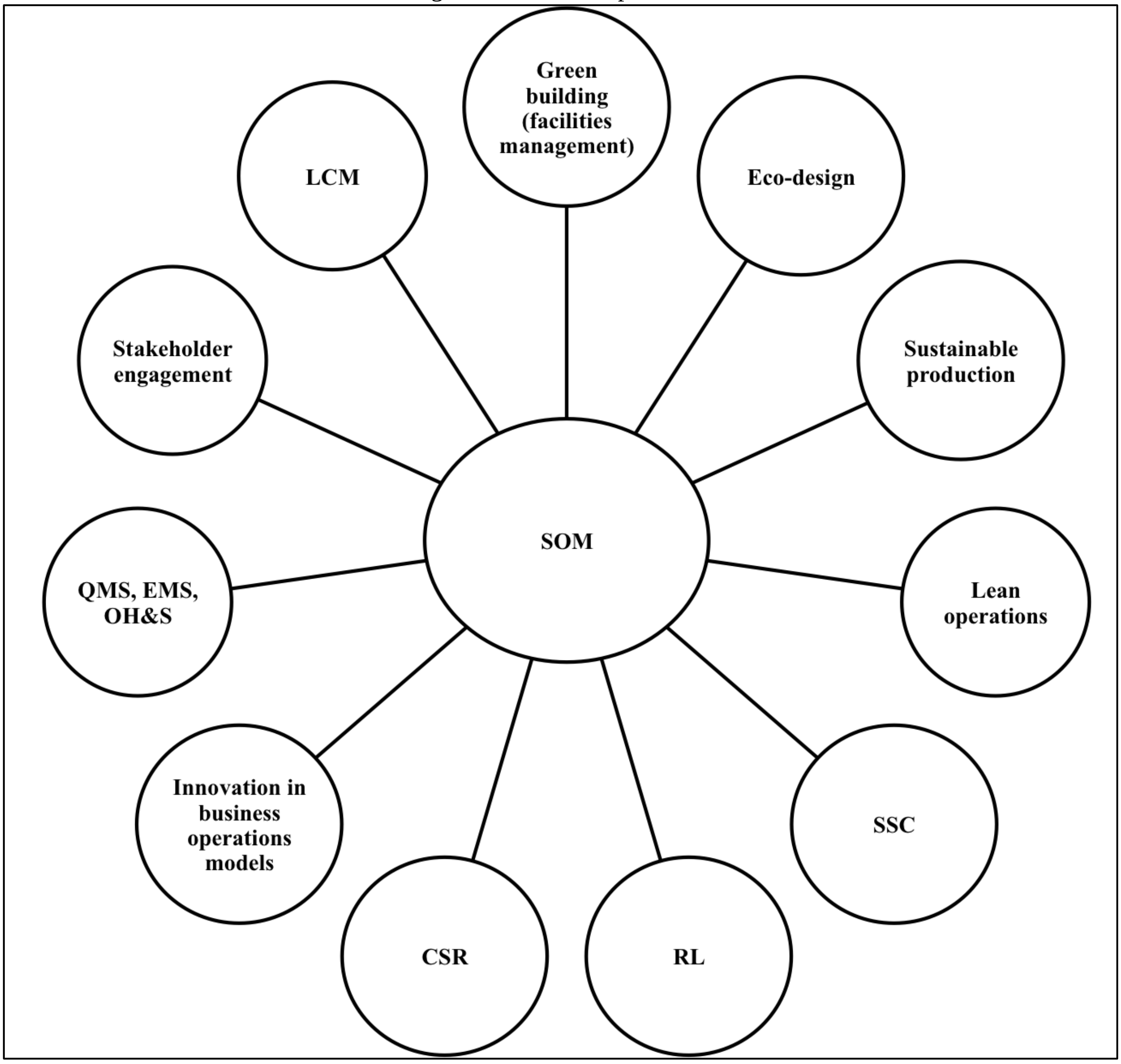



Source: adapted from Bettley and Burnley, 2008, p.880.

Nunes et al. (2013) have compiled SOM capabilities in seven main areas: (1) green buildings (facilities management), (2) eco-design (product and process development), (3) sustainable production (transformation processes), (4) sustainable supply chains (inbound and outbound logistics and supplier relationships), (5) RL, (6) CSR (internal and external communities), (7) innovation in business operations models (interface with other functions).

These seven areas encompass the main capabilities indicated by previous authors. However, we believe that some capabilities need to be added: integrated management system (quality, environment and social system management), life cycle management (LCM), and stakeholder engagement. Figure 4 represents the SOM capabilities considered in this research.

Figure 4 - SOM´s capabilities




Source: adapted from Kleindorfer et al., 2005; Bettley; Burnley, 2008; Gunasekaran; Spalanzani, 2012; Nunes et al., 2013.

The additional capabilities are relevant to supporting the integration of sustainability. LCM methodologies especially support sustainable product design and manufacturing processes (JOVANE et al., 2008; VALDIVIA et al., 2009; HEIJUNGS et al., 2010). Stakeholder engagement is critical to CSR, innovation models, and SSC (GAO; ZHANG, 2006; GRAYSON, 2011; MATOS; SILVESTRE, 2013).

A report from KPMG (2012, p.132) highlighted the need to integrate the areas and functions of all companies and actors in the value chain:

> […] to unlock the potential of a changing world, companies need to address the full range of organizational areas and functions […] include portfolio management, mergers and acquisitions, R&D and supply chain management and purchasing. It also includes departments such as communications, investor relations, government relations and public policy, human resources, risk and compliance, audit, financial reporting and tax (KPMG, 2012, p.132).

An integrated management system also supports the integration of economics, environmental and social (internal and external) dimensions relating to CSR, innovation, and sustainable production. Krajnc and Glavic (2005) suggested that performance indicators be grouped into a single platform to support the decision-making process. Consequently, to assess the performance of sustainable operations, the sequence of sustainability indicators must be logical and traceable in order to be replicated and comparable throughout the life cycle.

## 2.3. SUSTAINABLE OPERATIONS MANAGEMENT AND MATURITY MODELS

Hoffman and Ehrenfeld (2013) organized the evolution of corporative sustainability into four waves:

- 1960 – 1980: Regulatory compliance: complying with laws and regulations in response to environmental movements, such as the Club of Rome (1968).
- 1980 – 2000: Strategic environmentalism: a concern with reducing waste in product design and production processes (end-of-pipe) is added to compliance objectives and occupational safety.
- 2000 – 2010: Sustainability: solidification of the paradigm that climate change is caused by humans and new technologies are urgently needed to generate and conserve energy, food, and water. Companies begin to incorporate sustainability into their strategies and translate them in their mission and vision statements as well as their corporate values.
- 2010 – ?: Transformation and redefinition of the role of companies in society. This represents the correction/transformation of unsustainable models, and the emergence of sustainable business models that include the dimensions of the TBL.

As described in Hoffman and Ehrenfeld's third wave (2013), research reports from KPMG and MIT/BCG confirmed that aspects of sustainability have been gradually incorporated into business strategies with more intensity over the last decade  (KPMG, 2011;

HANNAES et al., 2011; KIRON et al., 2012).

According to Veleva et al. (2001, p.449): “[…] developing sustainable systems of production is a continuous, evolutionary process of setting goals and measuring performance”. The main objective of the model created by Veleva et al. (2001) is to help organizations to change their management processes, moving from compliance/conformity indicators to a complete set of sustainability indicators that respresent a sustainable system.

Based on previous models from Hayes and Wheelwright (1985), Wheelwright and Bowen (1996), and Hart (2005), Kleindorfer et al. (2005) proposed a framework for sustainable operations considering internal and external evolution in sustainable strategies:

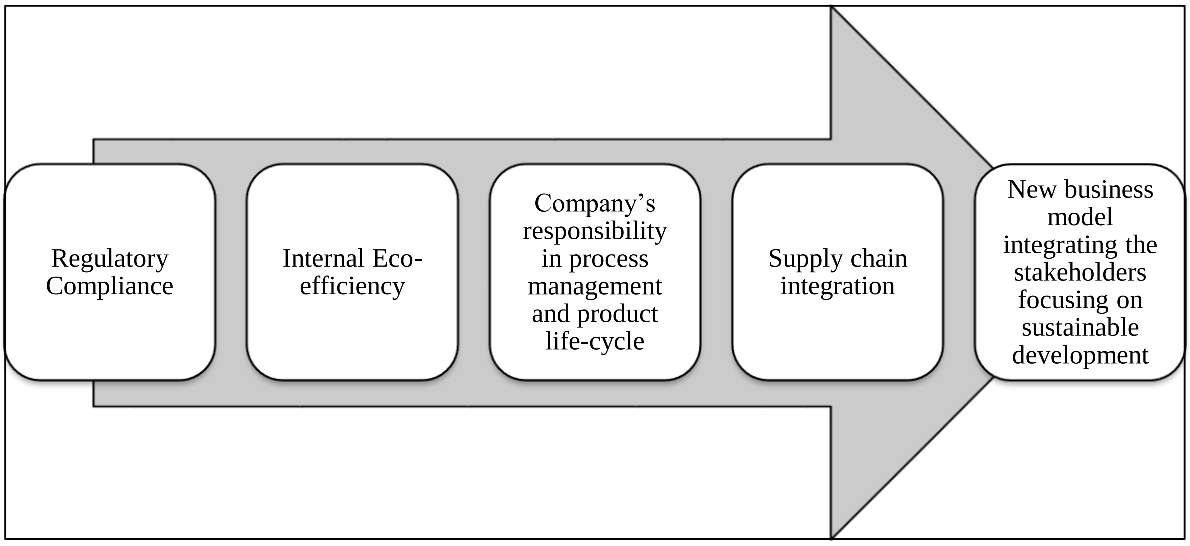
- 1 and 2 - continuous process improvement for internal operations and the extended supply chains (e.g. minimize process waste, enhance resource productivity, lower product life cycle impact, and increase transparency/accountability);
- 3 - develop capabilities focused on recovering pollution during manufacturing, substituting non-renewable or toxic inputs, and redesigning products to reduce material and energy consumption during the life cycle;
- 4 - develop capabilities for long-term sustainability in products, processes and supply chains (e.g. support collective actions).

To Lubin and Esty (2010), initial sustainability initiatives towards OM strategies were focused on costs and risk, and over time were directed towards new creating strategies and value, and valuing intangible resources such as brand and organizational culture. In this sense, companies need to evolve in their sustainability strategies and processes to respond to challenges or “megaforces” which are changing the business environment.

Based on these initial concepts, it can be inferred that the integration/implementation of sustainability in business can follow a trajectory, which originates from the very evolution of the concept, as described by Hoffman and Ehrenfeld (2013). Figure 5 shows this trajectory.

Maturity models have been used to represent this evolution of the integration of sustainability into OM.

Figure 5 - Evolutionary trajectory for sustainability integration




Source: adapted from Veleva et al., 2001; Kleindorfer et al., 2005; KPMG, 2011; Lubin; Esty, 2010; Hannaes et al., 2011; Kiron et al., 2012; Hoffman; Ehrenfeld, 2013.

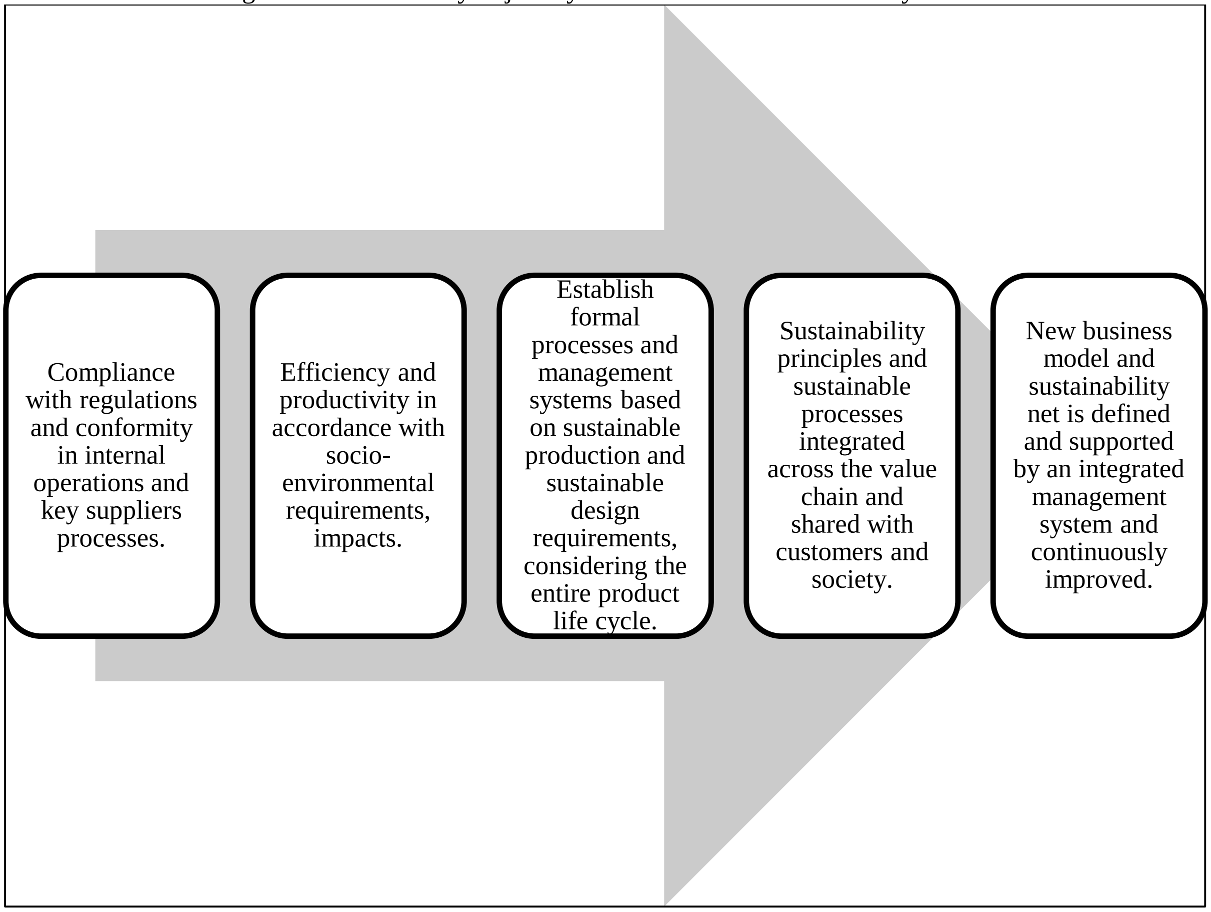
Pinheiro de Lima et al. (2012) summarized the evolution of the themes treated in the maturity models related to the context of SOM from 2001 to 2012:

- 2001 – 2003: focused on continuous improvement, product life cycle, evolutionary process, coordination strategies (companies, communities and government (local, regional, and national).
- 2004 – 2005: life-cycle management, quality of working life and social aspects, supply chain management, innovation sustainable nets, sustainability capabilities.
- 2006 – 2008: social sustainable supply chain, governance, participative structures, TBL: integration and coordination.
- 2009 – 2012: sustainable enterprise engineering, co-evolutionary systems, sustainable energy management, TBL integration: IT. HRM, SCM; total, net and open sustainable innovation.

The evolution of the themes described above and the results obtained by Pinheiro de Lima et al. (2013) and complemented by Machado et al. (2015) indicate evolution similar to the model described in Figure 5.

The maturity models developed in the field of SOM therefore follow an evolutionary pattern that is characterized by the sequence described in Figure 6 (MACHADO et al., 2015). The complete list of the models can be found in Paper III.

Figure 6 - Evolutionary trajectory for SOM identified in maturity models




Source: adapted from Machado et al., 2015.

The evolution described in Figure 6 indicates that the full integration of sustainability into operations only can be achieved when the supply chain and stakeholders are integrated into business management, including strategies development and decision-making processes.

### 2.3.1. The Capability Maturity Model

Many of the maturity models in the area of SOM which were studied by Pinheiro de Lima et al. (2012, 2013) were developed based on the capability maturity model (CMM) and capability maturity model integration elements (CMMI), which in turn were developed by the Software Engineering Institute at Carnegie Mellon University (SEI, 2010).

Both models became a reference for developing maturity models, including models for sustainability (SEI, 2010). The model put forth by Mani et al. (2010), called the sustainability manufacturing maturity model (SMMM), shows the use of guidelines from the CMMI.

In this sense, the structure and elements provided by the capability maturity model (CMM) and the capability maturity model integration elements (CMMI) can be understood as adequate references for structuring a maturity framework, as described in Exhibit 5.

Exhibit 5 - CMMI element description

| | |
|---|---|
| Maturity | The extent to which a specific process is explicitly defined, managed, measured, controlled, and effective. Maturity implies a potential for growth in capability and indicates both the richness of an organization's software process and the consistency with which it is applied in projects throughout the organization. (PAULK et al., 1993, p. A-20). |
| Levels | […] describe an evolutionary path recommended for an organization that wants to improve the processes it uses to develop products or services (CMMI, 2010, p.21). |
| Maturity Levels | […] sequence of levels (or stages) focused on matures a subset of the organization's processes, preparing it to move to the next maturity level[…] A maturity level consists of related specific and generic practices for a predefined set of process areas that improve the organization's overall performance (CMMI, 2010, p.26). |
| Process area | A process area is a cluster of related practices in an area that, when implemented collectively, satisfies a set of goals considered important for making improvement in that area (CMMI, 2010, p.ii). |
| Generic Goals and Practices | […] applies to multiple process areas. A generic goal describes the characteristics that must be present to institutionalize processes that implement a process area […] The generic practices associated with a generic goal describe the activities that are considered important in achieving the generic goal and contribute to the institutionalization of the processes associated with a process area (CMMI, 2010, p.13). |
| Specific Goals and Practices | A specific goal describes the unique characteristics that must be present to satisfy the process area. […] The specific practices describe the activities that are expected to result in achievement of the specific goals of a process area (CMMI, 2010, p.13). |

Source: Paulk et al., 1993; SEI, 2010.

According to CMMI (SEI, 2002), reaching a certain level of maturity means that all the processes have been completely institutionalized and added to the processes of the previous levels. For CMMI:

> Institutionalization is an important concept in process improvement […] institutionalization implies that the process is ingrained in the way the work is performed and there is commitment and consistency to performing (i.e., executing) the process (SEI, 2010, p.65).

The definition of CMMI indicates that institutionalization is related to organizational changes. The very CMMI model is guided by cycles of change that seek to institutionalize improvements and good practices (SEI, 2010).

Elkington (2004) affirms that changing to a sustainable model is complex, and it can be difficult for many companies to attain this change. To Schein (2004), one of the problems which are central to the current context is survival in and adaptation to the external environment, as well as integration of internal processes so that companies can continue to survive and adapt. In this process, the key is meeting the needs of the company's main interested parties.

For Borland (2009, p.564), integrating sustainability into strategic planning requires changes of individual, collective, and cultural paradigms. According to this author: “Changing corporate values, beliefs, assumptions and principles to fit with strategic sustainability are essential for successful implementation”.

## 2.4. ORGANIZATIONAL CHANGE MODELS AND ASPECTS FOR SUSTAINABILITY

For Nadler et al. (1995), the drivers of processes of organizational change can be grouped as follows: processes of discontinuity in the organizational structure, technological innovation, macroeconomic crises and trends, legal changes and regulations, market and competitive forces, and organizational growth.

The emerging challenges related to sustainability, such as those represented by Elkington’s ‘seven sustainability revolution’ (2004) and KPMG’s “sustainability megaforces” (2012) present characteristics which may be related to the drivers described by Nadler et al. (1995).

According to Deloitte (2010) "[...] the goal should be to embed sustainability considerations into a company’s strategy and operations in such a way as to enhance business value and derive a competitive advantage”.

For Millar et al. (2012), the processes of implementation and organizational change are key to the sustainability agenda. The process of transition towards sustainability requires incremental and transformative changes in the concepts of production, consumption, and business, representing systematic changes in the markets and in the organizational systems (RYAN et al., 2012).

Stoughton and Ludema (2012) identified two aspects of how companies should change their culture to become sustainable: (1) change fundamental paradigms, in other words, promote significant transformation and cultural change (e.g., Borland, 2009), and (2) sustainability requires moderate changes directed at improvements in processes, procedures, and reward systems (e.g., Epstein; Buhovac, 2010).

Authors such as Ryan et al. (2012) and Stoughton and Ludema (2012) also consider that implementation of sustainability into operations requires actions that are aligned with both approaches.

The contextualist model of change proposed by Pettigrew (1987, 1989, 2012), which is comprised by the three pillars of context, content, and process (described in Exhibit 6), allows an analysis of the processes of organizational change from a temporal perspective, as well as from inside and outside the company and its relationships; in other words, it allows different visions of the same occurrence.

Exhibit 6 - Pettigrew´s approach

| Strategic Changes | Description |
|---|---|
| Content<br>"What" of change | The content of the area of transformation, i.e., the content of the strategic change linked to the context inside and outside the company. |
| Context<br>"Why" of change | Macro and micro-environment and political context in which the company operates, and through which the ideas of change will occur. |
| Process<br>"How" of change | Identification and explanation of the process standards to demonstrate how the processes model the outcomes. |

Source – adapted from Pettigrew, 1987; 2012.

One of the central points of Andrew Pettigrew's model (1987, 2012) is the importance of action and leadership in the process of organizational change. As with the models by Mintzberg (1978), Burgelman (1983), the 'E' and 'O' theories by Berr and Nohria (2000), and Kotter's model (2007), Pettigrew's model also considers that the process of change in companies involves actions, reactions, and interactions from and between the various parties of interest, involving multilevel and continuous processes.

There are key aspects related to the process of organizational change and models connected to the factors which have been previously identified (Exhibit 7).

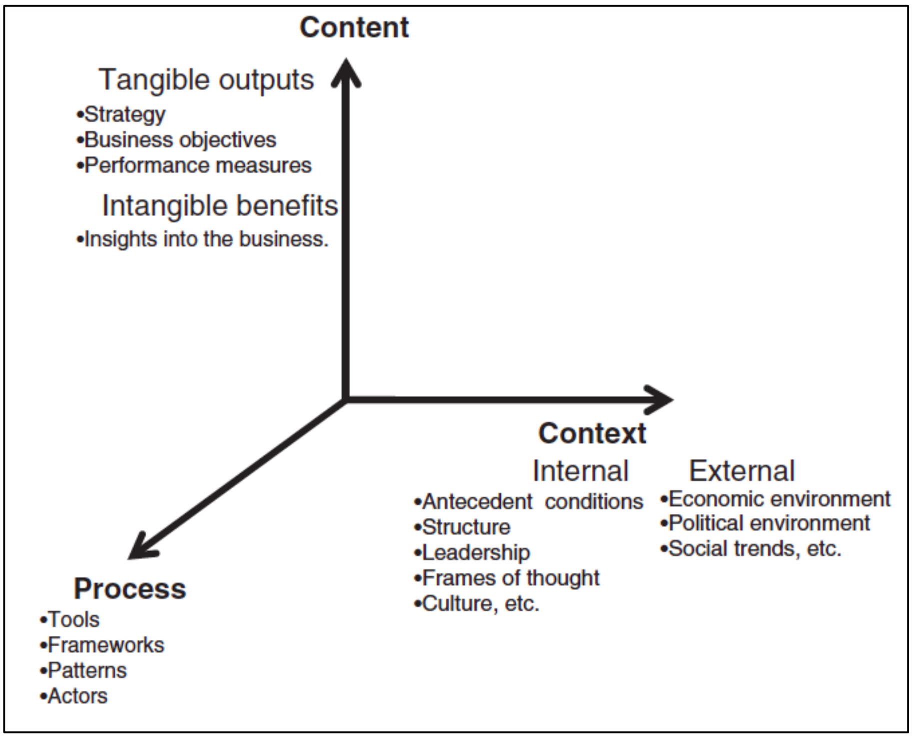
Exhibit 7 – Evaluation of Pettigrew´s model

| **Model** | **Context** | **Content** | **Process** |
|---|---|---|---|
| Leavitt (1965) | Technology and structure | Technology | Structure, technology, people and tasks |
| Rockart and Scott Morton (1984) | Structure | Strategy and management process | Individuals and their roles |
| Daft (2001) | Strategy and structure<br>Culture | Strategy and structure | Technology<br>products and services |
| Mintzberg (2003) | Strategic apex, support staff, and middle line | Ideology | Middle line, operating core, and technostructure |
| Galbraith (2005) | Rewards | Strategy | Processes and people |
| Peters and Robert H. Waterman (1982) | Structure, shared values, and style | Strategy | Systems, staff, and skills |

Source: the author, 2015.

In general, the models consider that the organizational aspects should be balanced, interrelated, and interdependent. This characteristic brings them closer to the contextualist model (shown in Figure 7) which considers perspectives from inside and outside the company, as well as the relationships between these perspectives.

Figure 7 - Three essential dimensions for understanding strategic change




Source: adapted from Pettigrew et al., 1989.

Pettigrew's model (1987, 2012) has been used in different areas such as human factors, e-commerce education, performance management, and manufacturing strategies (DAWSON, 2005; TORASKAR; BONN LEE, 2006; PLATTS, 1994; FRANCO-SANTOS; BOURNE, 2005).

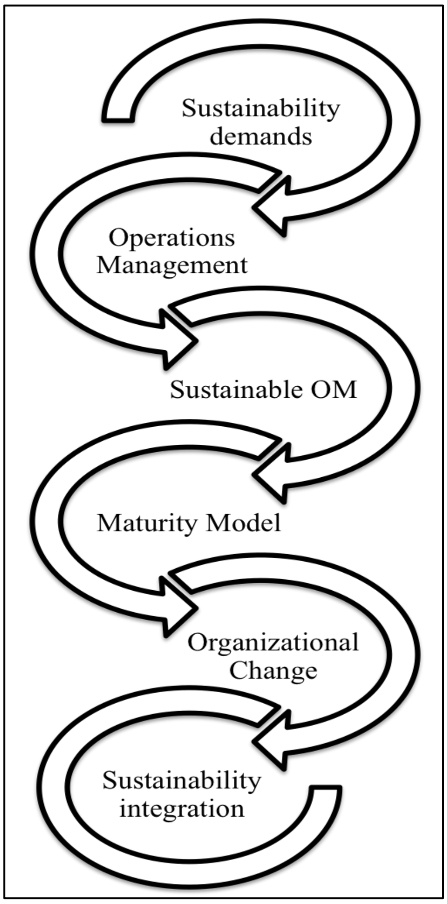
However, the model has been criticized for not offering practical managerial advice to classify the 'context' and because the meanings of 'context' and 'process' may overlap (BUCHANAN, 1991; DAWSON, 1994; CALDWELL, 2006). Despite the criticism, the contextualist model is considered an adequate structural model for representing the set of relevant organizational aspects related to the processes of organizational change required for sustainability.

Along these lines, Pettigrew's model (1987, 2012) was utilized in identifying the maturity models and frameworks that were the base for developing the conceptual model, guiding the design of the survey questionnaire in order to guarantee that the main aspects of change were covered (Paper IV); finally, the dimensions were included in the form which summarizes the levels, presented in Paper V.

## 2.5. SUMMARY OF THE MAIN CONCEPTS OF THE DISSERTATION

In accordance with the information presented in sections 1 and 2, Figure 8 presents the relationship between the principal themes.

Figure 8 - Concepts supporting the research in this dissertation




Source: the author, 2015.

- Sustainability represents how to achieve sustainable development.
- Sustainability means balance/integration of the TBL dimensions.
- SOM represents TBL integration into operations management, considering activities throughout the entire value chain.
- Maturity models are considered a relevant tool for companies dealing with complex sustainability demands, providing a starting point and organized steps for process improvement.
- The processes of implementation and organizational change are fundamental for the sustainability agenda, which requires systemic changes in the markets and in the organizational systems
- The junction of SOM strategies and maturity models or frameworks can result in an evolutionary path towards full sustainability integration.

Complementary theoretical concepts are provided in the five papers presented in **APPENDIX 1**.

The next section presents the research design and the methods applied in each research phase.

# 3. RESEARCH DESIGN

This chapter presents the methods used to perform the research. First, the main research approach is justified. Next, the different methods used are presented, along with their relation to the research objectives.

The decisions about what methods to use were derived from the overall purpose and aim of the research. In addition to this, the feasibility of the different methods under consideration was taken into account.

This research seeks to broaden the concept of triangulation to its three macro steps, where the proposed model will be based on four main sources: literature (academic and professional); case studies, panel studies, and survey data collection.

## 3.1. QUALI-QUANTI DESIGN

As stated in the introductory section, the shift to sustainable models can be considered one of the most complex in history, and not all organizations will be able to go through this transition (ELKINGTON, 2004).

For Boyer and Swink (2008) the problems related to operations research and supply chain management (ORSC) are complex and require multiple approaches for a broad understanding that permits the development of theories explaining business processes. The authors classify ORSC research as "social science", and the empirical data are fundamental to identifying the social and behavioral elements involved. Multiple empirical methods can provide the variety of perspectives needed to improve operations and supply chain research.

For Brewer and Hunter (2006, p.14), “Multimethod research, considered in the broadest sense, includes any research that contributes in any way to gaining a multimethod view of a social phenomenon”. But no method is perfect. Each method, when applied appropriately, can provide empirical validity and theoretical generalizations about social aspects (society and social life); however, not applying them alone does not allow other interpretations for the phenomenon. The multimethod approach permits the strengths of the different methods to be combined to offset each method's natural weaknesses, and is indicated for research areas with little intellectual and social integration.

This study is characterized as a multimethods study, which combines qualitative and quantitative approaches. For Ensslin (2008), quali-quantitative studies are indicated when the problem is represented by questions that are not very structured, and problems involving actors, contexts, and processes.

According to Martins (2010, p. 56):

> […] the possibility of using all methods and data-collection techniques available, instead of being restricted to those of each approach, can provide more comprehensive evidence than would be provided by separate approaches [...] it is possible to work with broader research questions that would not be completely answered using one of the approaches alone [...] one kind of evidence obtained by one of the approaches does not tell the complete story, or the researcher cannot be confident that this type of evidence can answer the research question.

In their editorial in the *Journal of Operations Management*, Boyer and Swink affirmed "[...] multiple approaches are required in order to develop a holistic understanding of operations and supply chain management phenomena" (BOYER; SWINK, 2008, p. 339). Analysis of empirical data is fundamental to validating business process models.

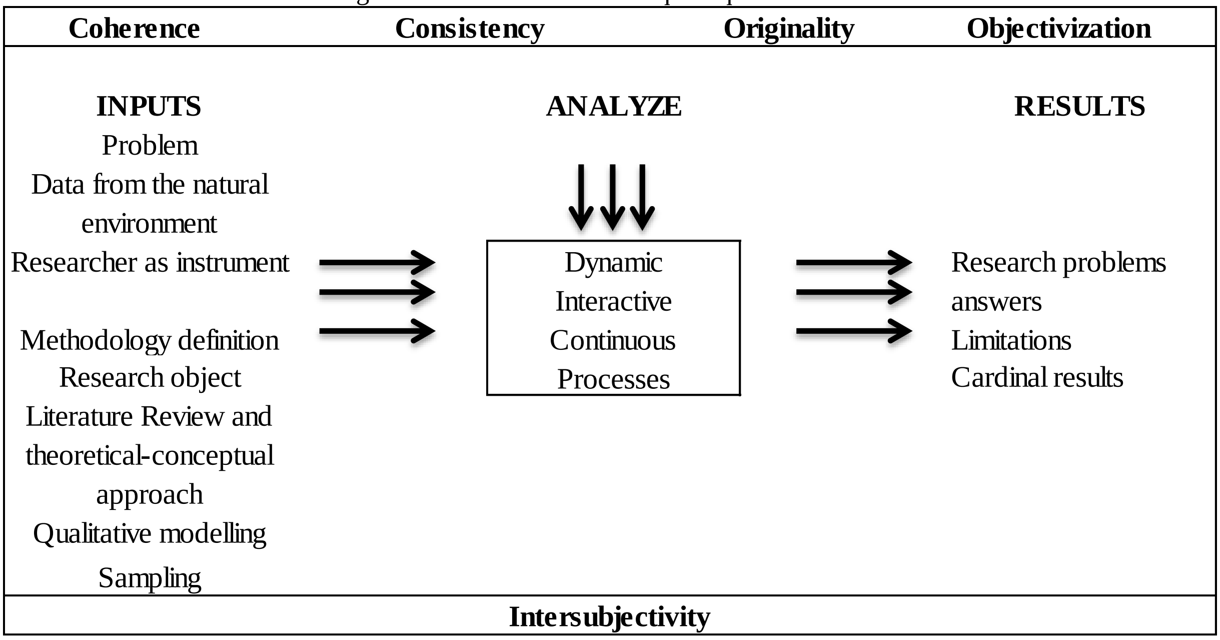
For Lovejoy (1998), this theory is composed of fundamental theories and empirical relationships, which provide "building blocks" used to explain a higher-level phenomenon.

In the field of industrial engineering, it is common to seek answers to specific problems based on quantitative analysis (mathematical models and simulations), but there are gaps in the sense of understanding the nature of the problem, in other words, solutions are sought for questions which are not exactly known. In this way, research moves towards adopting multiple approaches in addition to a statistical model, which also favors subjective aspects in explaining the problem and how social systems and meanings can impact a given problem, or help explain it (ENSSLIN et al., 2000; ENSSLIN; VIANA, 2008)

Ensslin (2008) presented a quali-quantitative research design model for the field of industrial engineering (Figure 9). Based on the studies by Demo (1986), the theoretical-practical research design proposed presents the following internal and external criteria for scientific validity:

- coherence: logical argumentation, well-connected;
- consistency: argumentative quality;
- originality: innovative, contributing knowledge;
- objectivation: attempts to reproduce reality as closely as possible;
- intersubjectivity: validity of the reigning scientific argument, prevailing opinion of scientists.

Figure 9 - Ensslin's model for quali-quanti research




Source: adapted from Ensslin (2008).

The establishment of an initial research project containing linked steps and interrelated objectives sought to meet the criterion for coherence. The decisions to submit the partial results at conferences in the field, where the results could be evaluated by qualified experts, and to submit the project to other researchers (as described in section 1.5), were made to fulfill the conditions for consistency.

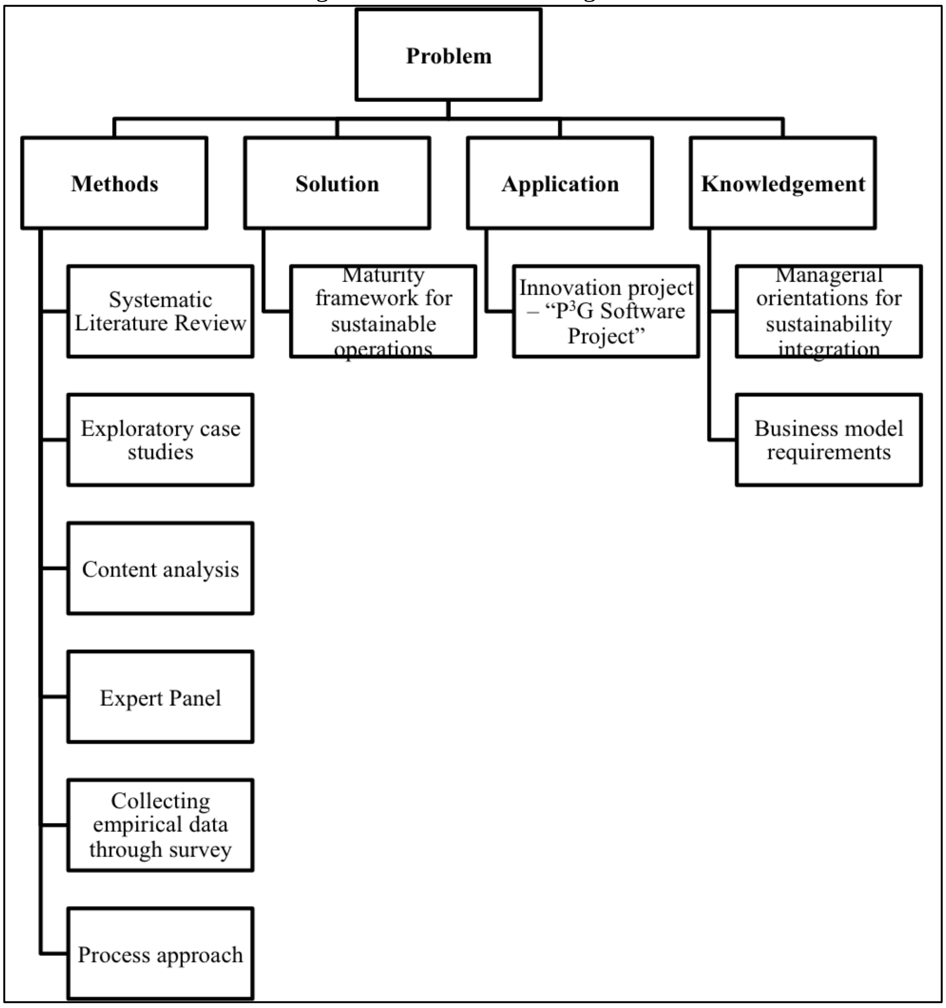
Data collected in the two reviews of the literature sought to ensure the criteria of originality (a primary requirement for a doctoral thesis) and guided the choice of journals for submission of the papers which were generated; the exploratory case studies and the survey questionnaire sought to meet the criterion of objectification and to provide the elements needed to reproduce reality. The search for state-of-the-art sustainable operations management and the academic and professional maturity models as well as collecting data from global studies addressed the external criterion of subjectivity.

Based on the decision tree by Creswell and Clark (2006), the quali-quantitative approaches were applied sequentially, following explanatory criteria, where the goal was to seek explanations for the results of the quantitative approach or even to better understand the characteristics of the population after the quantitative study. In the case of this survey, the purpose of applying the quantitative approach was for the second reason, in the systematic literature review and in testing the organization of the maturity levels

## 3.2. QUALI-QUANTITATIVE RESEARCH DESIGN

Based on the model by Martins (2010, p. 7), the problem solving adopted in this survey is shown in Figure 10.

Figure 10 - Problem-solving flow




Source: adapted from Martins, 2010.

Because the main objective of this research is to compile a conceptual framework, based on and supported by empirical data, it was considered appropriate to analyze whether the characteristics of the scientific models presented by Franck (2002) were met, and whether Ensslin's criteria (2008) were met. In this sense, scientific models need: (1) to simplify the representation of the reality; (2) to clarify what is considered essential in this reality; (3) to be testable; (4) to themselves become the object of study; (5) to be conceptual; (6) to allow measurement and calculation; (7) to explain the reality; (8) be a fictive representation of the reality; (9) to represent systems; (10) to be isomorphic and homomorphic (having the same form) to the systems represented.

Initially provided for scale development in measurement models, the model by MacKenzie et al. (2011) inspired the development of the conceptual framework. The steps suggested by the authors are: (1) Conceptualization: develop a conceptual definition of the construct; (2) Development of measures: generate items that represents the construct, and assess the content validity of the items; (3) Model specification: formally specify the measurement model; (4) Scale evaluation and refinement: collect data to conduct the pretest; (5) Validation: gather data from a new sample; (6) Norm development: develop norms for the model.

Each method was chosen in order to meet the requirements. The research methods adopted were applied in the three research phases, described in Figure 2. The overall research method is outlined in Exhibit 8.

Exhibit 8 - Research focus, goals, methods applied and scientific model characteristics

| | **Paper** | **Focus** | **Methods** | **SO** | **Franck's (2002) requirement** |
|---|---|---|---|---|---|
| **1st phase** | PAPER I | Identify the state of the art related to sustainability and operations management in the field | • Systematic literature review<br>• Social network analysis<br>• Multivariate data analysis<br>• Content Analysis<br>• Cycles of Theory Building | SO1 | 5 |
| **2nd phase** | PAPER II | Identify the standards for implementing sustainability through practices, trajectories, motivations, barriers, and the evolutionary path. | • Case studies | SO2<br>SO3 | 1 and 2 |
| | PAPER III | Mapping the evolution of sustainability maturity models applied to operations management | • Systematic literature review<br>• Content Analysis<br>• Term Network | SO4 | 5 |
| | | Theoretical-practical model of maturity in sustainable operations management | • Expert panels<br>• Multivariate data analysis | SO5 | 5 |
| **3rd phase** | PAPER IV | Maturity framework for sustainable operations management | • Survey data collection | SO6 | 3, 4, 7 and 9 |
| | PAPER V | Apply the concept of maturity in a practical study | • Process Approach | SO7 | 6, 8 and 10 |

Source: the author, 2015.

The procedures and methods used in the research are described in the following section.

## 3.3. DATA COLLECTION AND ANALYSIS

In order to avoid repeating the information described in the papers, this section provides a non-exhaustive description of the methods used in the research, supplemented by a description of the methods found in the papers. In this way, the general concepts and objectives of the application are described.

### 3.3.1. Systematic Literature Review (SLR)

The first step in a research project is attempting to understand the current stage of the field of knowledge relative to your research topic (Levy; Ellis, 2006).

SLR is characterized as a replicable, scientific, and transparent means of reducing bias through exhaustive literature searches and by providing an audit specification of the reviewers' decisions, procedures and conclusions (MULROW, 1994; COOK et al., 1997). According to Mulrow (1994), "[…] systematic literature review is needed to refine these unmanageable amounts of information". For Cook et al. (1997), "Investigators need systematic reviews to summarize existing data, refine hypotheses, estimate sample sizes, and help define future research agendas.

According to Hart (1998) and Tranfield et al. (2003), SLR brings more reliability to the knowledge development process, and methodological rigor to the reviewing process.

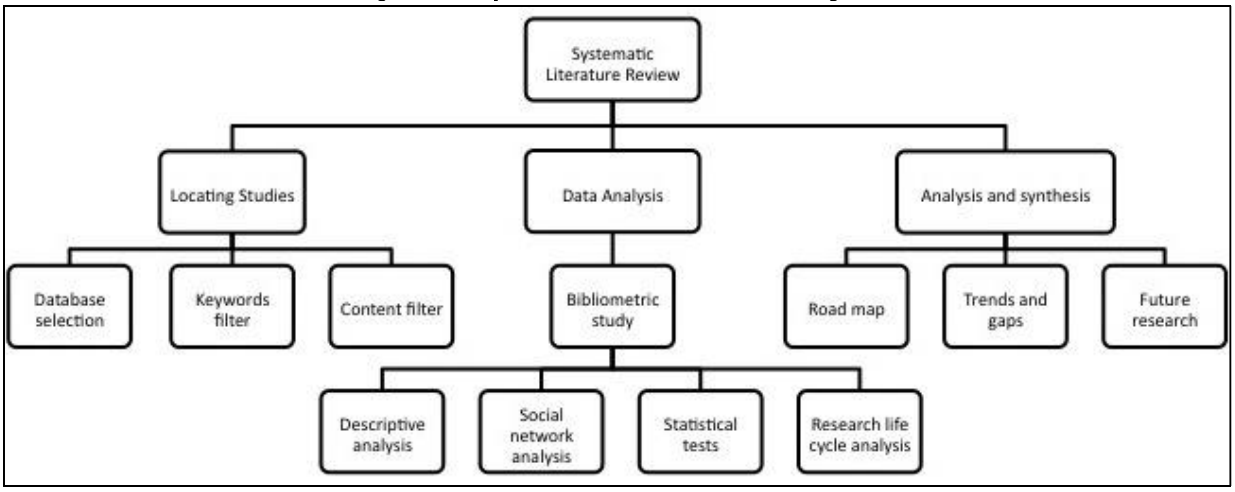
Mulrow (1994) sets out arguments for the use of systematic review: the amount of data available; the need to generate and integrate data for decision-making; the fact that it is a feasible way to conduct scientific research, the general results of several surveys can be compiled into systematic reviews, it permits analysis of the consistency relationships between study results, it allows inconsistency and conflicting results to be identified, statistical analysis of metadata from systematic research can be used to identify trends and map research opportunities, increased accuracy in estimating risk or the effect of the sample size, and improved reflection of the reality in an existing area of knowledge related to a particular area.

In order to clearly and properly define the research questions, the use of literature review is relevant not only for mapping the approaches to the studied topic, but it allows refinement or more specific targeting for some topics, as well as identifying gaps for new research approaches. In this way, it is possible to position the object of the research within the context in the field (CROOM, 2005).

For Levy and Ellis (2006), SLR is useful for several reasons: the researcher scales and better understands the field of knowledge related to the topic, identifying gaps and opportunities for new approaches, helps to build a solid theoretical basis for the research, contributes to the foundation for defining the research problem, helps to justify the research and its contribution, and helps define and plan the research method, goals and other issues for the research.

Guidelines for conducting SLR can be found in several studies, such as: Webster and Watson, 2002, Tranfield et al. (2003), Kitchenham (2004), Levy and Ellis (2006), Armitage and Keeble-Allen (2008), and Conforto et al. (2011), among others. Based on the authors presented, the research design of this literature review was developed to meet these requirements (Figure 11).

Figure 11 - Systematic literature review design




Source: adapted from Webster; Watson, 2002; Tranfield et al., 2003; Kitchenham, 2004.

The procedures adopted to conduct the review of literature in the field of sustainability within the context of operations management (OM) were selected based on previously conducted field mapping studies. Among these, the following stand out: Sower et al., 1997; Pilkington and Heyes (1999); Pilkington and Fitzgerald, 2006; Bayrakatar et al., 2007; Seuring and Muller (2008); Taylor and Taylor, 2009; and Pilkington and Meredith, 2009.

The approaches adopted (Exhibit 9) seek better explain the relationships between the authors and the impact on scientific production in the field, strengthening inferences and providing a more robust targeting for the evolution of sustainability studies in the field of OM.

Exhibit 9 - Strategies and objectives

| Strategy | Objectives |
|---|---|
| Bibliometrics - Descriptive analysis | ✓ Productivity of the authors;<br>✓ Countries represented by the studies;<br>✓ The researchers' countries and institutions;<br>✓ Chronology of the most commonly used research methods in assessing the degree of maturity in the field;<br>✓ Most cited references;<br>✓ Identification of predominant themes (keywords). |
| Analysis of social networks | ✓ Obtain measures for the centrality of the network;<br>✓ Most cited and most influential authors;<br>✓ Identify central and peripheral authors;<br>✓ Identify research communities (clusters) of authors and keywords;<br>✓ Degree of concentration of the author networks (density).<br>✓ Visualization of author networks |
| Statistical Tests<br>- Kolmogorov-Smirnov (KS)<br>- Spearman<br>- Linear regression<br>- Kruskal-Wallis<br>- Mann-Whitney<br>- Chi-squared | ✓ Test measures of network centrality as valid discriminants for field mapping;<br>✓ Analysis of the degree of influence positioning in the network had on the productivity of the authors.<br>✓ Determine which of the variables exerts greater influence on productivity and establishes positioning in the network |

Source: the author, 2015.

The exploratory study was conducted based on bibliometric data extracted from 495 papers published from 1995-2011. The sample is considered relevant because it comes from selected academic databases and from relevant journals that principally communicate research results in the area of operations management. Details and complementary information are available in Paper I.

### 3.3.2. Content analysis

To Bardin (2011), content analysis can be used to enrich exploratory analysis or to prove hypotheses/affirmations, which can then be used in a complementary manner.

Content analysis consists of using techniques to clarify and systematize the content of the messages and expressions in order to produce knowledge from the data analyzed. More meanings and senses can be found in the text than through a normal reading; in other words, a "profound meaning" is gleaned from the texts. The reading done by analyzing communications content is not a "word for word" reading, but instead one that looks for background meaning (ROCHA; DEUSDARÁ, 2005; BARDIN, 2011).

Based on this premise, in order to increase the understanding of how sustainability has been incorporated into the traditional themes of OM and its evolutionary path, content analyses were conducted at two different times: (1) review of the literature on sustainable operations management (Paper I), and (2) analysis of the academic and professional maturity models (Paper III).

For validation, the conduct must meet and respect some quality criteria (FREITAS; JANISSEK, 2000):

- Reliability: it must be objective and the results should be independent of the instrument used for measurement, as it is convenient to minimize the differences in point of view between the analysts. Verification of reliability is intended to provide a base for inferences, recommendations, decision-making support or even acceptance of a fact.
- Logical validity: an analysis is valid when the quantified description it provides about content is significant for the original problem, and faithfully reproduces the reality of the facts that it represents.
- Inference: some of the expressions have more than one interpretation, and even positive or negative interpretations, depending on the context.
- Empirical validity: instead of convictions, prudence and humility are recommended for drawing conclusions.

The quality criteria are related to the quality of conceptual elaboration done by the researcher *a priori* and to the accuracy of the procedures for translating them into variables, research outlines, or analytical categories. Bardin (2011) organizes the process of content analysis into four stages: (1) definition of the sample; (2) categorization; (3) choice of the units of analysis; (4) qualification. In the first application of the content analysis, stage 3 resulted in the selection of 70 papers (from a total sample of 495 papers). The details of the other strategies and applications are described in Paper I.

In the definition step, it is necessary to demarcate and define the universe that is being studied. In categorization, the dimensions that will be analyzed are defined along with the rubrics, which will be the base for classifying and quantifying the content. In the analysis units, parameters related to the content, to contexts, and to spatial or temporal features are established. Finally, the qualification stage allows the characteristics of the texts to be combined with the universe studied.

Both the results obtained in the content analysis and the social networking analysis were conducted from the perspective of the survey life cycle, which is described below in section 3.3.4.

### 3.3.3. Social and Term Network Analysis

Social relations in the network of authors contribute to developing scientific knowledge and establishing a discipline. Understand these relationships supports the mapping of knowledge in a particular field (WASSERMAN; FAUST, 1994; ROSSONI, 2006; LEYSDESDORFF, 2007).

Almeida and Vosgerau (2007) explain that through networks, it is possible to obtain an overview of the encoded information, permitting the establishment of relationships and theories and comparisons of subjects. For Rossoni and Hocayen-da-Silva (2008), the indicators obtained from analyzing social networks may indicate how contacts (direct or indirect) correlate with scientific production and the intellectual mapping of a discipline.

By having a privileged position in a network, a determined "actor" may obtain advantages in the exchange of information, in addition to having more influence and greater recognition among the other components of the network who hold less favorable positions (HANNEMAN; RIDDLE, 2011). Through the analysis of the social network, cohesive subgroups (clusters) can be identified: these feature stronger, direct, cohesive, intense and frequent ties (WASSERMAN; FAUST, 1994).

Using UCINET/NETDRAW software, the method was applied in the literature review step (Paper I) with the following main objectives: (1) identify the authors with a greater level of interaction and influence in the sample analyzed, by means of their position in the network; (2) determine the level of concentration of the community; (3) identify the formation of groups in the community, the main topics discussed, and their distribution between the groups; (4) identify gaps and opportunities to conduct research that will contribute to the development of the field of study of SOM.

In the second stage (Paper III), the main objective was to extract and organize the data into five levels of maturity (a number defined based on the literature review) related to the decision-making areas and traditional performance objectives (identified in the preliminary study by Pinheiro de Lima et al. (2012). The software chosen for this purpose was Atlas.ti, due to operational advantages that were considered relevant. According to Walter and Bach (2009) Atlas.ti offers: flexibility because it can be adapted to different research, agility and ease in the analysis process, the ability to record the steps in the analysis, facilitating empirical proof of the interpretations and changes during the process. Atlas.ti does not automate the analysis process, and requires interpretation by the researcher.

According to Pinheiro et al. (2008), the decision-making areas define the domain of the operations functions. Hayes and Wheelwright (1984) explain that the areas of decision-making and performance directly influence operations strategy. The results of organizing the data are summarized in managerial criteria and related capabilities for each maturity level, described in Paper III. This result was important for developing the conceptual framework.

The results also allowed the identification of elements to evaluate each level, which were related to the CMMI level criteria and defined the decision-making on the scale used to evaluate the practices and processes in the survey questionnaire (Non-existent, Initial, Managed or repeated, Defined, Quantitative Managed, Optimized). This step in the project was conducted with the support of a scientific initiation student (participant in the PIBIC program) and reported through the research technical report (in Portuguese).

### 3.3.4. The Theory Life Cycle

According to Popper (1972), knowledge evolves through the emergence and autonomous corrections of errors; for this to occur, the practical problems must be faced with the assistance of the theoretical methods, i.e. through trial-and-error cycles where created hypotheses can be tested and subjected to the validations. Nevertheless, even after testing, a theory cannot be considered true. We can say it is better compared to previous theories because it succeeded in the tests that proved the other theories to be false (CHALMERS, 1993).

For Carlile and Christensen (2005), the development of a theory occurs in two phases: (1) the descriptive, which aims to create greater familiarity with respect to a fact or phenomenon, utilizes literature surveys, interviews, visits, and other sources; (2) the normative, which tries to create an acceptable theory for a fact or phenomenon, and is occupied with the "whys" of facts or phenomena that contribute to or determine the occurrence.

In both the descriptive and normative phases, the researchers must go through three stages (Exhibit 10):

Exhibit 10 - Stages for constructing a theory

| | Stage | Description |
|---|---|---|
| 1 | **Note** | Observe phenomena and carefully describe and measure what you can observe to incrementally develop the theory. Without a detailed and precise description, researchers can be induced to define concepts that do not depict reality, or do so in a fallacious manner. In this step, constructs are also developed, i.e., abstractions that allow researchers to understand the essence of phenomena: how they are and how they occur. |
| 2 | **Classification** | Researchers classify the phenomena into categories to simplify and organize their observations in order to highlight possible relationships between the phenomena and the results of interest. Descriptive categorization schemes are referred to as frameworks or typologies. |
| 3 | **Define Relationships** | Researchers attempt to explore relationships between the attributes of the categories defined during the classification stage, and the results observed. Relations should be identified and characterized through quantitative and qualitative analyses.<br>The results of these relationships are the models that represent the studied phenomena. |

It is necessary to think about "theory" as a body of knowledge that researchers cumulatively create in each of the three stages of the descriptive and normative phases. This causes reflection on how theories are constructed: (i) Firstly, by observing a reality, proposing a model to explain it; (ii) Secondly, by proposing a model that will be tested in practice (CARLILE; CHRISTENSEN, 2005).

In the model by Carlile and Christensen (2005), development of a theory must go through three steps, in a way that interacts with the descriptive and normative phases: (i) observation (constructs); (ii) categorization (frameworks); (iii) definition of relationships (models). When passing through the three phases, the researchers develop the *inductive* part, and using the results they obtain, they can improve the developing theory, adopting the *deductive* part of the process. Moving from top to bottom, in an attempt to "test" the hypotheses that were formulated inductively, that is, if the deductive process were used only to validate the hypotheses, we could not assert that the theory was improved, only that it was tested.

In the field of OM, Neely (2005) developed a proposal for the cycle of developing a theory to assess maturity in the field of "performance measurement systems". Neely's cycle consists of five phases: (i) identification of the problem, (ii) proposal of frameworks, (iii) validation of the frameworks, (iv) empirical research, (v) validation of the theory.

As can be seen, the Neely’s cycle (2005) was published concurrently with and presents similarities to the Carlile and Christensen model (2005); however, Neely’s model does not present the formal separation of the normative and descriptive phases.

Based on the concepts presented, Carlile and Christensen's model (2005) was considered to be more consistent and, because of its similarity to the Neely's model (2005), applicable to the field of OM. A more detailed model may help ensure more robust results for studies. The model was used in the SLR to help define the lifecycle stage of the research in the field of sustainable operations management.

Is fundamental to the field of OM that theories be based on the descriptive and normative cycles so that the phenomena can be described and explained in an in-depth and comprehensive manner to consolidate the frontiers of OM.

### 3.3.5. Multivariate Data Analysis

In order to reduce the limitations of the power of generalization and extrapolation of the qualitative studies, this study also is supported by the complementary nature of the quantitative studies to increase the power of explanation and validation of the proposed theoretical-practical model.

Following suggestions by Hair (2005) and Field (2009) a set of multivariate data analysis were applied in different phases of the research. First, as described in Exhibit 9 - Strategies and objectives, statistical tests were applied in the SLR to improve the reliability and quality of the findings. Second, cluster analysis was conducted on the data collected by the panel of experts, grouping the most relevant SOM practices. Then, using data collected through a survey questionnaire, cross-reference tables were generated, followed by clusters and discriminant analysis.

Complementary concepts, strategies and decisions are provided in the Papers I, III, and IV.

### 3.3.6. Case Studies

Studies conducted over the past 30 years in the field of OM guide research in the field based on empirical research methods (BUFFA, 1980; MEREDITH et al., 1988; 1989; PILKINGTON; MEREDITH, 2009; TAYLOR; TAYLOR, 2009). According to Nakano and Fleury (1997), an increase has been seen in the use of the case study in industrial engineering, especially when it comes to organizational studies.

For Stuart et al. (2002), case studies applied in the field of operations management offer opportunities to improve understanding of complex issues. Case studies are applied to explore an area that has not yet been studied, or when theories have not yet been formulated, or in situations where integrations/combinations between theories are necessary to help construct new theories (STUART et al., 2002; BARRAT et al., 2011).

In their review of the literature, Barrat et al. (2011) state that case studies will continue to explore new areas of OM, and this will lead to innovative and important contributions to the field.

In order to identify the standards for implementing sustainability through practices, trajectories, motivations, barriers, and the evolutionary path. The multiple case study approach was considered, contributing to a power of generalization for the results (EISENHARDT, 1989; YIN, 2001).

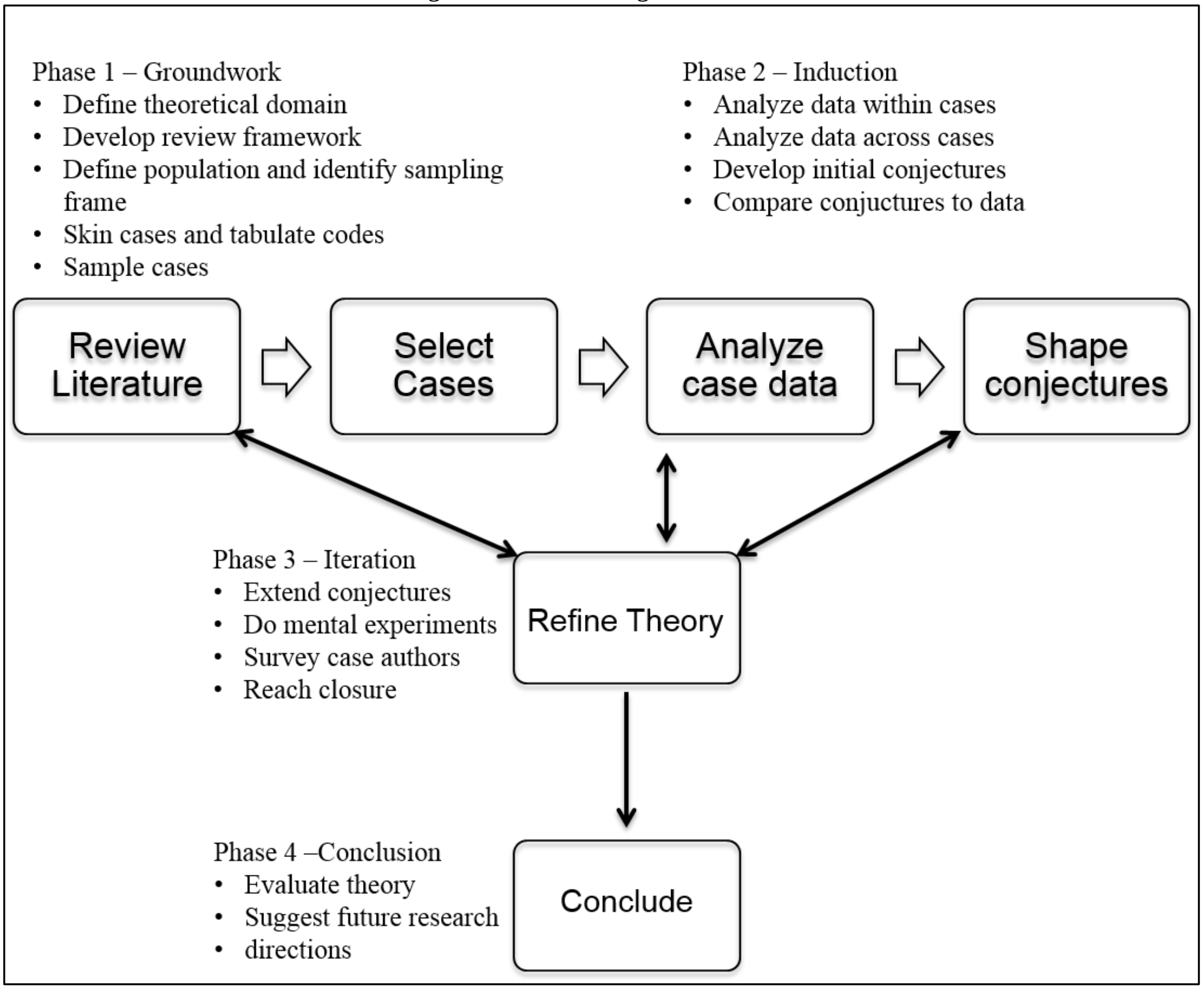
In order to mitigate the depth limitations attributed to multiple case studies and to validate the established construct, different sources of evidence were considered. Using triangulation techniques to process collected data which may confirm patterns or produce new perspectives on the object of study, contributing to the formulation of new theories (EISENHARDT, 1989; LEWIS, 1998; MCDONNELL et al., 2002; STUART et al., 2002; MIGUEL, 2007; MIGUEL; SOUZA, 2012).

Lewis (1998) proposed a methodological framework for conducting the data triangulation process, shown in Figure 12, which will also be used as a reference for analyzing the data collected in multiple case studies. The triangulation model contributes to a more comprehensive analysis of complex and dynamic situations.

According to Miguel and Souza (2012), contemporary concepts in operations management have been developed using case studies, and this strategy must focus on addressing quality aspects and triangulating results for enrichment and deepening of analysis with multiple sources of evidence. The case study protocols are available in the APPENDIX 2, and more details are provided in Paper II.

With respect to case selection, as indicated by the literature review, companies recognized for their sustainability management exhibit elements that can be used to identify them and differentiate them from traditional companies (KIRON et al., 2013a,b).

Figure 12 - Data triangulation model




Source: adapted from LEWIS, 1998, p. 459.

Consequently, the following criteria were adopted to select companies that: (i) have management systems certified by ISO 9001, ISO 14001, or OHSAS 18001 standards; (ii) are signatories to some sort of voluntary commitment related to SD (AGENDA 21, Global Compact, etc.), (iii) publish sustainability reports using GRI or Ethos models, (iv) present evidence of their strategic sustainability goals in their Mission, Vision, or Values statements.

### 3.3.7. Expert Panel

According to MacKenzie et al. (2011), "[…] once items have been generated for representing the focal construct, they should be evaluated for their content validity". In this matter, a third research strategy adopted for modeling the maturity framework was to consult independent subject-matter experts.

This qualitative approach was considered to identify each level's content organization and to determine key processes related to each requirement that integrates the levels, and secondly, the second panel was used to validate the maturity framework structure based on CMMI components. Both applications were described in Paper IV.

According to Flynn et al. (1990), a panel study is "[…] very useful in defining terms and making predictions". Van Looy et al. (2013) have applied panel studies to develop a business process maturity model that includes academics and practitioners.

Following the suggestions of MacKenzie et al. (2011) in the panel used to define the set of SOM capabilities, a matrix was generated relating different aspects of maturity levels. These aspects were listed at the top of the columns, and the capabilities in the rows. The second panel was conducted through Skype interviews with six experts, who received the questionnaire by mail prior to the interview. The interviews were recorded.

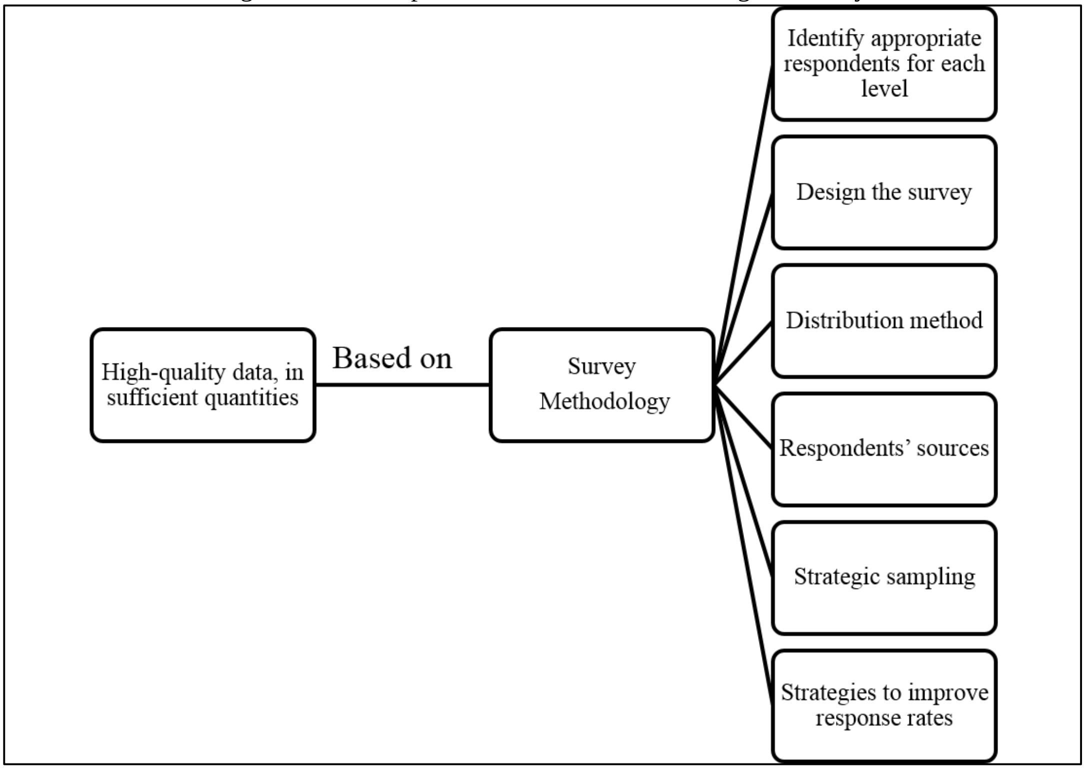
In both panels, a pre-test was applied prior to adjusting the protocol and the content. Both protocols are listed in APPENDIX 3. In addition, to reduce the limitations that are characteristic of this method, careful attention was give to expert selection. Both panels included practitioners and academics with experience in operations management, sustainable operations and maturity models. Exhibit 20, Exhibit 21, and Exhibit 22, which appear in APPENDIX **3**, presents the characteristics of the experts who participated in the two panels.

### 3.3.8. Survey data collection

According to Rungtusanatham et al. (2003), significant progress is being seen in the quantity, quality, and rigor of empirical research in the field of OM, which has become legitimized as a methodology that contributes to understanding of the main issues and challenges of the field.

The model by Melnyk et al. (2012), which is illustrated in Figure 13, is directed at mitigating the limitations attributed to data collection using a survey questionnaire, including "[...] obtaining a representative sample, which provides accurate data of sufficient quantity to permit the use of appropriate statistical analysis".

Figure 13 - Conceptual framework for conducting the survey




Source: adapted from Melnyk et al. (2012, p.4)

Still according to Melnyk et al. (2012), survey-type data collection is a well-developed method, but must be accompanied by practices that ensure significant rates of return, such as a follow-up process. This study considers the guidelines in the models by Forza (2002) and Melnyk et al. (2012) for execution.

Qualtrics© software was chosen for providing the questionnaire, collating the data, and conducting the initial statistical analysis. According to Klassen and Jacobs (2001), alternative research technologies, including Web pages, have presented good results, and also have lower application costs and tolerate lower rates of response.

# 4. FINDINGS FROM THE PAPERS

This section summarizes the main findings reported in each of the five articles. The objective is to provide an overview that allows an understanding of the general context and the main perspectives addressed.

## 4.1. PAPER I - TRENDS AND OPPORTUNITIES IN THE FIELD OF SUSTAINABLE OPERATIONS MANAGEMENT

*Paper submitted to Journal of Cleaner Production (under review)*

*Appendix 1*

Based on the categorization and organization of information extracted from 495 papers, this was a general study on the sustainable management of operations in order to examine opportunities for further research and trends among researchers.

The sustainability theme also helped to establish OM as a discipline, and the increasing number of publications over time reflects a positive trend in scientific research publications in these inter-related areas. The evolutionary stage of sustainability research in OM confirms that research conducted over the past ten years has increasingly focused on testing concepts and models proposed in previous decades, thus demonstrating that this research area is evolving into a mature research lifecycle for establishing strong theories.

The number of published articles on the subject discussed has increased markedly from 2008-2010, which accounted for 49% of the total. This growth indicates that sustainability is receiving increasing attention, in line with growing interest in sustainability worldwide.

There has also been a significant increase in publications since 2007, which can be credited to the growth of discussions regarding environmental management, supply chain management, and corporate social responsibility. Some of these themes have influenced the academic production of authors.

Joseph Sarkis is the author with the greatest number of publications in the sample; the community has identified his studies on green supply chain management and environmental management as relevant. Sarkis represents the leading country (USA) concerning the number of published research, and the second institution in terms of number of researchers (Clark University), a fact that indicates the formation of research groups dedicated to the theme of SOM. Research remains concentrated in the USA and Europe; however, despite the fact that universities from developed countries are leading research on sustainability, the participation of universities in developing countries remains relevant (e.g. China, Brazil, Turkey and India).

The results depict a community that is dedicated to studying sustainability through a different lens, although it is still poorly integrated. However, according to Wasserman and Faust (1994) on the other hand, networks that are more open create favorable conditions for generating new ideas and insights.

The predominant themes among the authors cover several aspects of sustainability, mainly related to five common macro themes: supply chain strategies, environmental management, manufacturing strategies, corporate social responsibility, and sustainability performance management and measurement. The keyword analysis revealed several theories that have been linked to other field studies in OM. These include Life Cycle Assessment (LCA), Sustainable Manufacturing, Corporate Social Responsibility (CSR), Environmental Management and Cradle to Cradle®.

The papers are found in 139 journals, ratifying the OM interface with the engineering and business disciplines, but also indicating the current trend that includes the sustainable perspective in several areas, thus enlarging the applicability and validation limits of this subtopic in scientific communities. The concentration of papers in relevant journals in the OM field and the increase in quantitative analysis are also positive factors contributing to the development of a theory regarding sustainable operations management.

The study of sustainability in the field of OM presents an important contribution in response to the push for SD. This is evident in studies aimed at meeting the dimensions of the Triple Bottom Line, summarized in Exhibit 11.

Exhibit 11 - Sustainable OM research contributions to the Triple Bottom Line approach

| **TBL Dimensions** | **Research theme contributions** |
|---|---|
| Economic | Supply chain management; corporate social responsibility and risk management. |
| Environmental | Environmental management; green supply chain management; green lean supply chain management; life cycle assessment; cleaner production, closed loop supply chain and green product development |
| Social | Health and safety management, corporate social responsibility and socially responsible purchasing. |
| Dimensions' integration | Sustainable supply chain management; sustainability performance, integrated management system, sustainable value-added. |

Source: the authors, 2014.

These and other complementary results were relevant to identifying the approach with which sustainability is being developed in the OM field, and boundaries and main capabilities, represented by analysis of the keywords. The inclusion of sustainability research has expanded the boundaries of OM, both in terms of global operations, as well as environmental and social impacts and meeting the demands of internal and external stakeholders.

The gaps and opportunities identified also were relevant to supporting the research focus: (1) the field is seeking new models that can lead to a sustainable competitive advantage, thus integrating practices and processes involving production, operations and society; (2) there is a gap between sustainability discourse and practice, and in this sense, empirical research is strongly recommended; (3) the field of OM still calls for multidisciplinary and multi-method studies, since OM theories alone are unable to deal with specific situations such as the integration and study of aspects related to the social dimension.

Opportunities for future research are related to four main directions that represent the integrated approach to sustainability research and practice in operations, considering the three dimensions of TBL and their interrelations to the decision-making and coordinating processes.

- Sustainable supply chain management: green supply chain management and responsible supply chain, such as risk management, global supply chains, and socially responsible purchasing.
- Sustainable manufacturing strategies: focused on eco-efficiency, life cycle assessment, green and lean systems, and cleaner production.
- Sustainable performance management and measurement systems: development of sustainability indicators and integrated management systems.
- Decision-making models: maturity models to implement and assess sustainable operations management based on corporate social responsibility.

These approaches are relevant to society because they are a proactive way of integrating sustainability for strategically designing enterprise systems and networks.

## 4.2. PAPER II – SUSTAINABILITY INTEGRATION THROUGH AN OPERATIONS MANAGEMENT LENS

*Paper will be submitted to Business Strategy and the Environment*

*Appendix 1*

This is an exploratory study based on multiple cases, following the premise that case studies offer opportunities for a better understanding of contemporary and complex issues (Voss et al., 2002, Gibbert et al., 2008, Barrat et al., 2011). The study demonstrates the relevance of operations management in achieving sustainability integration.

The results confirm that company operations fit with existing sustainability principles. Regulatory compliance and market pressures represent the main drivers for sustainability integration and internal awareness the main barrier. As a key driver, regulatory framework represented by laws, specific industry regulations, standards, voluntary commitments and sustainability reports are guiding practice adoption and set a path for sustainability integration based on the balance of the quality, environmental, health and safe, and social management systems for the entire value chain.

Practices cover most of the SOM capabilities, although companies need to cover aspects related to sustainable product development and LCA for products and processes to establish product disassembly strategies (remanufacturing/reuse/recycling) and to consider product impact during the life cycle, including production (Exhibit 12). Both approaches are needed to provide resources for more sustainable decisions involving choices in raw materials, technologies and RL.

Exhibit 12 - Patterns for sustainable operations management

| **SOM aspects** | **Practices related** |
|---|---|
| Sustainable Supply Chain Management (SSC) | Regulatory compliance; Eco-efficiency strategies; Energy and hydric efficiency; GHG control; Risk management; Suppliers development program (OH&S and GHG emissions); EMS |
| Reverse Logistics (RL) | Regulatory compliance; Eco-efficiency strategies; Waste management; Recycling/reuse/remanufacturing; EMS |
| Closed Loop supply chain management (CLSCM) | Regulatory compliance for the entire value-chain; Risk Management – raw materials and production processes; Stakeholders' engagement (awareness and dialog); RL; Waste management; Recycling/reuse/ remanufacturing; EMS |
| Sustainable and lean production | Eco-efficiency strategies; Lean 6 Sigma methodology (continuous improvement); Risk Management; QMS/EMS; Innovation programs |
| Integrated management system | QMS / EMS / OH&S / Social Responsibility - implemented but not managed in a single management system. |
| Corporate Social Responsibility (CSR) | Stakeholders' engagement (dialog); CSR policies (Conduct and Ethic Codes); Voluntary commitments; Corporate governance structure; Support collective actions; Transparency - Communication - Financial and Sustainability Reports |

The level of application and the set of practices vary from one case to another. The main findings for each case are synthesized by research propositions.

- Proposition 1 - Firms operations strategy are developing a reactive-proactive pattern regarding sustainability aspects, adjusting their strategies and systems to be in compliance with socio-environmental requirements, developing a management component for their internal operations, and expanding their policies to their supply chain or operations network.
- Proposition 2 – Drivers for sustainability integration motivation does not differs significantly from the traditional strategic business drivers, but the difference lies in its scope and motivation 'power' that may vary according to the industry maturity and how companies activities are interconnected to their environments.
- Proposition 3 – The main barrier for sustainability integration is not, in fact, a conceptual or ideological obstacle, but it resides is in the traditional resistance to organizational change or innovation processes.
- Proposition 4 - Standards, sustainability reports, and voluntary commitments, have been influencing and guiding sustainability integration, however, the requirements supplied by the same are not sufficient for creating a sustainability integrated management system and to support their deployment at operations level.
- Proposition 5 - Sustainability is part of companies' strategic agenda and their organizational design must be reviewed to develop the new required competences, which not only focus on compliance and reporting demands, but are oriented to integrate sustainability practices to their business model competitive strategy.
- Proposition 6 - The sustainability mainstream in operations strategy create opportunities for establishing new strategic performance objectives and decision areas policies, based on the conciliation of companies' resources and market needs that demand sustainable products and processes, which cover the whole supply chain and product life cycle

Not considering specific industry standards, companies are using a common set of standards, reports and voluntary commitments to guide and communicate their sustainability practices**.** These are ISO 9001 (QMS), ISO 14001 (EMS), OHSAS 18001 (OH&S), ISO 26000 (orientative), GHG Protocol, Global Compact, Millennium Development Goals, and

GRI Report. According to the sustainability managers, the certification approach is a safe path for sustainability integration based on the systemic and continuous improvement approach provided by these standards.

Specific legal and regulatory regimes shape their business environments (support associations and other collective actions); embed sustainability in their operations.

In terms of strategies to aid sustainability integration, companies sought to:

- Develop a legal and regulatory regime for internal and external operations.
- Define ‘sustainability’ as a strategic item developing a `sustainability strategy´ supported by a strong leadership and a corporate governance structure.
- Establish QMS, EMS, OH&S and Social accountability system.
- Mapping risks and adapting operations based on eco-efficiency strategies and OH&S work conditions.
- Incentive and establish suppliers´ policies relate to eco-efficiency and health and safe work conditions for suppliers.
- Adhere to voluntary commitments related to SD and support collective actions focused on SD.
- Develop performance goals and metrics based on the sustainability regulatory framework.
- Measure sustainability performance and reporting the results using recognized models, as GHG protocol and GRI report.

Suggestions on the development of a business model that suppose sustainable operations based on the cases results are summarized as follows:

- Address sustainability in an explicit, coordinated and integrated way considering the entire value chain.
- Define aspirations and goals for sustainability moving beyond incremental change.
- Adapt the performance management model for a comprehensive model including all stakeholders. The Performance Prism by Neely et al. (2002) may be such an option, since it allows for the incorporation of sustainability indicators provided by the regulatory framework to develop a more strong sustainability strategy.
- Develop proactive approaches to anticipate change in the regulatory regime.

- Invest in training for managers improving the internal awareness and establishing links between remuneration and sustainability performance indicators.
- Incentive innovation programs in the value chain.
- Assist customers, employees and suppliers to realize their ethical and ecological aspirations, strengthening RL strategies and consolidating CLSC, and adopt LCA strategies for Green Product Design and production processes.
- Define links between sustainability practices and economic performance, including tangible and non-tangible results (e.g. financial indicators, productivity results, and reputation). Sustainability business cases may help, and related recommendations can be founded in Schaltegger et al. (2012) and SustainAbility and IFC (2012).

Corporate governance is important for supporting sustainability integration, mainly through a strong leadership and a separate function for sustainability. An important trigger for evolution in sustainability integration is the effort to link sustainability strategy to economic value and profits and changes the business model accordingly**.** The findings are related to large company operations and strategies. Small and medium sized enterprises may benefit from suggestions on how to improve their operations through SOM**.**

## 4.3. PAPER III – SUSTAINABILITY INTEGRATION THROUGH AN OPERATIONS MANAGEMENT LENS

*Paper submitted to Internation Journal of Production Economics*

*Appendix 1*

Based on literature review, case studies, and expert panels, this study develops a maturity framework defined by sustainable operations management theory, in order to support the sustainability integration process.

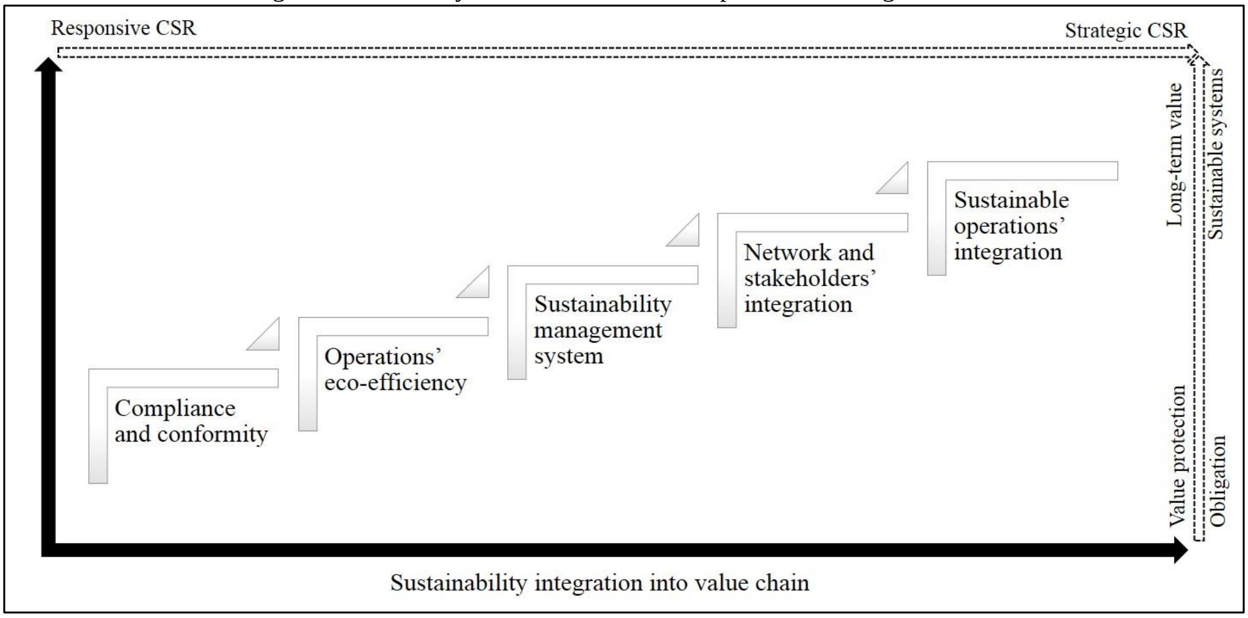
In the area of sustainable operations management, maturity models have been developed for specific purposes, e.g., sustainable production, sustainable supply chain management, corporate social responsibility, and life cycle management. However, the lack of models that look at sustainability through the evolution of sustainable operations capabilities in an integrated way was verified.

The findings pointed out that there is an evolutionary path, which goes from an initial approach focused on compliance and a firm's value protection, to an innovative approach, based on corporate social responsibility supporting operations integration into a sustainable system, and long-term value development.

The framework includes the two emerging approaches described by Nunes et al. (2013) for sustainable operations: (1) focused on the decision making processes - adding sustainability criteria to the strategic decisions in OM; (2) adoption of SOM practices, linking green operations and CSR initiatives.

Maturity in SOM can be understood as a sequence of capability improvement levels that enable the company to conduct its operations in a sustainable manner. Five evolutionary levels define the "Content" of maturity, according to sustainable operations management theory (Figure 14). The five levels represent an evolving and cumulative process of practices and experiences that propel a company to seek standards of excellence in operations with a focus on long-term gains, innovation, and continuous improvement.

Figure 14 - Maturity levels for sustainable operations management




**Level 1 -** Compliance and conformity: company recognizes its obligations and responsibilities. Company's facility and internal operations need to be in compliance with general regulations (government laws, license to operate, etc.) and conformity with specific industry requirements. In general, compliance and conformity are focused on all aspects related to license to operate, environmental regulations (identifying and controlling impacts), and ensuring good labor conditions, and human and child rights. This focus is not only on internal operations and on facilities, but also to be extended to key suppliers. This approach is reactive and important to the economic dimension, since the company reduces risks with non-compliance, avoiding fines or operational restrictions.

**Level 2 -** Operations eco-efficiency: company needs to ensure its efficiency and productivity in accordance with socio-environmental requirements; more than identify and control, all impacts need to be reduced. Key suppliers must be included in product design focusing on reducing impacts related to materials, natural resources, and carbon footprint.

**Level 3 -** Sustainability management system: socio-environmental capabilities become formalized, defined, and managed by continuous improvement and optimized processes. Company establishes formal processes for sustainable production and sustainable product design, focusing on customer demands. Eco-efficiency strategies are dedicated to energy efficiency and use of renewable resources, including product design and manufacturing processes; extended to the supply chain, eco-efficiency is focused on risk management, reducing carbon footprint, and establishing reverse and closed supply chain systems, considering the entire product life cycle.

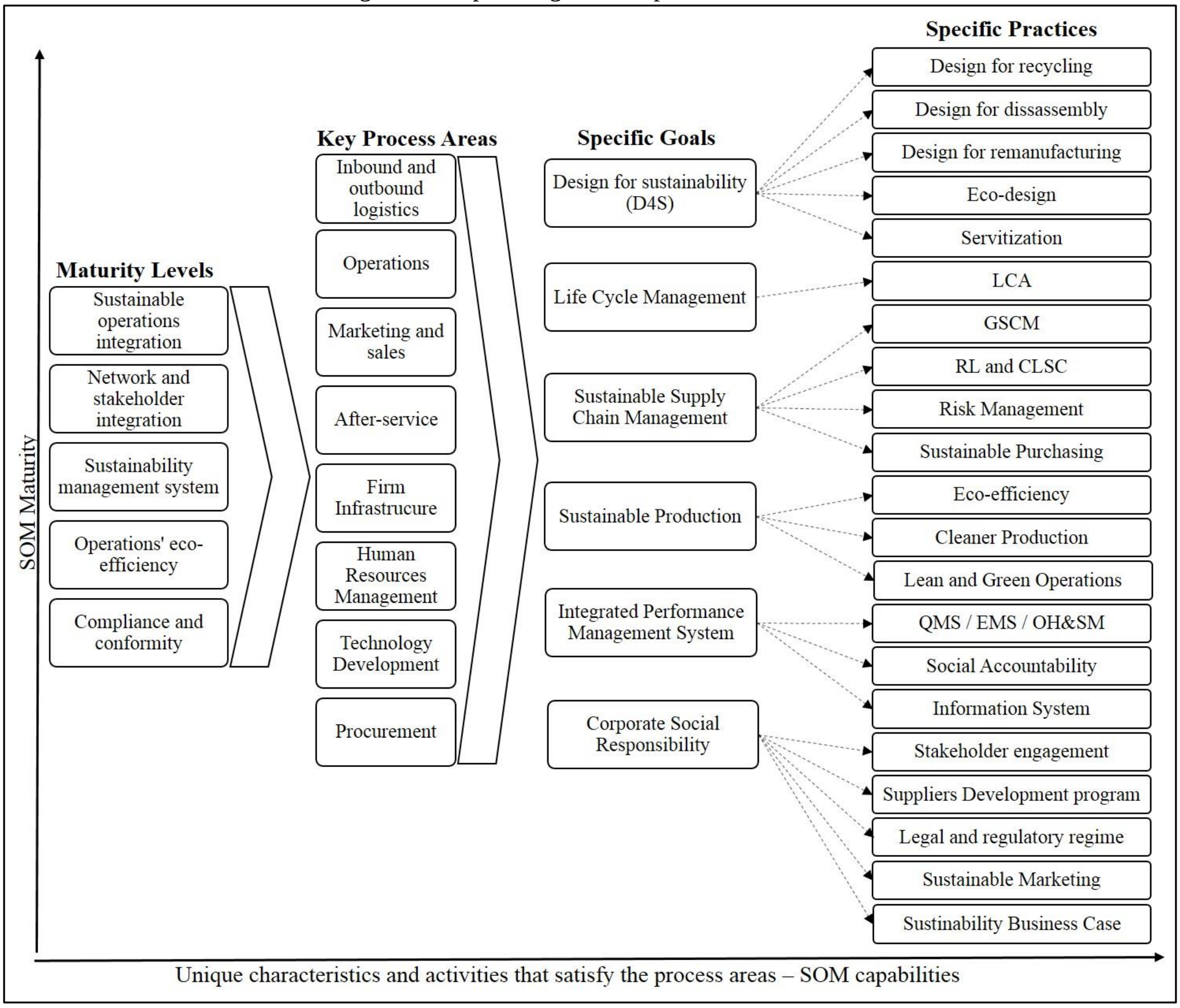
**Level 4 -** Network and stakeholders integration: sustainability principles and processes are integrated across the value chain. Suppliers, customers, and other stakeholders engage and corroborate on company´s sustainability strategies and operations.

**Level 5 -** Sustainable operations integration: a wide sustainability net is defined, based on an integrated management system established across the supply chain and guided by a new business model based on innovation, looking for more sustainable processes in a continuous improvement system.

Levels four and five emphasize the observation similar to that of Bob Willard (2010) in the 5-Stage Sustainability Journey model: *"[...] About 90% of the behaviours of Stage 4 and Stage 5 companies look the same [...] It's the motivation that differs. Stage 4 companies "do the right things" [...] Stage 5 companies are successful businesses so that they can continue to "do the right things."*

Thus, in the framework presented here, what differentiates levels four and five is the consolidation of a new business model based on the innovation and continuous improvement of sustainable processes. The integration of sustainability in the value chain can be carried out via the development of capabilities related to the scope of sustainable operations management. Figure 15 shows the proposed framework, relating the process areas, objectives, and specific practices.

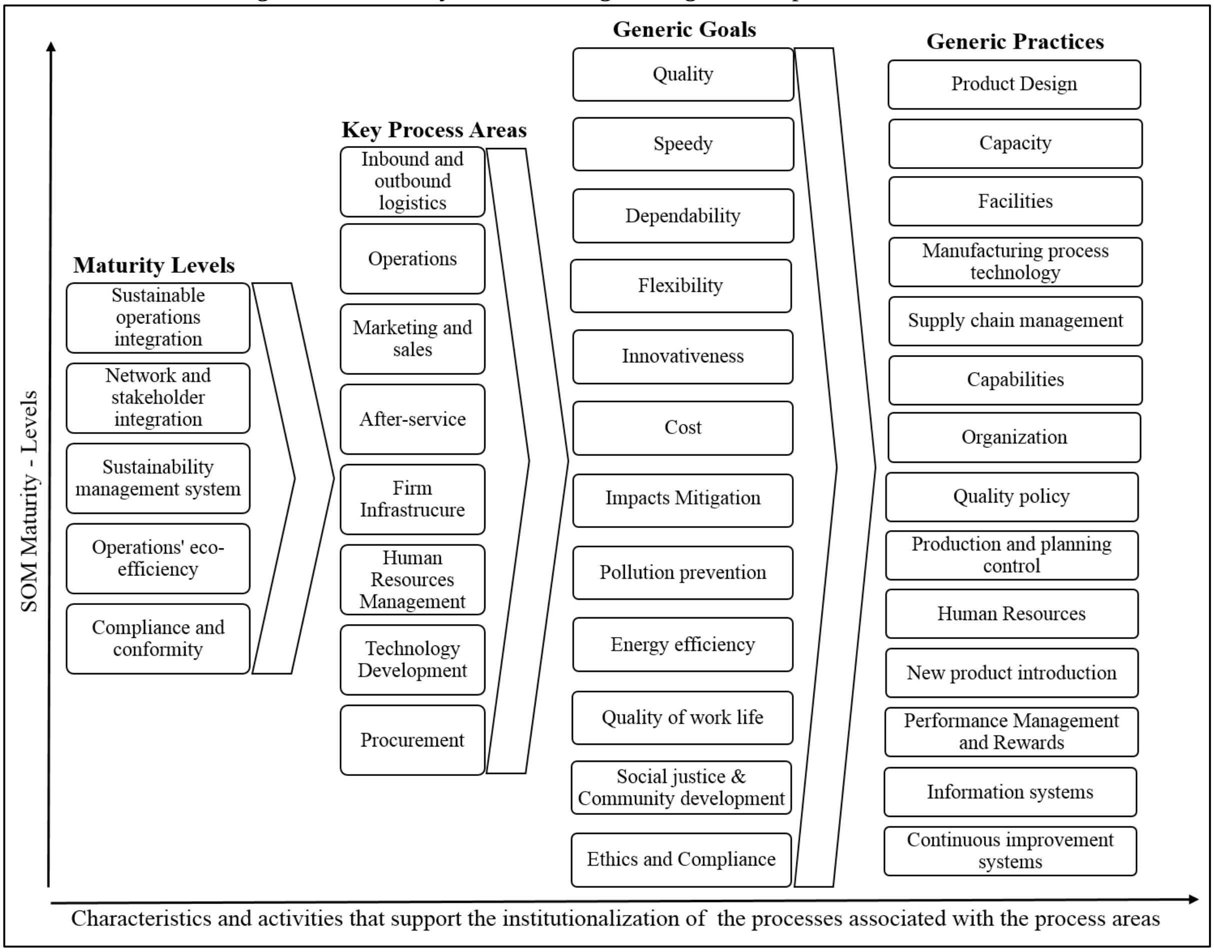
Figure 15 - Specific goals and practices' context




According to the CMMI (SEI, 2010), generic goals are considered required components, i.e. they represent what the company must do to implement a process area. Figure 8 shows the proposed framework, relating the process areas, objectives, and generic practices.

Adapted to the context of the management of sustainable operations, performance dimensions represent the generic goals associated with the value chain processes. In the CMMI model (SEI, 2010), the generic practices are expected components, i.e. they represent the description of the processes that satisfy the generic goals and contribute to the institutionalization of the processes associated with a process area. In the proposed model, the decision areas take on the role of generic practices, i.e. adding principles of sustainability to the traditional context, the decisions areas should contribute to meeting the performance dimensions.

Figure 16 - Maturity framework - generic goals and practices' context




The proposed framework does not intend to be an instrument for implementing sustainability in itself, but together with the norms and guidelines for sustainability and other initiatives, form an integrated sustainability management system that involves the company and its value chain, extending the results and actions to all of society.

## 4.4. PAPER IV – CAPABILITIES' ORGANIZATION FOR SUSTAINABLE OPERATIONS MANAGEMENT

*Paper submitted to International Journal of Operations & Production Management*

*Appendix 1*

Based on the conceptual framework developed and presented on Paper III, the present research aims to identify the level of implementation of sustainable operations practices in a sample of manufacturing/transformation and infrastructure companies. It also looks to verify the organization of a maturity framework for sustainable operations and the presence of strategic patterns for sustainability integration.

Overall, the results indicate that the companies identified by the respondents have the following characteristics: large companies, headquartered in South America (mostly in Brazil), with operations and business in Brazil and abroad. Sustainability has been integrated into the strategic agenda, particularly in the last decade, and management systems are aligned with the dimensions of TBL. Most of them already publish some kind of sustainability report, and around 50% already support some kind of voluntary commitment.

Results also showed a trend in which larger and more complex companies present a bigger number of implemented sustainability practices. This does not mean that this tendency was not also seen in smaller companies. Companies that are part of more structured and regulated chains, such as automotive and pulp and paper firms, and even those that identify market gains through the adoption of practices tend to have a higher level of sustainability integration.

Paper IV addresses the following research question: *Which operational capabilities and organizational aspects can a company manage in order to achieve high maturity in sustainability implementation?*

The results indicated that sustainability integration can be organized through six main dimensions that can be descrided as SOM capabilities:

- Dimension 1 – Sustainable Life Product Management: LCA; D4S; Reverse Logistics and Closed Loop Supply Chain;
- Dimension 2 – Sustainable Production: Lean and green process; Sustainable Purchasing; Eco-efficiency strategies; Cleaner Production; Quality Management System; EMS;
- Dimension 3 – Social Responsibility and Accountability: OH&S management;
- Dimension 4 - Value-chain integration: Suppliers Development Program; Stakeholder engagement; Information System;
- Dimension 6 - Corporate Responsibility: Sustainability Business case; Sustainable Marketing.

These capabilitites can be viewed as complementary processes that can be organized and managed in an integrated manner, observing variables’ cluster results. Identified SOM capabilities could be also be clustered as evolutive levels to be in accordance with MIT/BCG research that are fully described in Kiron et al. (2012) and Kiron et al. (2013a,b), and summarized in Exhibit 13.

Exhibit 13 - Clusters of variables

<table>
<tr><th>Cluster</th><th>Evolution level*</th><th>Evolution level focus</th><th>Capabilities’ focus</th><th>General evidence</th></tr>
<tr><td>1</td><td rowspan="2">Embracers</td><td>Sustainability as a competitive condition and on the strategic agenda</td><td>Compliance<br><br>License to operate</td><td>The variables point to processes that ensure compliance in the dimensions of TBL, including the compliance by key suppliers. Some variables, even though they seem to belong to other groupings, are aimed at compliance issues, such as: Q21.11, Q21.13, Q.22, and Q.23.11. The variable 21.9 indicates that the sustainability strategy should be developed based on the values, mission, and vision defined by the company.</td></tr>
<tr><td>2</td><td>Changes in operations frameworks and strategies driven by sustainable practices’ financial benefits. Creates a sustainability business case</td><td>Eco-efficiency</td><td>The variables point to the identification, necessary negotiations, and mitigation of environmental impacts in both internal and supplier products and manufacturing processes. Definition of criteria for managing the product life cycle, including decisions for facilitating reverse logistics and closed-loop supply chain. The variables Q19.9, Q19.10, and Q.19.11 represent triggers for the next level.</td></tr>
<tr><td>3</td><td>Harversters</td><td>Sustainability-related actions and decisions adding economic value to profits. Business model changing because of sustainability opportunities.</td><td>Processes management and control<br><br>Performance management</td><td>The variables point to the definition of systems and processes that formalize procurement processes and internal processes for sustainable production and eco-efficiency.</td></tr>
<tr><td>4</td><td>Sustainability-driven Innovators</td><td>Profiting from sustainability efforts and changing business models to sustain profit generation. Addressing the significant sustainability issues (i.e., material sustainability).</td><td>Value-chain engagement</td><td>The variables indicate the consolidation of sustainability criteria in the value chain, based on the engagement of customers and suppliers<br>The variable Q.21.12 represents a trigger for the next level.</td></tr>
<tr><td>5</td><td>Walkers</td><td>Significant sustainability issues are used as a way to mitigate threats and identify powerful new opportunities and value creation<br>Supporting collective action to identify material sustainability in a specific sector.</td><td>Sustainability integration</td><td>The variables indicate the consolidation of the strategic sustainability management and the positioning of the company and its value chain as agents of sustainable development.</td></tr>
</table>

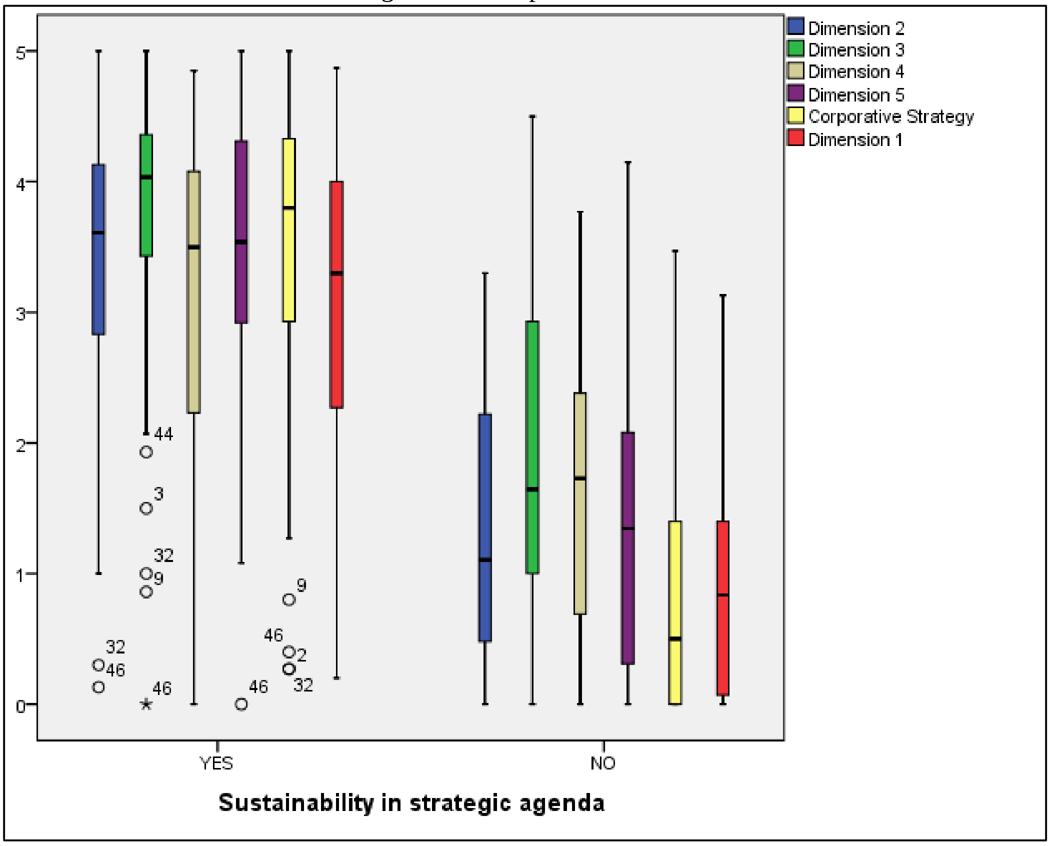
*Source: adapted from Kiron et al., 2012, 2013a,b.

The grouping of variables is also supported by the set of capabilities and resources proposed by Gavronski (2012).

Eccles et al. (2012) state that what differentiates sustainable companies from traditional companies is engagement with the needs of stakeholders and collaborators, promoting a culture of innovation and transformational change. The variables present in the first three clusters point to the gradual changes in motivated operations, primarily from the financial benefits provided by adopting sustainable practices. Beginning with cluster 4, the company adopts an extramural posture, supporting and contributing effectively to collective actions that contribute to sustainable development, as pointed out by Kiron et al. 2013a,b.

Boxplot representation presented in Figure 5 and the formed clusters indicate that the maturity levels proposed in conceptual framework are acceptable. The same applies to the levels of evolution for operations' decision areas and performance goals. The results also support the organization of specifics goals and practices in the proposed framework.

Figure 17- Bloxpot dimensions




The bloxpot indicates that for most part of the respondents, which affirms that sustainability is part of company's strategy (*n*=46), corporative strategies and process/practices related to SOM are defined and managed through quantitative indicators.

It is also observed that, in the cases where sustainability is not considered as part of the company's strategy, issues related to sustainable production (Dimension 2), social accountability (Dimension 3), value chain integration (Dimension 4), and corporate responsibility (Dimension 5) have in fact some level of implementation, however, such practices do not seem to be aligned to the strategic direction (Strategy).

In respondents' clusters, the organization in three clusters is the one with more distinct patterns.

In the groupings by respondents, the organization in three clusters presented the most distinct patterns. Exhibit 14 presents the results of the groupings, including the respondents' statements about their company's position regarding sustainability (*n*=48).

Exhibit 14 - Cluster of respondents

| Cluster cases | Main Characteristics |
|---|---|
| 1<br>*n*=38 | Qualified respondents (as measured by length of time spent in the position related to sustainability and level of experience and knowledge about the company's sustainability strategy); strategy embedded in the management agenda (in 50% of cases for over 10 years); management systems related to all dimensions of TBL (e.g., QMS, EMS, OH&S, and Social Accountability); publication of sustainability reports (e.g., GRI); signatories of voluntary commitments (e.g., Global Pact); and practice implementation levels concentrated among levels 3 (Defined), 4 (Quantitative Management), and 5 (Optimized). |
| | Position regarding sustainability: "compliance strategy," "innovative," and "from compliance to innovative." |
| 2<br>*n*=14 | Practice implementation levels concentrated among levels 1 (Initial) and 2 (Managed or Repeated). In this grouping, only two respondents consider themselves an expert/leader in sustainability; most say they are a beginner or have some knowledge but are not an expert. In terms of how long sustainability has been part of the strategic agenda, there were two distinct groups: six respondents stated that the topic is not part of the agenda, and six stated that sustainability has been integrated into the business for a short time (1 to 5 years). |
| | Position regarding sustainability: "compliance strategy," and "innovative." |
| 3<br>*n*=12 | They can be considered "outliers," even though, in some cases (*n*=4), the respondents state that sustainability is embedded in the company's strategic agenda. The cases differ from the other groupings mainly in the smaller number of employees (between 50 and 1000), incipience in the level of implementing sustainability, and the fact that they do not publish sustainability reports or even support voluntary commitments. It is important to highlight some of the respondents' characteristics: most stated that their position is not related to sustainability and that they have little or no knowledge of how sustainability affects the business. |

The cases from Cluster 3 were considered outside the group of companies engaged in integrating sustainability, still incipient on the topic, or with low quality ratings due to the respondents' perception or lack of knowledge, as the statements about the companies' positioning exemplify (e.g., "*None"* was indicated by respondents 23, 29, 37 and 39; *"intends to include sustainability in the agenda"* was indicated by respondent 32; and "*I have no information on this subject"* was indicated by respondent 61).

Based on the evolutionary pattern of the MIT/BCG framework, Table 1 presents considerations about the cases of clusters 1 and 2.

Table 1 - Clusters of respondents

| Cluster | Evolution Level* | Description | Evidences (average of responses) |
|---|---|---|---|
| 1 | 'Harversters' to 'Sustainability-driven Innovators' | Strategies and practices are defined, but not quantitavely managed and optimized. It could be said that sustainability is being integrated to the business model and to companies' operations, and receiving support from top-level management. | Q18.7 = 3,73<br>Q18.8 = 3,31<br>Q18.9 = 3,68<br>Q18.10 = 3,28<br>Q18.14 = 4,21 |
| 2 | 'Embracers' | Sustainability is being integrated in the business model, but in an early stage. It is considered relevant for competitiveness, but not clear defined for operations and for the business model as a whole. | Q18.7 = 1,71<br>Q18.8 = 2,00<br>Q18.9 = 1,85<br>Q18.10 = 1,00<br>Q18.14 = 2,42 |

*Source: adapted from Kiron et al. (2012, 2013a,b)

Another distinctive aspect of the groupings is the region where the companies' headquarters is located, as well as that of the companies with which they negotiate. In Cluster 3, most of the companies have headquarters and focus their operations and business in Brazil. In Cluster 2, five cases have headquarters outside Brazil, in countries in Europe/Scandinavia and North America, and global operations and businesses (in more than three countries). In Cluster 1, 12 cases have international headquarters, and 19 cases (most of which are in the Global category) have operations and businesses in foreign countries.

Based on these results, it can be said that there is a tendency that the level of integration of sustainability is higher in multinational companies or companies, which are devloping operations and business with other countries. One of the causes can be the legal and market requirements related to these regions.

Partial least squares technique (PLS) was used to test the scale's validity and reliability. Three conceptual framework variations were tested (Table 2, Table 3, Table 4). Tests corroborated towards the integration of sustainability in operations and business originates from a top-down approach, i.e., that can be characterized as a deliberate strategy, represented by Framework 2. However, the best results of Framework 1, may indicate that the sustainability integration is originated from planning and top-down definitions, but are also influenced by bottom-up demands, which resulted in the realized strategy.

Table 2 - Framework 1 - PLS analysis

| Framework 1 | $R^2$* | t-Stat. |
|---|---|---|
| Strategy – Cluster 1 | 0.938 | 59.580 |
| Strategy – Cluster 2 | 0.931 | 78.677 |
| Strategy – Cluster 3 | 0.886 | 39.883 |
| Strategy – Cluster 4 | 0.858 | 31.620 |
| Strategy – Cluster 5 | 0.950 | 84.344 |

Table 3 - Framework 2 - PLS analysis (a)

| Framework 2 | $R^2$ | T-Stat. |
|---|---|---|
| Strategy – Cluster 1 | 0.901 | 28.865 |
| Strategy – Cluster 2 | 0.855 | 24.638 |
| Strategy – Cluster 3 | 0.775 | 12.657 |
| Strategy – Cluster 4 | 0.767 | 15.028 |
| Strategy – Cluster 5 | 0.895 | 39.219 |

Table 4 - Framework 2 - PLS analysis (b)

| Framework 2 | Communiality (AVE)* | Cronbach's α | Composite realibility** |
|---|---|---|---|
| Cluster 1 | 0.783 | 0.980 | 0.982 |
| Cluster 2 | 0.683 | 0.978 | 0.980 |
| Cluster 3 | 0.707 | 0.968 | 0.971 |
| Cluster 4 | 0.674 | 0.959 | 0.964 |
| Cluster 5 | 0.782 | 0.977 | 0.979 |
| Strategy | 0.812 | 0.983 | 0.985 |

*AVE values greater than 0.50 suggest convergent validity at the construct level
** CR values greater than 0.70 indicate acceptable reliability

Framework 3 (Table 5), as well as Framework 1, results are not conclusive for communality (AVE), Cronbach's α e Composite realibility indicators. Besides that, this framework showed high multi-collinearity (VIF) between the studied dimensions and strategy, having loading factors above 3.3 (Diamantopoulos and Siguaw, 2006).

Table 5 - Framework 3 - PLS analysis

| Framework 3 | $R^2$ | T-Stat. |
|---|---|---|
| Cluster 1 | 0.346 | 1.449 |
| Cluster 2 | 0.226 | 0.679 |
| Cluster 3 | 0.022 | 0.136 |
| Cluster 4 | -0.113 | 1.213 |
| Cluster 5 | 0.512 | 2.206 |

Thus, based on framework internal consistency and reliability analysis, SOM's capabilities organization in six dimensions was considered tested and validated. They can be used for organizing a SOM maturity framework, which considers the capabilities and organizational resources evolution in an integrated way for the entire value chain.

Paper IV findings could be summarized through the following statements:

- In order to achieve a high maturity level in implementing sustainability, a company needs to have strong leadership that defines and supports the overall sustainability strategy.
- There is a reactive–proactive pattern to sustainability integration that evolves from 'Embracers' to 'Walkers'.
- Drivers for sustainability integration motivation does not differs significantly from the traditional strategic business drivers, but the difference lies in its

scope and motivation 'power' that may vary according to the industry maturity and how companies activities are interconnected to their environments.

- Standards, sustainability reports, and voluntary commitments, have been influencing and guiding sustainability integration.

Sustainability is part of companies' strategic agenda and their organizational design must be reviewed to develop the new required competences, which not only focus on compliance and reporting demands, but also are oriented to integrate sustainability practices to their business model competitive strategy and operations. The best results could be achieved for suatainability integration through a deliberated strategy, that is cleared supported by the top-level management.

The model's internal consistency and the reliability of its measurements validate the organization of SOM capabilities into a maturity model for sustainable operations management that considers the evolution of organizational skill resources to be integrated with the value chain.

The groupings illustrated by the boxplot graph and the clusters indicate the acceptability and reliability of the maturity levels proposed as well as the levels of evolution for operations' decision areas and performance goals.

The study's limitations include the number of cases examined, the sample size, the average time spent to complete the questionnaire, the difficulty of identifying the professionals in each company who could answer the questionnaire's broad questions, some firms' policies to not participate in surveys, and some companies' refusal to discuss sustainability. Even so, it is worth noting that some of the respondents praised the questionnaire's scope.

## 4.5. PAPER V – IMPLEMENTING A SUSTAINABILITY INDICATORS DESIGN PROCESS FRAMEWORK

*Paper submitted to Computers in Industry*

*Appendix 1*

This paper shows the results of a two-year research cooperation project between XX University ISE Department and YY Software Company for developing a sustainability indicators generation software prototype called P3G®. The project started on January 2012, and in its first year developed de conceptual model and the technical requirement for software design and programming. In the second year, the software was developed and tested. Results presented in this paper refer to a test application in Company ZZ.

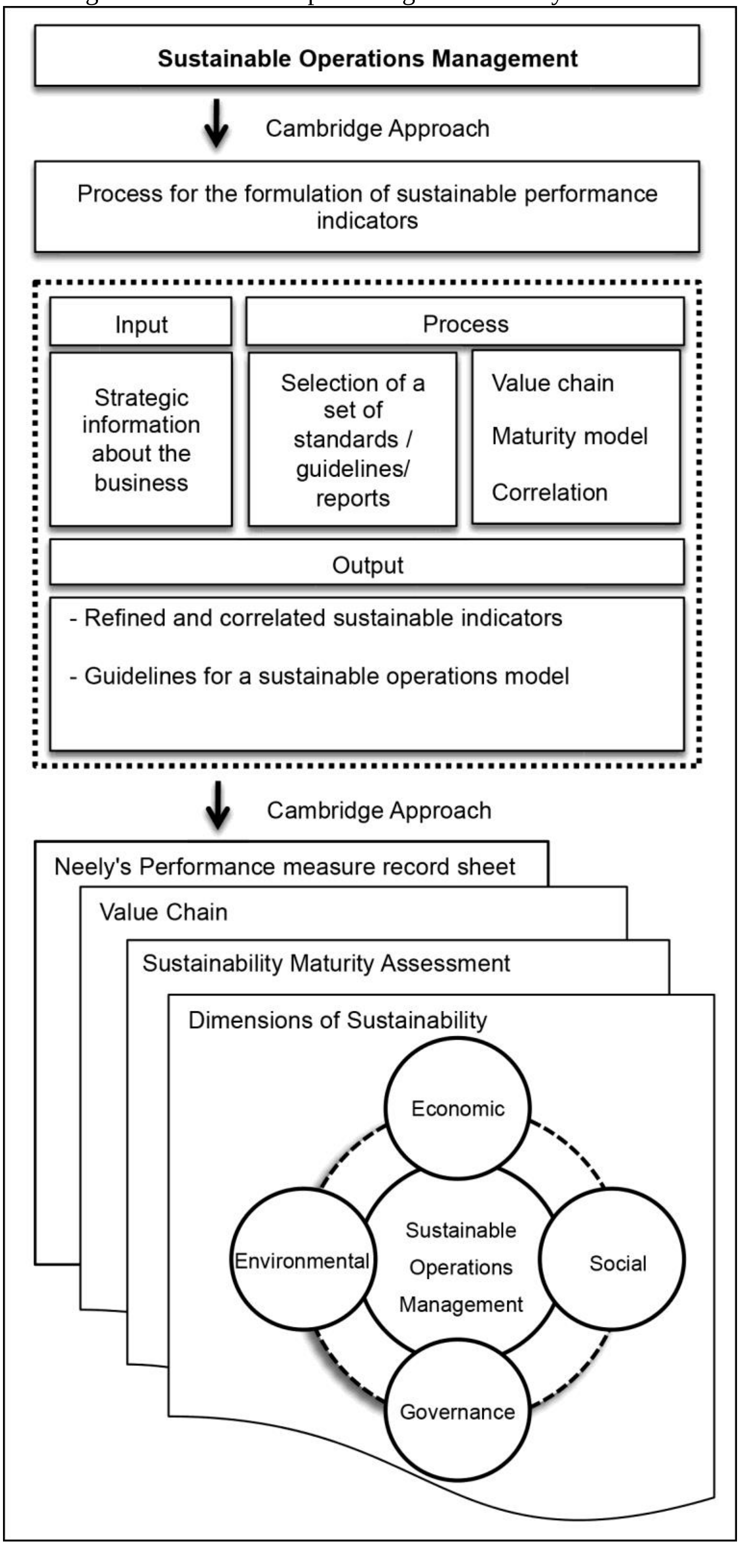
Hasna (2010) comment that sustainability should be approached by companies considering its multiple aspects and dimensions in a coordinated and integrated way, he also observed that the economic system is defined by SD in terms of value creation. Transforming sustainability strategies into actions requires new performance indicators for measuring company performance, and the management model itself also need to be redesigned. It is essential that the strategy, structure and management system be aligned to coordinate actions and motivate the teams in the process of implementing sustainability (McCartney, 2009, Epstein and Roy, 2001).

The conceptual model presented in this paper that support sustainability indicators generation is based on extended view of TBL that includes Governance, correlated to value chain activities and organized according to a maturity based model.

The process for producing sustainability indicators result in a 'meta data' set defined by Neely et al. (1997) framework. Information presented in Figure 18 follow a simple input/process/output structure, defining as input: business strategy definitions, sustainability scope (economic, environmental, social, and governance), value chain scope, and normative documents and standards scope. Process defines how the inputs could be synthesized in coherent set of measures, that is, transforming normative documents and standards requisites in measure specifications. Output organizes information for publishing sustainability measures, as well some graphics to represent relationships among the designed measures and TBL dimensions, value chain activities and maturity levels.

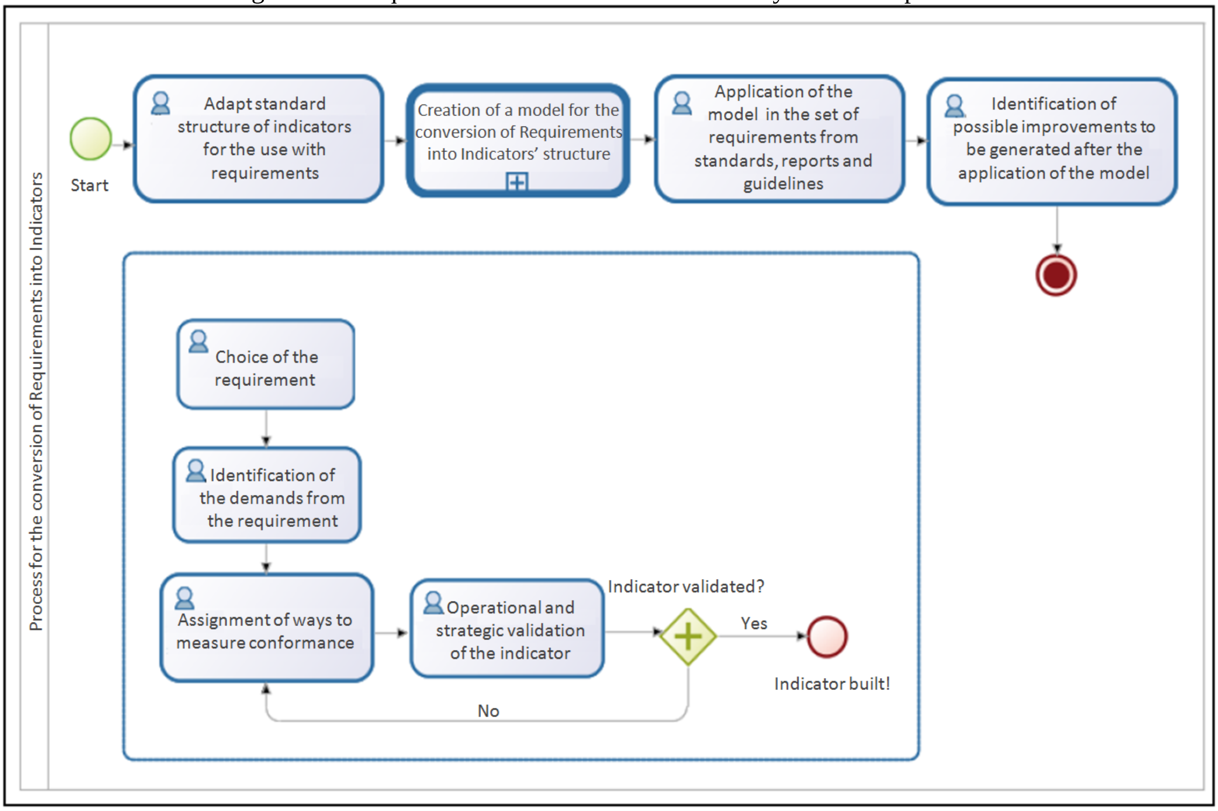
There are two critical features of sustainability indicators process/software prototype: the first challenge is to transform sustainability normative framework requisites into indicators. A process was developed to transform requisites into indicators (Figure 19) based on: (1) to attend requisites demands and to allow its management; (2) to establish a standard procedure for converting requisites into indicators; (3) to have traceability in terms process information flux; (4) to enhance liability and consistency through sustainability indicators database (Hundzinski et al., 2013).

Figure 18- Process for producing sustainability indicators




Source: Machado et al., 2012.

Figure 19 - Requisites conversion into sustainability indicators process




Source: adapted from Hundzinski et al., 2013.

The process end when the activity 'identification of possible improvements to be generated after model application' reach an acceptable quality level, that is, the process is repeated through multiple refinements and improvements until indicator validation. The multiple and successive refinements are related to: indicators assessment to assure coherence among them and the requisites that they are related to; value chain and maturity levels categorization improvement process; indicators application classification. Sustainability indicators follow an information structure inspired by Neely et al. (2002), in which several fields that form integrated information set define a performance measure. Figure 20 presents the sustainability indicator record sheet.

Figure 20 - Sustainability indicator record sheet

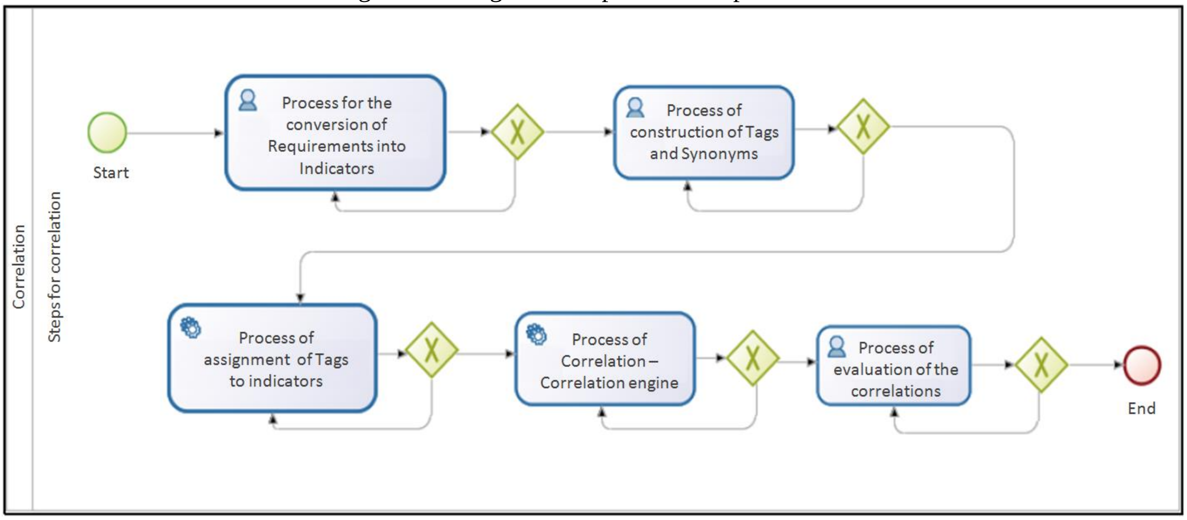
| Indicator record | Existing indicator |
|---|---|
| Standard | |
| Requirement | |
| Indicator | |
| Description | |
| Category | |
| Theme | |
| Sub-theme | |
| Dimension | |
| Value Chain | |
| Maturity Level | |
| Type | |
| Correlation | |
| | |
| Propose | |
| Refers to | |
| Target | |
| Formula / Metrics | |
| Frequency of measurement | |
| Frequency of reviews | |
| Who measures? | |
| Data source | |
| Who is responsible for the measurement? | |
| What do they do? | |
| Who act on the data? | |
| What do they do? | |
| Notes and commentary | |

Source: Neely et al., 2002.

The second challenge for designing and implementing the sustainability indicators generation process is to correlate indicators. For this task content analysis techniques were applied to the sustainability normative framework in order to identify similar requisites. Coding procedures were used for producing ‘comparative’ tags, and they are the key element for correlating sustainability indicators. Figure 9 shows the process of tags creation.

Each activity described in Figure 21 is iterative process that follows improvement and refinement cycles. Quality criteria established by sustainability experts define tag creation process end.

Figure 21 - Tag creation process and procedures




Source: Kluska et al., 2013.

The test conducted in Company ZZ was planned according the following activities: (1) Sustainability diagnostic survey application; (2) inputs formalization to orient the process of generating sustainability indicators (3) assessment of sustainability indicators generated list in terms of present and desired situations; (4) sustainability indicators assessment report workshop; (5) workshop for completing sustainability indicators record information sheet.

It is a mature company that is defining its multiple business based on sustainability principles. Two scenarios could be organized using information obtained through test application. They are projections based on the selected regulatory framework, that is: GRI - Global Reporting Initiative, NBR ISO 14001, Global Compact, OHSAS 18001, NBR ISO 26000, NBR ISO 9001 and AA 1000 AccountAbility.

Scenarios 1 and 2 show improvement potential in terms of indicators number by running a correlation algorithm. It is clear for these two case an improvement rate of 30%, but if an individual indicator analysis is performed the improvement rate tends to be better. Indicators analysis provided systemic and integrated view of the entire system for managing sustainability, providing a collective learning about connections, interfaces and integration that could implemented in processes and systems used for managing sustainability aspects and/or issues.

Reaching sustainability maturity levels 4 and/or 5 should be a strategic goal for companies that intends to integrate sustainability to their business models. Companies in levels 4 and 5 developed their sustainability management system and are able to define their business based on sustainability values, but could also establish sustainability as factor for differentiate them in competition.

Companies that are qualified to apply the process could reach: (i) Competence for identifying indicators for new certification implementation processes; (ii) Shorten time required for implementing new elements in sustainability regulatory framework (standards, reference documents and report guidelines); (iii) Low cost for implementing a new process and/or certification; (iv) Simplification in maintaining and actualizing the sustainability regulatory framework; (v) Integrated management for sustainable operations.

# 5. DISCUSSION

This section presents a discussion of the empirical and theoretical findings. The analysis will be done from the perspective of the scope and the research questions.

## 5.1. THE MATURITY OF SUSTAINABLE OPERATIONS MANAGEMENT RESEARCH

*RQ1. How have sustainable operations management and studies developed over the last two decades?*

*RQ2. How mature is sustainability research in terms of knowledge?*

The systematic literature review described in Paper I showed that the increase in discussions of sustainability, climate change, and the new parameters for SD have been incorporated into OM, mainly in the last decade.

Sustainability issues in OM have emerged from strong environmental regulatory requirements and competitive pressures. However, the evolution of studies on socio-environmental management, especially on supply chain management, has contributed to research moving beyond a focus on compliance towards innovation processes, as in the trend observed by Bayrakatar et al. (2007) and Gunasekaran and Ngai (2011).

SOM is been considered relevant for researchers and practitioners in dealing with contemporary issues. The approach it provides can help companies achieve their traditional economical goals and results, while at the same time reducing impacts and preserving the environment, ensuring good working conditions and human/child rights in the value-chain, and supporting society in the transition toward a new sustainable model for both production and consumption.

In this sense, the inclusion of sustainability research has expanded the boundaries of OM. The set of capabilities that have been developed in the area of SOM covers: internal facilities sustainability, including sustainable production and eco-efficiency strategies; sustainable supply chain management; sustainable product design and life cycle management; integrated management systems (QMS/EMS/OH&S/Social Responsibility); and corporate social responsibility including customer engagement and sustainability marketing (KLEINDORFER et al., 2005; BETTLEY; BURNLEY, 2008; GUNASEKARAN; SPALANZANI, 2012; NUNES et al., 2013).

Therefore, the SOM approach satisfies the sustainability issues and requirements for companies pointed out by Elkington (2004), Porter and Kramer (2006), Clinton (2012), and the 'ten sustainability megaforces' described by KPMG (2012).

Research on SOM is maturing and evolving, in other words, becoming broader and more comprehensive, in order to establish strong theories. This is important to help to consolidate limits, and reconcile theory and practice in the OM field, as highlighted by Slack et al., 2004 and Kleindorfer, 2005. In this sense, SOM still calls for multidisciplinary and multi-method studies, since OM theories alone are unable to deal with specific situations.

Besides the exploratory-descriptive nature of this thesis, both perspectives were considered. The adoption of the organizational change aspects provided by Pettigrew et al. (2012), the CMMI maturity approach applied in the OM context, and the other theories involved in the SOM context together yielded a relevant multidisciplinary perspective. Qualitative and quantitative methods, which are described in Papers I-V, were applied to expand the understanding of results and to improve the reliability and validity of the research.

This integrated approach permit responses to broader questions, for example, how operations can contribute to the integration and management of sustainability dimensions in the business model, which became the focus of this thesis.

## 5.2. HOW COMPANIES ARE RESPONDING AND ADAPTING ITS BUSINESS MODELS AND OPERATIONS TO SUSTAINABILITY CHALLENGE?

*RQ3. How do company operations fit with concepts of sustainability?*

*RQ4. How do sustainable operations impact and change business models?*

*RQ6. Which operational capabilities and organizational aspects can a company manage in order to achieve a high maturity level in implementing sustainability?*

*RQ7. How can performance goals and operational decision areas evolve from the perspective of sustainability?*

The findings of the exploratory case studies and the survey show that sustainability has been integrated into the companies, especially in the last decade, and that operations are in accordance with the concepts of sustainability within these companies.

The findings in Paper IV reinforce that to achieve more sustainable operations considering their value chain, based on the TBL management, they need to integrate sustainability into their strategic agenda established through strong leadership, which includes sharing a clear and strong vision with all stakeholders with regard to defining sustainability, as pointed out by Stoughton and Ludema (2012) and Kiron et al. (2012, 2013a,b).

The need for a top-down approach was confirmed by the analysis of PLS using Mintzberg's (2003) theory. The results indicated that the 'executed strategy' must be the result of a 'deliberate strategy', i.e., it must originate from prior planning and intentions about sustainability issues related to the business. This allows the company to glimpse the opportunities and benefits of adopting more sustainable practices and processes, which can translate into tangible and intangible benefits, as described by KPMG (2012), for the company to respond to the mega-trends of sustainability.

Middle managers are conducting sustainability integration, in accordance with Stoughton and Ludema (2012), who affirm that middle managers are bringing sustainability into their companies. However, a top-down approach is required, with senior leaders taking the responsibility to deploy and lead sustainability throughout the company, changing the organizational culture.

Another important aspect which was identified is that although integration of sustainability began with issues which were reactive in nature (e.g. compliance or obligation issues), the companies that integrated sustainability were able to subsequently develop more proactive and innovative approaches. According to Boons et al. (2003), sustainable innovation represents the integration of sustainability considerations (TBL dimensions) into the company, i.e., applied to products, services and technologies, and changing business and organizational culture.

To achieve a level of management based on sustainable innovation, there is a trajectory that can be analyzed on the basis of the maturity perspectives identified by Nascimento et al. (2013):

- the level of implementation and the maturity of more sustainable processes and practices are positively related to the time when the matter was addressed and disseminated within the company;
- the level of integration of sustainability is directly related to the evolution and maturity of the involved capabilities, in other words, to the extent that they begin to effectively integrate the business model and are quantitatively managed and optimized (e.g. 'Embracers' to 'Walkers' by Kiron et al. (2012, 2013a,b);
- the companies can adopt an evolutionary path to sustainability, which starts from an initial compliance stage through to the to the integration of sustainability (TBL

integration) in operations and the business model, with innovation as an enabling factor (NIDUMOLU, 2009 Boons et al., 2013 KIRON et al., 2013a).

In this way, evolutionary and business management patterns emerged, indicating the relevance of the maturity approach in processes and capabilities for the company to achieve its sustainability goals.

This reaffirms what Bayraktar et al. (2007), Bettley and Burnley (2008), Ferrer (2008), and Drake and Spiler (2013) said that SOM is vital to addressing the complex issues related to sustainability.

The tests conducted with experts and survey respondents indicated that the capabilities related to SOM can be grouped by dimensions, representing sustainability goals to be achieved: sustainable product design based on life cycle management; sustainable production; social accountability; value-chain integration: and, corporative responsibility.

The maturity of these SOM capabilities, supported by a corporate strategy that considers sustainability issues, can lead the company to a higher level of integrating sustainability (NIDUMOLU, 2009; BOONS et al., 2013; KIRON et al. 2013a).

## 5.3. A FRAMEWORK FOR SUSTAINABLE OPERATIONS MANAGEMENT MATURITY

*RQ5. How are maturity models for operations management employed in the sustainability context?*

*RQ8. How can the maturity framework for sustainable operations support implementation of sustainability*

*Main RQ: how can the capabilities of sustainable operations evolve and be managed in order to provide support for companies to improve and carry out sustainability integration processes?*

Studies carried out by Pinheiro de Lima et al. (2012, 2013), helped to identify a set of maturity models and frameworks related to SOM. As described in Paper III, even if they are directed at specific questions, the models showed a standard of levels for the topics which were approached from compliance through to the level of defining a new business model.

Sustainable operations management must be conducted through the companies' value chains, guided by strategic performance goals, which evolve from value protection perspective (directly linked with compliance) to long-term value creation, linking economic performance to socio-environmental gains, and creating a innovative business environment with collaborative strategies between the value chain participants and other stakeholders, as described in section 5.2.

The interviews with experts in Paper III and the work of Silvius and Schipper (2010) validated the use of a maturity model or framework to translate and organize the complex aspects of sustainability in capabilities. The capability maturity model, represented by CMMI, was considered a good reference, and adaptation of some of its elements was also considered appropriate: "*The CMMI is a basis which is greatly considered in procedural matters […]" (Reviewer 6)*; *"The structure is relevant to performance management systems" (Reviewer 2)*.

Based on the advice of Veleva et al. (2001) "[...] Developing sustainable systems of production is a continuous, evolutionary process of setting goals and measuring performance", it is considered that the maturity of operations is related to setting performance goals aligned to the TBL and to new directions for operations decisions that also are guided by a pattern of evolution towards sustainability, presented in Paper III.

Establishing goals and measures that link sustainability performance and economical performance is a challenge. According to Lubin and Esty (2014), sustainability reports are relevant to management and are an important source of information, but they do not yet effectively support the generation and understanding of indicators that help to economically quantify the business value of sustainability for investors. According to the authors: "[…] companies must systematically capture and report the sustainability-driven business impacts they are already seeing, and those they aim to generate, in terms that mainstream investors comprehend".

The new version of GRI G4 (GRI, 2014) and the sustainable business case approach assist the company in identifying the critical factors (material sustainability) related to sustainability to meet strategic and economic objectives from a long-term perspective (STRANDBERG, 2009).

The points discussed above validated the thesis that joining the structure of maturity models with the SOM approach can result in an evolutionary framework to integrate sustainability into business, based on the sustainability of operations management maturity.

Five levels support and guide the maturity of the capabilities, the performance objectives, and the operational decision areas: (1) Compliance and conformity; (2) Eco-efficiency of the operations; (3) Sustainability management system; (3) Network and integration of stakeholders; (4) Integration of sustainable operations. Based on guidance from these levels, the capabilities can be implemented in an integrated manner, as indicated by the cluster variables which are described in Paper IV.

## 5.4. DESCRIPTIVE VIEW OF SUSTAINABLE OPERATIONS INTEGRATION

In this section, the findings related to the organization of capabilities and maturity levels were summarized in charts to easily characterize the proposed maturity levels (Exhibit 15 - Exhibit 19)

The initial model for the chart, which is presented in Paper III, was submitted to the specialists, who considered the summary to be relevant but recommended: simplification of the dimensions addressed, the use of terms and explanatory statements for clarity; separate presentation of goals and generic practices, since they are applicable at all levels, according to the guidance from the CMMI model.

Accordingly:

- Generic goals (performance goals) are represented by market requirements related to sustainability, translated into traditional performance goals representing economic dimensions (quality; speed; reliability; flexibility; innovation; cost) and into social and environmental performance goals (impact mitigation; pollution prevention; climate change; quality of work life; social justice and community development; ethics and compliance).
- Generic practices (operations decision areas) represent the mobilization of organizational resources, i.e., a set of policies and activities relevant to the fulfillment of the performance goals.

Exhibit 15 - Characterization of maturity level 1

| **Level 1** |
|---|
| **General description for the level (performance Goal of the level)** |
| Compliance and conformity |
| **Generic description of the content (content in the area of change)** |
| Compliance and conformity are focused on all aspects related to operational licensing, environmental regulations (identifying and controlling impacts), and ensuring good labor conditions and human/child rights. Focus is on not only internal operations and facilities, but also extended to key suppliers. |
| **Generic description of the context (the drivers of change)** |
| Company's facility and internal operations need to comply with general regulations (government laws, license to operate, etc.) and conformity with specific industry requirements. |
| **SOM capabilities involved (relevant capabilities to achieve the goal)** |
| Reverse logistics, product design, lean and green processes, cleaner production, OH&S, sustainable purchasing, social purchasing, social accountability, information system, stakeholder engagement, and sustainable marketing. |
| **Focus of the SOM dimension (processes that must be implemented and management for continuous improvement)** |
| • Sustainable product design and management – requirements for new product design consider regulations and policies to ensure compliance. In addition, they consider environmental improvements to allow reverse logistic strategies relating to new alternatives for waste disposal and application of excess materials (reuse, recycling, or remanufacturing)<br>• Sustainable production – establishing production processes which allow waste reduction and better use of resources in internal processes, improving productivity and efficiency. Suppliers and other partners are involved in strategies to improve just-in-time processes.<br>• Social accountability – company's values need to be declared and identified in its activities and formalized in a code of conduct and ethics. These values must ensure healthy and safe work conditions in operations along the value chain. In addition, strong rules must be defined to combat gender discrimination and forced/slave labor while providing liberty of association and human and child rights. Company also needs to have procedures to assess and combat corruption and unfair practices in all operations within its value chain. Impacts and opportunities for local development of communities need to be assessed.<br>• Value-chain integration – focused on customer engagement, ensuring customer privacy. Information system supports the relationship between the company and customers.<br>• Corporate responsibility – marketing data that translate market demands are considered in developing solutions and production plans, and at the same time, production data related to sustainability can be used in the marketing plans. Transparency in external and internal communications is mandatory, focused on engagement and meeting stakeholder demands. |
| **Triggers for Level 2 (processes that can improve maturity)** |
| • Procedures to assess corruption-associated risks and promote activities combatting these risks in all operations along its value chain; processes to combat unfair competition practices;<br>• Internal and external communication processes are conducted transparently, focusing on engagement and meeting stakeholder demands. |

Exhibit 16 - Characterization of maturity level 2

| **Level 2** |
|---|
| **General description for the level (performance goal for the level)** |
| Eco-efficiency of operations |
| **Generic description of the content (content of the area of change)** |
| More than identify and control, all impacts need to be reduced. Key suppliers must be included in product design focusing on reducing impacts related to materials, natural resources, and carbon footprint. |
| **Generic description of the context (drivers of change)** |
| Company needs to ensure its efficiency and productivity in accordance with socio-environmental requirements |
| **SOM capabilities involved (relevant capabilities to achieve the goal)** |
| Life cycle management, reverse logistics, product design, closed loop supply chain, cleaner production, EMS, eco-efficiency, and sustainable business. |
| **Focus of the SOM dimension (processes that must be implemented and management for continuous improvement)** |
| • Sustainable product design and management – Sustainability is integrated as a requirement in developing new products, focusing on reducing risks and impacts. Processes related to life cycle assessment (LCA) are required to identify and reduce environmental impacts in products, from design/conception to end of life (stage of use). In design/conception of products, company needs to ensure reuse/recycling, or projects conducted together with partners to build infrastructure that guarantees reuse/recycling beyond the standard reuse/recycling streams. Suppliers need to be involved in product design to reduce environmental impacts in all product life cycle stages. Additionally, cooperative processes with suppliers are necessary to create more sustainable logistics systems.<br>• Sustainable production – Based on EMS requirements. Company tracks water, energy, and emissions internally and in the supply chain. Efforts and investments are applied in the use of alternative energy, water reuse, and carbon-neutral technologies. In order to be in total compliance, company carries out environmental remediation projects, such as cleanups or recovery related to past practices.<br>• Corporate responsibility – ensure that processes and products add value to business while at same time reducing environmental impact and benefiting society. |
| **Triggers for Level 3 (processes that can improve maturity)** |
| • Cooperative and co-development processes with suppliers to carry out strategies related to sustainable product design and sustainable supply chain requirements;<br>• Identify, through sustainable business cases, how processes and products can add value to business while reducing environmental impacts and benefiting society. |

Exhibit 17 - Characterization of maturity level 3

| **Level 3** |
| --- |
| **General description for the level (performance goal for the level)** |
| Establishing a sustainability management system |
| **Generic description of the content (the content of the area of change)** |
| Formal processes for sustainable production and sustainable product design, focusing on customer demands. Eco-efficiency strategies are dedicated to energy efficiency and use of renewable resources, risk management, reducing carbon footprint, and establishing reverse and closed supply chain systems. |
| **Generic description of the context (drivers of change)** |
| Socio-environmental capabilities become formalized, defined, and managed by continuous improvement and optimized processes. |
| **SOM capabilities involved (relevant capabilities to achieve the goal)** |
| Sustainable purchasing, QMS, lean and green processes, cleaner production, and eco-efficiency |
| **Focus of SOM dimension (processes that must be implemented and management of continuous improvement)** |
| • Sustainable production – company needs to develop a local network of suppliers and define sustainability criteria for selecting and assessing suppliers; QMS and EMS are totally defined and implemented. Changes/innovations are applied in processes and technologies to improve socio-environmental performance across value chain operations (e.g. replace hazardous or non-renewable materials with less dangerous or renewable ones, using more durable materials, internal reverse logistic strategies for reusing waste materials).<br>• Value-chain integration – suppliers are included in efforts to improve quality. |
| **Triggers for Level 4 (processes that can improve maturity)** |
| • Majority of the factory floor processes undergo statistical quality control<br>• Processes to develop the local network suppliers. |

Exhibit 18 - Characterization of maturity level 4

| **Level 4** |
|---|
| **General description for the level (performance goal for the level)** |
| Network and stakeholder integration |
| **Generic description of the content (content of the area of change)** |
| Suppliers, customers, and other stakeholders engage and collaborate in the company´s sustainability strategies and operations. |
| **Generic description of the context (drivers of change)** |
| Sustainability principles and processes are integrated across the value chain. |
| **SOM capabilities involved (relevant capabilities to achieve the goal)** |
| Social accountability, sustainable purchasing, information system, supplier development program, and stakeholder engagement. |
| **Focus of SOM dimension (processes that must be implemented and management of continuous improvement)** |
| • Social Accountability – Company cooperates with creation of public policies. Suppliers are encourage to be aligned with global sustainable development initiatives (e.g. Global Compact or Millennium Development Goals).<br>• Value-chain integration – information systems and technologies that support engagement of company and suppliers, sharing information about demand planning, transport, production, integrated performance data, and knowledge. This permits supplier involvement in redesigning the company’s internal processes. Regarding customers, the upper-level administration considers sharing information with customers to be fundamental, and supports activities and processes related to this practice. |
| **Triggers for Level 5 (processes that can improve maturity)** |
| • Company cooperates with processes to create public policies. |

Exhibit 19 - Characterization of maturity level 5

| **Level 5** |
|---|
| **General description for the level (performance goal for the level)** |
| Integration of sustainable operations |
| **Generic description of the content (content of the area of change)** |
| An integrated management system established across the supply chain and guided by a new business model based on innovation, looking for more sustainable processes in a continuous improvement system. |
| **Generic description of the context (drivers of change)** |
| A wide sustainability net must be defined. |
| **SOM capabilities involved** |
| Supplier development program, sustainable business case, sustainable marketing |
| **Focus of SOM dimension (processes that must be implemented and management of continuous improvement)** |
| • Value-chain integration – sustainability is integrated into business strategy in products and services, considering the entire value chain. Suppliers are encouraged to report their environmental performance.<br>• Corporate responsibility – company identifies material sustainability and measures performance effectiveness on sustainability issues, i.e., establishing measures for creating value from sustainability for the company´s reputation and brand, for all stakeholders, for the value chain. Company has processes to identify new business opportunities related to sustainability and apply efforts toward developing consumers with more sustainable aspirations. |
| **Triggers for a next level (processes that can improve maturity)** |
| • Material sustainability;<br>• Measures for value creation. |

# 6. CONCLUSION

This section presents the conclusions for this research. In addition, highlights contributions and originality aspects, frameworks' applicability and usefulness considering the cultural context and field of industries. Finally, reccomendations will be given for further research.

## 6.1. CONTRIBUTION AND ORIGINALITY

The major conclusion of this thesis is that sustainable operations management (SOM) can be viewed as consisting of a scope of capabilities which can be integrated, managed, and evolve from a compliance approach to an innovative approach, helping companies to improve and carry out sustainability integration processes.

By focusing on decision-making processes amd adoption of SOM practices, the maturity framework organizes the capabilities that must be guided by a business model and a corporative strategy that supports the dissemination of the meaning of sustainability and strategies throughout the company and its value chain.

In the corporate strategy, socio-environmental performance goals perform a new model of performance management, based on the TBL. However, the addition of new goals are not enough to establish a sustainability performance management system. They need to be managed in an integrated manner, with well-defined cause-effect relationships, clarifying the value proposition of the sustainability strategy.

The maturity of SOM capabilities is directly associated with the degree to which operations are integrated into the value chain, and the level of engagement with the supply chain, customers and other stakeholders. It is also highly dependent on the evolution of corporate social responsibility and upper-level leadership. Operations decision areas, guided by sustainability principles, support the achievement of performance goals.

Sustainability at the value chain level is carried out by the SOM capabilities and their evolution, represented by: sustainable supply chain management, sustainable production, sustainable product design and life cycle management, social accountability, stakeholder engagement and its integration into decision-making processes, and corporative responsibility (governance) processes.

This is not a trivial task, and this matter represents the complexity of the proposal. Other factors that indicate complexity are: the multi-method approach brings more complexity to the research process, the number of aspects considered in the framework, the multidisciplinary of the theme and related theories, sustainability integration is not a short-term task, but takes years to be implemented in order to companies become more mature in sustainability, both in strategy and operations terms.

The contribution of the research can be viewed through the main points below:

- the maturity framework for sustainable operations contributes to the field of OM in the sense that it contributes to reducing the gaps identified in the literature review: bringing together theory and practice (Slack, 2004); absence of specifications, norms, and frameworks to describe how operational performance can be tied to sustainability (Liyanage, 2007; Ueda et al., 2009; Singh et al., 2009; Bititci et al., 2012); introduce the framework that converts business strategies focused on TBL into implementable operational decisions (Ferrer, 2008); lack of a model for incorporating sustainability and "difficulty quantifying intangible effects" (Kiron et al., 2013a), and others.
- the framework also contributes to the practice of companies that need to develop a strategic vision of sustainability for creating value and determining how to implement this vision (Lubin; Esty, 2010; Epstein; Buhovac, 2010).
- fulfilling the guideline of being a framework that supports the processes of implementation and management of sustainability operations, the maturity levels can be applied in three mais situations:
    - guiding the strategy- be a guiding instrument in strategic plans for sustainable business models, orienting the necessary competencies for operations to reach the next stage towards the highest level in a homogeneous way;
    - auditing of sustainability– evaluation of postures and practices for the purpose of certification and/or sustainability communication processes;
    - definying a sustainable performance management system– based on the maturity levels and their specifications, sets of indicators from standards, guidelines and already-validated sustainability reports can be grouped in a more optimized and integrated way to the TBL.

The originality is supported by the fact that there are few studies dealing with modeling and analysis of SOM decision-making at strategic, tactical, and operations levels

(Gunasekaran and Irani, 2014). In addition, the literature review did not identified a maturity model in the SOM context, which considers SOM capabilities in an integrated way.

## 6.2. APPLICABILITY AND USEFULNESS

The maturity framework was evaluated and considered applicable and useful. The framework and its related concepts were evaluated in different stages of the research: (1) the first conceptual framework was presented at the 23th ICPR; (2) the experts evaluated the framework in three dimensions - *Feasibility (can the model be followed)? Usability (how easy it is to follow it)? Utility (does the framework provide a useful step towards solving the problem it is meant to solve)?;* (3) in the research cooperation project, a group of professionals from Company ZZ were invited to participate in a workshop related to assessing sustainability indicators and completing the sustainability record information sheet.

'Sustainability megaforces' represent severe constraints for companies, but also can bring opportunities for those that have a proactive and innovative business environment, such as: cost reduction, increased revenues, risk reduction, improving the company's image, development of human capital, and access to capital. SOM capabilities and OM theories and concepts can support this.

### 6.2.1 Cultural contex

The studies were based in companies with operations in Brazil and consequently subject to Brazilian regulations. Brazilian environmental laws are considered very advanced, and are some of the most complete in the world. According to the SustainAbility study, which was the product of a partnership between IFC and the Ethos Institute (2003), companies in emerging markets are benefiting from initiatives that combine progress with sustainable development.

Additionally, it is important to highlight that some of companies have headquarters and conduct business and operations abroad, which can have influence on sustainability requirements (e.g. for the forest industries, Forest Stewardship Council certification [FSC] is quite mandatory for opportunities in international markets).

### 6.2.2. Applicability to fields of industries

The empirical focus has been on manufacturing and infrastructure companies. The fields of industry which are most representative in the study context (including the case studies and survey) are: pulp and paper (12 companies), chemicals and petrochemical (8 companies), and automotive and agricultural machinery (6 companies).

The survey findings indicate that the framework fits the operations of large manufacturing companies, but some medium-sized companies are well-represented in the analyzed sample (19 companies), indicating that sustainability issues are relevant for these companies as well.

## 6.3 RESEARCH QUALITY AND VALIDITY AND FUTURE RESEARCH

The research quality and validity followed criteria for scientific validity and characteristics of the scientific models provided by Franck (2002) and Ensslin (2008). Strategies and decisions for perform quality and validity are described in sections 3.1 and 3.2.

We consider the majority of criteria to have been met, with the corresponding limitations of a study which is exploratory in nature. Future studies are recommended and necessary, especially to increase the power of generalization between the company-specific and industry-general situation.

In this sense, in-depth case studies conducted in specific sectors are recommended to be contrasted with the exploratory studies that comprise this thesis. More robust tests are recommended for the framework and for the characterization charts, and to complement the studies begun with the P3G Project for developing sustainable performance systems that make up the value chain.

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# APPENDIX 1

## PAPER I - TRENDS AND OPPORTUNITIES IN THE FIELD OF SUSTAINABLE OPERATIONS MANAGEMENT

Carla Gonçalves Machado[a], Edson Pinheiro de Lima[ab], Sergio Eduardo Gouvea da Costa[ab], Jannis Jan Angelis[c], Wesley Vieira da Silva[d]

[a] Industrial and Systems Engineering Graduate Program, Pontifical Catholic University of Parana, 80215-901 Curitiba, Brazil.

[b] Federal University of Technology - Parana, 80230-901 Curitiba, Brazil.

[c] Department of Industrial Management, Royal Institute of Technology – KTH, 100 44 Stockholm, Sweden.

[d] Department of Administration, Pontifical Catholic University of Parana, 80215-901 Curitiba, Brazil.

**Abstract**

The search for a sustainable development model is a priority for society, governments and companies alike, as reflected in legislation, standards, demand for transparency in economic activity, and positioning on environmental and social issues that call for new operations models and parameters that involve the whole supply chain. Based on a systematic literature review using Bibliometric Analysis, Social Network Analysis, Statistical Tests and Content Analysis, the authors analyzed the research trajectory of sustainability in the operations management context by analyzing 495 scientific papers published in journals from 1995-2011. The study develops the OM field by setting a structured mapping of sustainability in the operations context, presenting its evolution as well as key themes, authors and publications. The main contribution of the study is that it reveals that sustainability research has reached a level of maturity suitable for developing rigourous theories and practices that can contribute significantly to sustainable development. The research area has acheived a considerable degree of maturity in themes such as environmental management and supply chain management which have evolved from a reactive, for-compliance perspective, to a proactive approach, based on technological and process innovation to meet the triple bottom line. The operations management field has a relevant scope to contribute to sustainable development, by reducing social and environmental impacts in operations and creating opportunities for innovative approaches through sustainable business models.

KEYWORDS: operations management; sustainable operations management; literature review.

## 1. Introduction

Sustainable processes are being incorporated into the strategic agendas of corporations, thus confirming predictions that sustainability would become a key factor for maintaining and/or building competitiveness, and ushering in an era of transformation and adaptation in business models and operations [38, 37, 43, 22].

Drake and Spinler [15] reviewing Paul Kleindorfer's et al. study [33] analyzed whether sustainable operations management (Sustainable OM) is an enduring stream or a passing fancy. They argued that the climate crisis brings a higher level of uncertainty for industry (e.g.

regulatory, economic and legal risks from policy makers and non-governmental organizations) and, consequently:

> [...] Sustainable OM is likely to endure as an active and important stream if we deliver its implicit promise: to generate research that enables production and distribution systems to operate more efficiently with respect to their environmental and social impacts. Such research must ultimately advise and impact practice and/or policy. It can do so by (i) engaging practitioners and/or policy makers; and (ii) embracing the multidisciplinary nature of the sustainability challenge [15].

Thus, two main questions arise that this study seeks to answer: First, how have sustainable operations management studies developed over the last two decades? Second, how mature is sustainability research in terms of knowledge? The first question helps identify trends in relevant sustainable operations management studies, while the second question provides insights into the evolution and maturity of the research area within the OM field.

In this study, we have conducted a literature review to identify how and by whom the sustainability theme is being explored, and how it has evolved. It also identifies gaps, trends and research opportunities. This is important because many decisions that determine the impact of sustainability intersect with the flows from operations management, such as product design, technology and supply chain management, as pointed out by Drake and Spinler [19].

The literature review was designed based on bibliometric studies previously conducted in the OM field, i.e. Pilkington and Meredith [52]. The review is mainly distinguished by the scope of its sample, which encompasses nine different relevant databases, 139 journals and 495 papers published between 1995-2011.

The paper is structured as follows: the first part is dedicated to contextualizing the purpose of this study and the mapping of previous research in the OM field; the second part presents the research design and methodological approach; and the third part presents the applied methodologies, a discussion of the findings and conclusions.

This study contributes for updating sustainable operations literature review and, through this understanding, to identify opportunities and possible trajectories and paths that could orient future research and practical recommendations for designining and implementing operations strategies based on sustainability values. Thus, it helps academics and practitioners to better align sustainability efforts to an expanded vision for operations management and operations strategy.

### 1.1 Basic terminology

Acording to a report by the World Commission on the Environment and Development, sustainable development is "[...] that which meets the needs of the present without compromising the ability of future generations to meet their own needs" [69]. The consulting firm Deloitte and the International Institute for Sustainable Development then proposed the following definition for business enterprise: "[...] sustainable development means adopting business strategies and activities that meet the needs of the enterprise and its stakeholders today while protecting, sustaining and enhancing the human and natural resources that will be needed in the future" [31]. Note that the definition is aligned with the Triple Bottom Line principles formulated by John Elkington [17].

Sustainable operations models are driven by the production of goods and services in an economically viable manner using non-polluting production processes, conserving energy and natural resources; the production, development and delivery of products and services under healthy and safe conditions for all customers and employees in a way that is socially acceptable to meet the demands of stakeholders [65, 39].

For Kleindorfer et al. [33] sustainable operations management is a set of concepts and skills that allow companies to structure and manage their business in such a way that profits are maximized in balance with people and the environment. For them, the main contributions of the sustainability concept applied to OM are: green products and process development; lean and green operations management; and remanufacturing and closed loop supply chains. Sustainability-driven OM can help companies be more agile and adaptable in balancing profitability with the needs of the public and the planet, representing new opportunities for researchers to make a difference.

For Nunes et al. [49] sustainable operations cover 7 main areas: (1) green buildings; (2) eco-design (product and process development); (3) sustainable production; (4) sustainable supply chains; (5) reverse logistics; (6) corporate social responsibility - internal and external communities and (7) innovation in business models. Also, due to the complexity of issues a systemic approach strategy is recommended. Thus, the field of OM creates and/or modifies daily practices and decision-making models based on the Triple Bottom Line, incorporating variables related to sustainability into planning and operational management systems [71, 33, 30, 63, 64, 22].

## 2. Previous mapping of research in the operations management field

The OM field has evolved from efforts made to establish the boundaries, gaps and trends from the scientific knowledge generated, e.g.: [50, 58, 33, 51, 4, 13, 52, 61, 22]. Other relevant literature reviews have been conducted in the OM field, e.g. Seuring and Müller [119] and Seuring [57], which present a review of the sustainable supply chain field. However, in this section priority was given to studies dedicated to mapping the evolution of OM and Sustainable OM for the purpose of identifying the relevance of the topic sustainable operations management for the evolution of the OM field. According to Kleindorfer et al. [33] "[...] We are just beginning to understand and map the territory of sustainable OM".

Table 1 offers a synthesis of OM as characterized by the aforementioned research.

**Table 1** – A synthesis of the OM field mapping

| | |
|---|---|
| **Barriers to establishing OM as a discipline and research gaps** | The low participation rate of OM researchers in journals devoted to the field; limited development of theory with practice and gaps between sectoral priorities and OM research; gaps between the priorities of OM research and practitioner significance; a need for a greater level of integration with other fields of study; a need for quantitative analyses that better define the conceptual limits of the field and for studies that explore research methods used in other fields. |
| **Major themes over the last 20 years** | Manufacturing and operations strategy; Japanese strategies; productivity and competitive strategies; performance management; best practices; total quality management – TQM; just-in-time – JIT; business process reengineering-BPR; mass production; mass customization; supply chain management (SCM); resource based view (RBV); lean strategies; MRP/ERP systems; measure-balanced scorecards; qualitative and quantitative methods; process design and control; enterprise resource planning; service operations; project management; people management; support services. |
| **Emerging topics** | Integrated performance management and measurement system; sustainable resource-based view; human resource management; servitization; extended ERP (ERPII); lean, agile, and global SCM; closed loop supply chain management; virtual enterprise; sustainable supply chain management; sustainability; sustainable production; and, sustainable operations management. |
| **Importance of the OM field** | Capable of analyzing global-scale problems and changes (i.e., relevant to global issues and changes, including sustainability).<br>Competence to generate more sustainable processes and technologies.<br>Capable of building theories to explain real management phenomena.<br>Capable of designing and managing transformative processes that create value for organizations and society.<br>New concept for the OM function can help to deal with corporate changes, including market and social evolution. |

Source: [50, 58, 33, 51, 4, 13, 52, 61, 22].

Bayrakatar et al. [4] noted that the field of OM was especially well suited for this new perspective of sustainability. Taylor and Taylor [61] have argued that the field of OM is relevant to global-scale issues, including sustainability. As noted in Table 1, sustainability is already part of the OM research agenda. However, Gunasekaran and Ngai [19] observed that the theme sustainable operations still represents a gap in the OM field, which potentially can address various social and economic needs, such as the need for responsible supply chains.

Kleindorfer et al. [33] highlighted that the people part of the triple bottom line approach is "[...] notably absent from OM research to date". Also, the sustainable operations research will need to establish strong links with other fields and reinforce its original link with engineering.

Research gaps were identified in some complementary studies. For Linton et al. [105] there has been significant progress made in the theme sustainability in OM, such that researchers and managers should be considering the issues and impacts of sustainability in traditional models and practices. Examples include the evolution of approaches to green design, clean technologies, and environmental management. However, the authors' caution "[...] these subjects are not considered from the unifying perspective of sustainability".

It is important emphasize some points that the presented literature review complement the efforts developed in previous studies: (1) expanding the journals sample scope; (2) updating and extending the sustainability literature review delimited by operations management area; (3) mapping the author's groups and its main interests and contributions; (4) identifying the research evolution based on research life cycle maturity model during the last sixteen years.

## 3. Research Design

This literature review is based on the parameters of the 'Systematic Literature Review' (SLR). The SLR must be supported by methodological procedures for analyzing, understanding and synthesizing the literature, providing a solid foundation for the research theme and demonstrating contributions to the field of study [68, 62, 35]. An SLR can identify the scientific contributions to a specific field of study or a research question and the use of meta-analysis (quantitative analysis) provides a statistical procedure for synthesizing data, thus increasing the reliability and quality of the results [47, 62, 35]. The research design of this literature review was developed to meet these requirements (Fig.1)

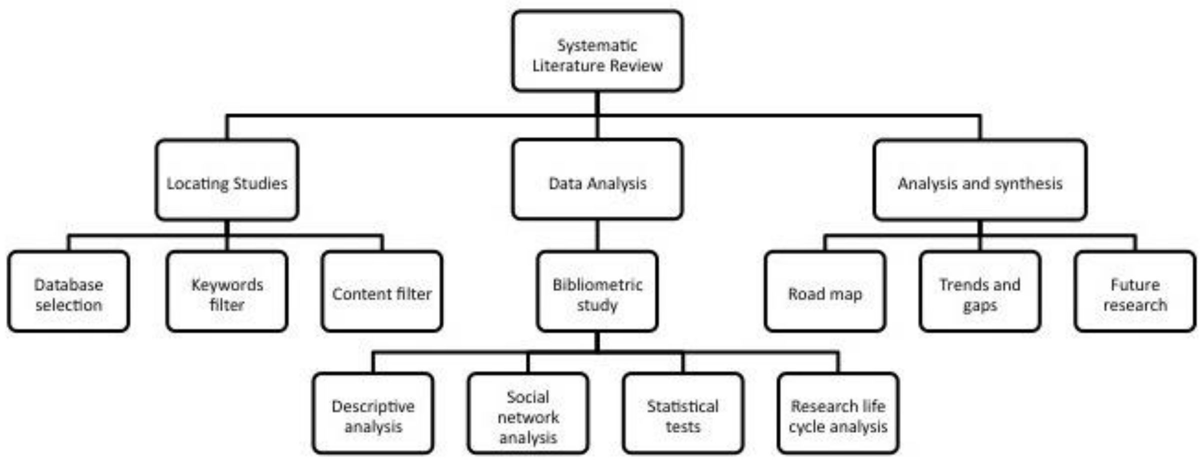


**Fig. 1** – Research design

The chosen strategies were intended to provide insight into relationships between authors and their impact on scientific production in the field, thereby strengthening inferences and providing a more rigorous perspective of the trends in research on sustainability in OM.
In order to clarify the SLR strategies, the next three items provide information about how the sample was formed and criteria for conducting social network analysis, statistical tests and content analysis.

**3.1 Locating studies and sample selection criteria**

Studies have mapped the OM field by examining its scientific production using bibliometric methods (i.e., bibliometric data analysis, citation and co-citation analysis, content analysis or social network analysis), based on the notion that bibliometric data (author, citation, date, keywords etc.) can serve as important indicators for tracking the evolution of a field of study [59, 44, 41, 60].

The exploratory study was conducted based on bibliometric data extracted from 495 papers published from 1995-2011. This revision can be distinguished by its extensive scope, which included 9 databases and 139 journals, showing the expansion of the OM field and its connection with other fields of study.

For the sample selection a general search of the ISI Thompson, Scopus, and CAPES journal databases, was conducted in order to identify academic bases connected to operations management and sustainability (Triple Bottom Line approach). Nine databases were selected: (1) Academic Search Premier/ EBSCO; (2) Emerald; (3) IEEE Xplore; (4) Scielo; (5) Oxford Journal; (6) Science Direct; (7) Springer Verlag; (8) Taylor and Francis; (9) Wiley Interscience.

Only full papers published in peer reviewed scientific journals were part of the sample. Other types of research, such as governmental literature, newspaper articles, technical reports, interviews, and abstracts were not included, as per Webster and Watson [68].

The papers selection consisted of three stages: (1) papers filtered by the keywords "sustainability" and "operations management", totalling 1000 papers; (2) papers filtered by relevance, content, and relationship to issues connected with the OM and triple bottom line context involving environmental, social and economic aspects, totalling 495 papers; (3) refined database for content analysis, taking into account papers by the twenty authors selected in by higher degree centrality, totalling 70 papers.

The sample is considered relevant because it comes from selected academic databases and from relevant journals that mainly communicate research results in operations management area. The bibliometrics data were used in this study for presenting a descriptive analysis, to provide data for the citation matrix, and to connect the results to the research life cycle analysis.

### 3.2 Social network analysis and statistical tests

One study assumption was that the establishment of a field of study depends on the social relationships existing among researchers. Scott [56] has argued that the very notion of a field implies the existence of a group of researchers who share common interests and relate more strongly to each other than to researchers outside the field. Studies have confirmed that a social network analysis provides understanding of such these relationships by allowing for the mapping of knowledge bases and assessing the development of scientific knowledge and the level of consolidation of a given discipline [54, 70, 41, 60].

Hanneman and Riddle [26] have argued that an author in a privileged position may have advantages in the exchange of information, and greater influence and recognition than other, less privileged members of the network.

The centrality network measures, including degree centrality, betweenness and closeness, are relevant for analyzing the actor's importance in a social network because they provide information for indicating the respective degree of importance and influence in the social network among different authors [9, 67, 7, 26]. The centrality measures chosen for the author's network analysis were:

- Production - number of papers published in the selected sample.
- Degree - authors with a greater measure of centrality have a higher number of connections, tend to occupy a privileged position and exert greater influence in the network.
- Closeness - authors separated from other authors by shorter distances can be considered more accessible, i.e., they can reach other members of the network via shorter, more accessible paths, and thus have more influence.
- Betweenness - an author who is a connector between two other authors in the network occupies a structurally privileged position.
- Effsize – or structural holes represent gaps between two authors and opportunities for new contributions. Authors have access to different flows of information, and the hole represents both an opportunity to mediate the flow of information from

> different sources and an opportunity to take the initiative on projects derived from linking the opposite sides of the structural hole. Individuals whose contact networks have many structural holes are those who have access to greater knowledge and control over new opportunities (sources of innovation).

According to Wasserman and Faust [67], statistical analyses make it possible to test theories about networks from a probabilistic viewpoint, and to describe and better understand behavioral and relationship patterns among the authors in a network.

In accordance with the concepts presented, the scientific production of an author is assumed to be dependent on the relationships he or she builds in the academic community, such that a privileged position in the network tends to increase an author's productivity. The measures of centrality are assumed to reflect the position of each author with respect to the center or periphery of the network, and are expected to differ between different groupings of authors. Accordingly, in this study the following hypotheses were developed and tested:

H1: There is significant association between the independent variables (network centrality measures) and the dependent variable (production).

H2: Authors' placement in the network, as represented by measures of centrality, has a significant effect on the production of each author.

H3: There are significant differences between centrally located and peripherally located authors.

Technically, the first hypothesis aims to verify whether authors' academic production is associated with their positions in the network, according to centrality concepts of the social network theory. The second hypothesis ascertains 'how' network position affects authors' production. The third hypothesis identifies the most representative authors in sustainability research. Thus, the three hypotheses complement each other for verifying if the centrality measures are reliable variables for mapping and qualifying the research community.

In the literature analysis the three hypotheses represent the findings validation, that is, showing the representative authors, themes and how the research communities are been formed in this specific research theme. Mapping the research community is relevant for updating the literature review and corroborates for answering the first research question that seeks to identify and to understand the 'territory' and the trends on sustainable operations management studies, as suggested by Kleindorfer et al. [33].

## 3.3 Content Analysis

For Freitas and Janissek [19] there is something to be discovered in the analyzed texts. The content analysis was carried out according to the four steps of Freitas and Janissek [19]: (1) definition of the sample; (2) categorization; (3) choice of the units of analysis; (4) qualification. Steps 1 and 2 were conducted in the full sample selection processes and step 3 was defined through the selection of the paper sample originated from the twenty authors with the highest degree centrality in the network studied, representing the scientific relevance of the sample.

The units of analysis were 'theme' and 'publication year' and they were studied through a manual procedure. The seventy papers selected for the sample were qualified by year of publication in order to identify the progression over time, and to associate them to sustainability and operations management topics and their contributing authors.

## 4. Data Outcomes

Bibliometric information (author name, institution, country, research method, year of publication, and keywords) was organized with the aid of Mendeley software. The collected data were organized in an Excel® spreadsheet in the following manner: (i) author and co-author, keywords, publication year, institution, and other relevant data were inserted, (ii) the data were checked in three rounds to ensure that the information was complete and reliable.

Garfield [20] states that studying only first authors may compromise the results of bibliometric analysis, thus all authors were taken into consideration in this study. Also, the limitations presented by Taylor and Taylor [61] regarding favoritism was not considered, as when an author mentions other authors motivated among other things, by the prestige of the older researchers with longer careers, controversial papers or other reasons that make the quote lose its value.

### 4.1.1 Descriptive analysis

Analyzing the papers' year of publication revealed an increase over time in the number of articles published on sustainability themes (Figure 2). The increase was especially notable from 2008-2010, which accounted for 49% of the total.

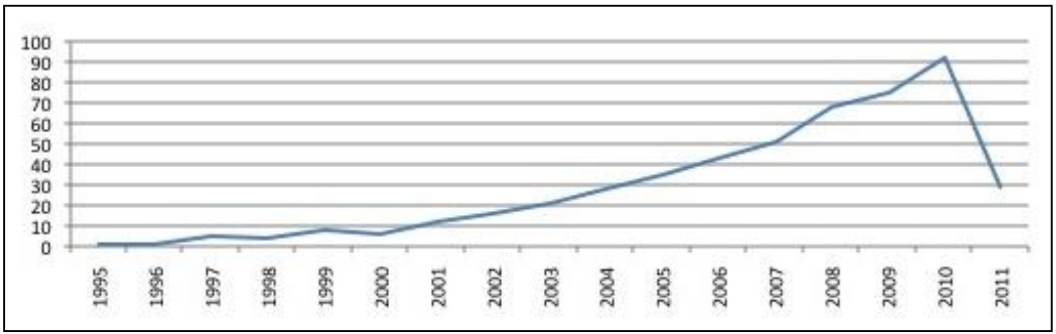


**Fig. 2**. Growth in the number of papers in the sample (number of papers per publication year)

The growth in the number of publications indicates that sustainability is receiving increasing attention from both researchers and journals, in line with the growing interest in sustainability worldwide. The 2011 data show a decline in the number of publications (29 articles). Among the various potential explanations for the decline, it is possible that authors are evolving from earlier, broader discussions about sustainability and focusing on more specific themes because the field is maturing and 'sustainability' *per se* no longer is sufficient to cover all of them.

There has also been a significant increase in publications since 2007, which can be credited to the growth of discussions regarding environmental management, supply chain management and corporate social responsibility. The five keywords with the highest Degree Centrality (DC) corroborate this idea: Sustainable Development (DC:118); Environmental Management (DC:86); Supply Chain Management (DC: 83); Sustainability (DC:69); Corporate Social Responsibility (DC:56).

Some of these themes have influenced the academic production of authors. Figure 3 lists the authors with the largest number of publications and shows Joseph Sarkis to be the author with the greatest number of publications in the sample.

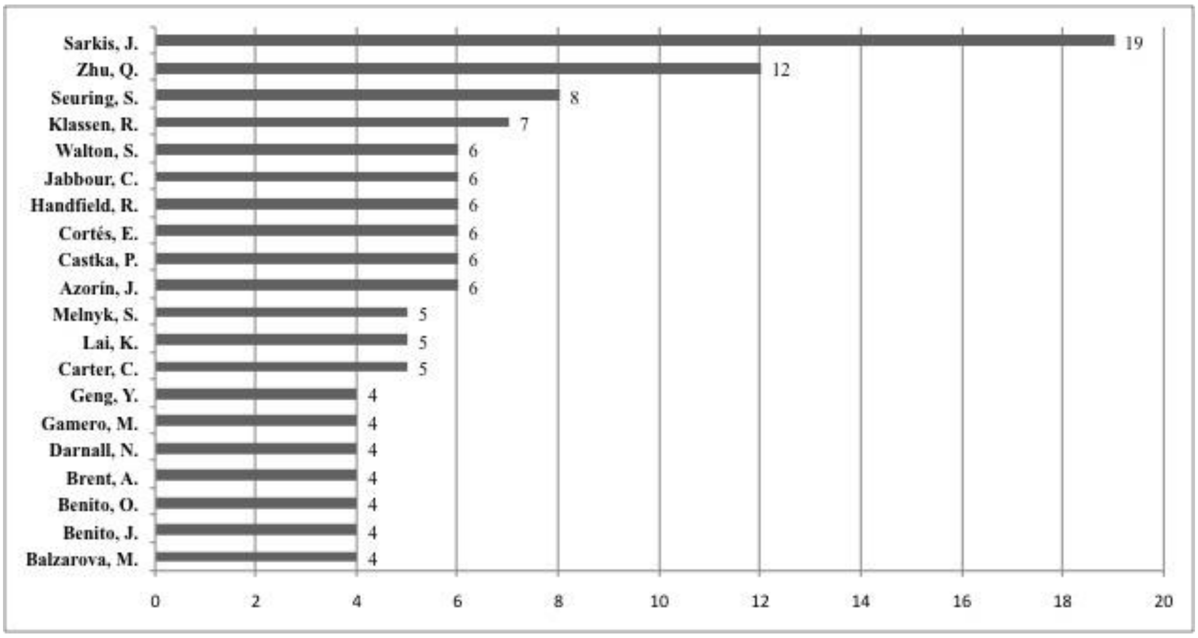


**Fig. 3.** Leading authors ranked by the number of papers in the full sample

It is important to note that Figure 3 was generated from all authors listed in the papers. Co-authorship was not excluded. For example, of the twelve Qinghua Zhu papers listed, nine are co-authored with Joseph Sarkis focusing on primary research with Chinese companies.

The theme sustainability requires a multidisciplinary approach to its implementation given its interdisciplinary nature. The analysis of the identified journals in the sample confirms this direction in the triple bottom line and operations perspectives. A total of 139 different journals were identified and the twenty with the highest number of papers are listed in Figure 4.

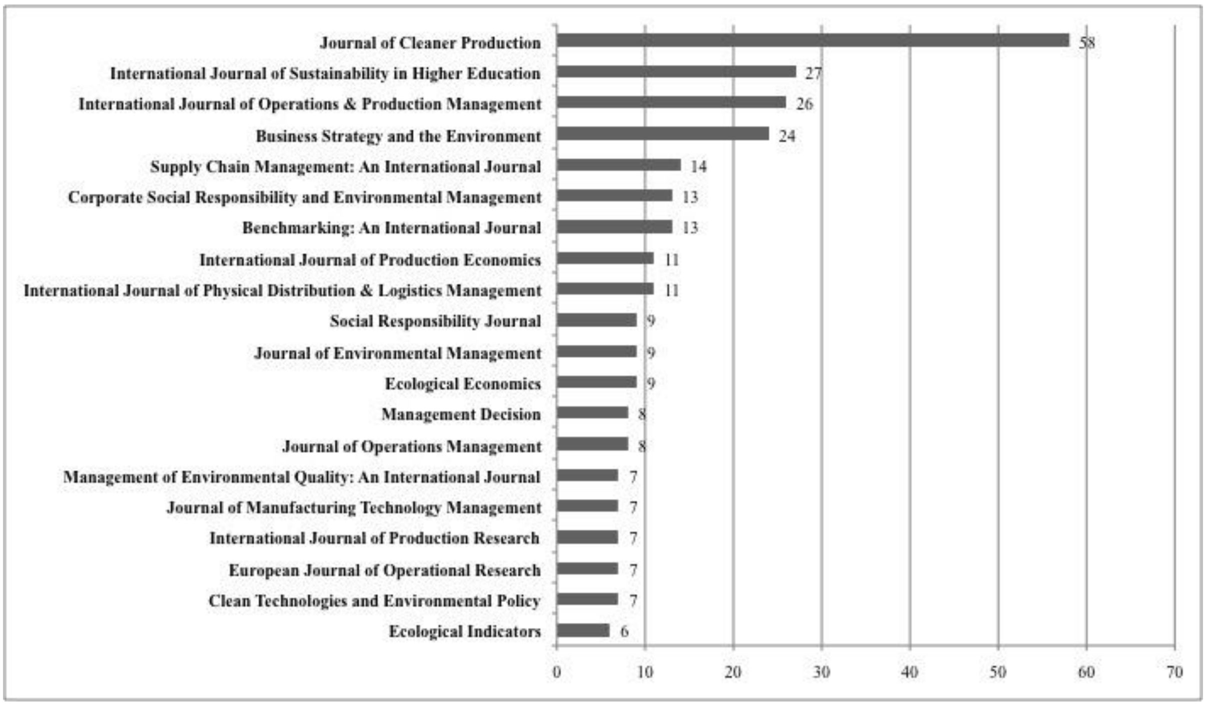


**Fig. 4.** Leading journals ranked by the number of papers in the full sample

The journals listed in Figure 4 account for more than 56% of the 495 papers, which indicates both their relevance in the field and the degree to which they are preferred by authors. The publication of papers in OM-focused journals is a good indicator of the evolution of the discipline, and corroborates arguments by Pilkington and Liston-Hayes [50] and Pilkington and Meredith [52] regarding its consolidation.

The multidisciplinarity of the journals also reflects links between the field of OM and others fields related to engineering and management, corroborating the trend towards incorporating sustainability into several areas. This expands the limits of applicability and reflects its validation by different scientific communities.

As a complementary analysis of the mapping of authors who have worked on the theme, data were collected on author origin (nationality and institutional affiliation). The 20 most represented countries and institutions of author’s origin are listed in Figures 5 and 6.

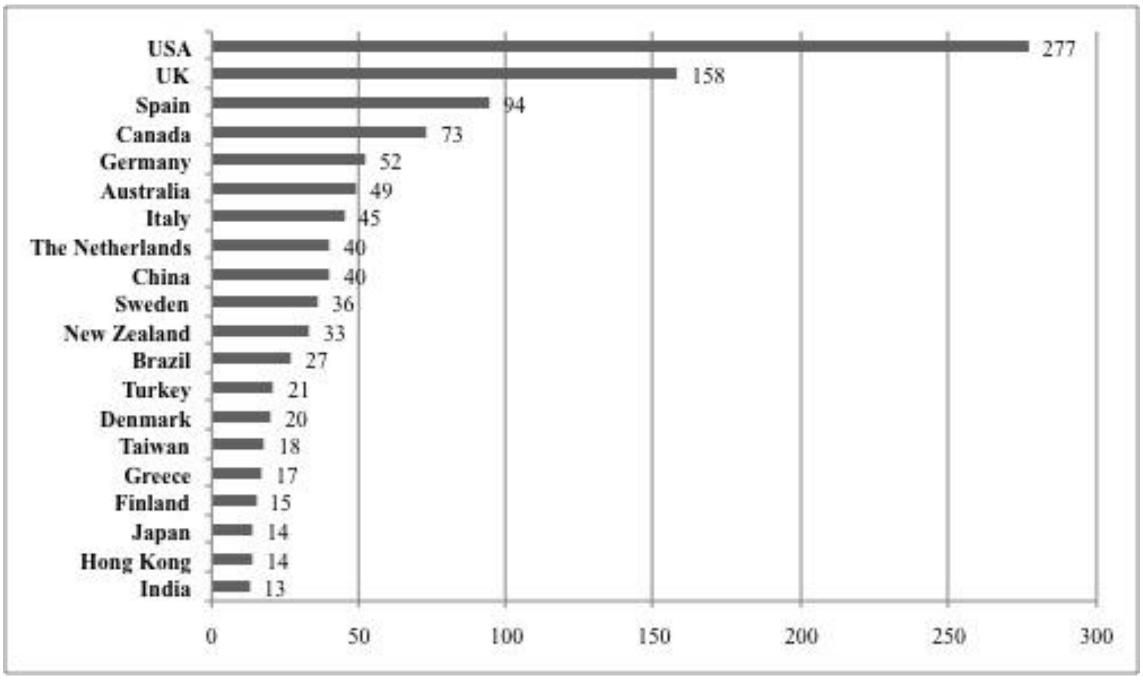


**Fig. 5.** Leading countries ranked by the number of researchers

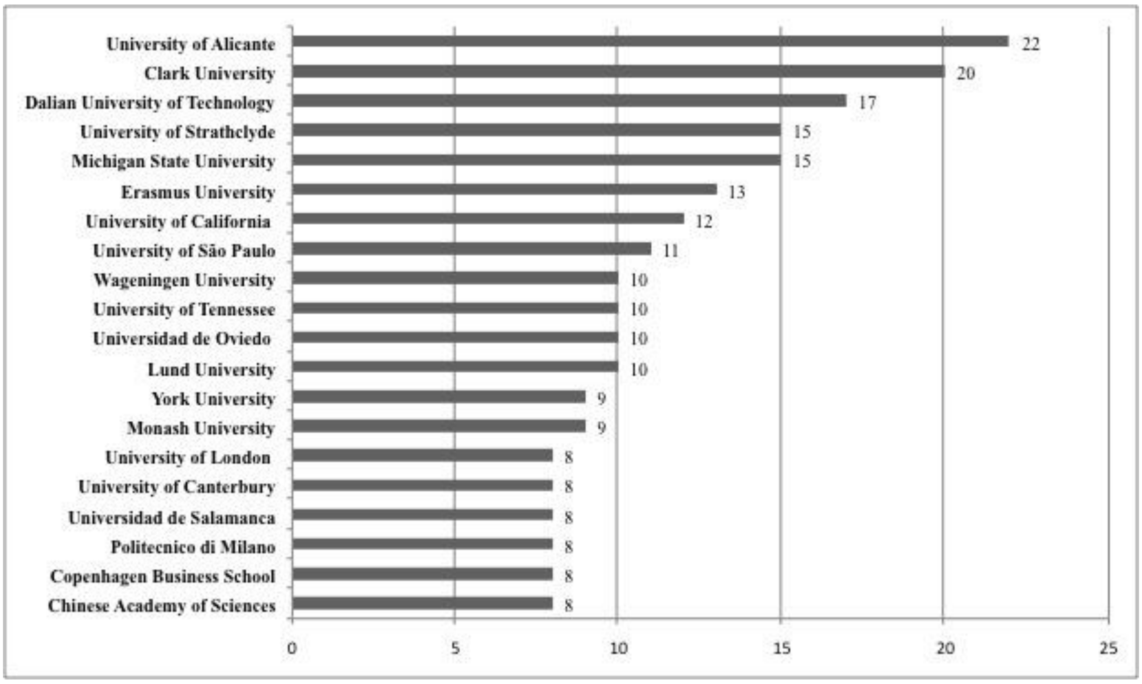


**Fig. 6.** Leading institutions ranked by the number of researchers

Research remains concentrated in the USA and Europe, and this may be one reason for the low concentration of network connections. The studies conducted by Spanish and American universities focus on 'environmental management' and 'green supply chain management' and were mainly published between 2008 and 2010. Note that despite the fact that universities from developed countries are leading the research on sustainability, the participation of universities from developing countries remains relevant.

The globally connected studies reveal that this theme is important for the OM discipline as a whole and offers an opportunity to form a global research agenda for the sustainable operations management area.

### 4.1.2 Life cycle research

According to Lovejoy [42], Amundson [1] and Carlile and Christensen [10] it is crucial that the field of OM develop theories that permit modern-day phenomena to be described and explained in a broad and thorough manner, thereby consolidating the limits of OM. Because different research strategies contribute to this goal, to identify the evolutionary stage of sustainability research focused on methodologies used in the studies by authors with the highest centrality degree, among the refined sample of 70 papers.

The papers were grouped by year of publication, making it possible to track the evolution of the theme in the OM research field by looking at the temporal trends of the different research methods used (Figure 7).

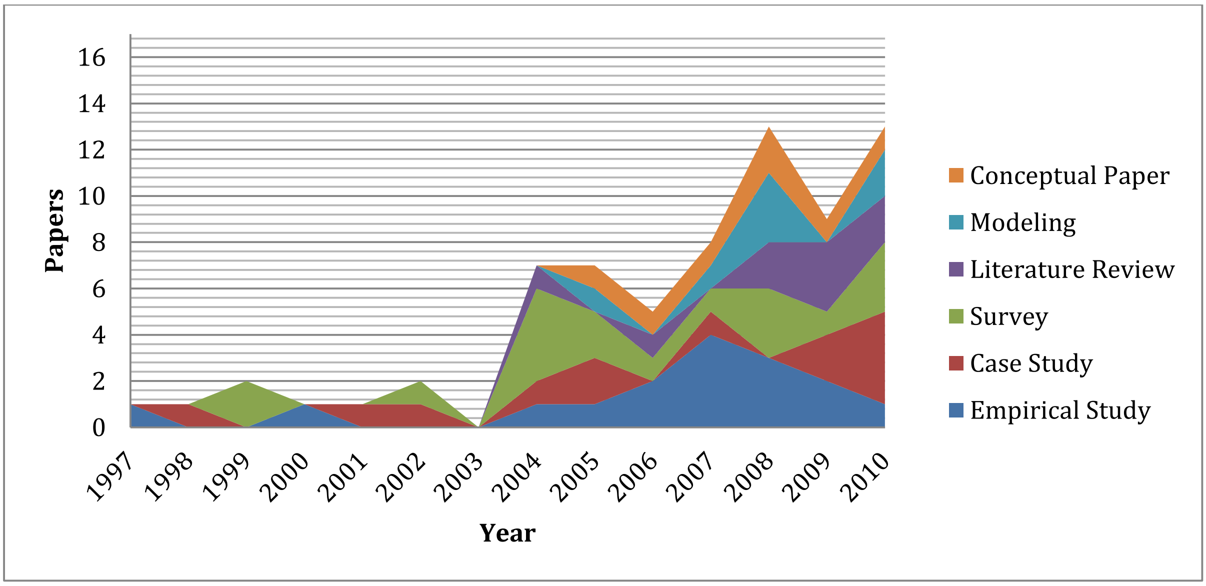


**Fig. 7.** Trends over time of the methods extracted from the sample of 70 papers

Research can be rated as follows: (i) exploratory, characterized by approximation to a certain topic and search for likeliness in relation to a fact or phenomenon; (ii) descriptive, characterized by a thorough knowledge of a problem in order to provide a description of the fact or phenomenon; (iii) explanatory, characterized by the production of a plausible theory for the fact or phenomenon, searching for the “whys” which contribute to or determine its occurrence; (iv) explanatory or normative, characterized by the analysis and explanation of the "whys" related to a certain phenomenon, assisting in its comprehension, thus finding out and measuring the causal relations among them [10].

The data show that papers published from 1997-2004 covered empirical research (3), case studies (4), literature reviews (1) and surveys (7), while papers published since 2005 have included models (7), conceptual studies (7), empirical research (13), case studies (9), literature reviews (8) and surveys (11). This indicates that the research conducted in the field has become broader and more comprehensive in terms of the methods used, to better understand the studied phenomenon.

This methodological analysis confirms the growing interest of the OM community in sustainability research and shows that research conducted over the past ten years has increasingly focused on testing concepts and models proposed in previous decades, thus demonstrating that this research area is evolving into a mature research lifecycle for establishing strong theories, thus answering the second research question proposed.

### 4.2 Social network analysis and statistical test

For the network analysis, an initial database of 927 authors was extracted from the dataset. A sample of 137 authors was then selected to prepare the sociomatrix. The authors from this sample were selected based on their association with at least two items in the dataset, resulting in 397 articles (80% of the total production).

A square 137 x 137 author citation matrix was constructed in order to generate social networks using UCINET/Netdraw software, extract measures of centrality (degree, betweenness, closeness, effsize), and visualize the author network.

The network (one-mode network) formed by the authors based on the measure degree centrality of the nodes illustrates the formation of a rather compact community with some more distantly located authors (Figure 8).

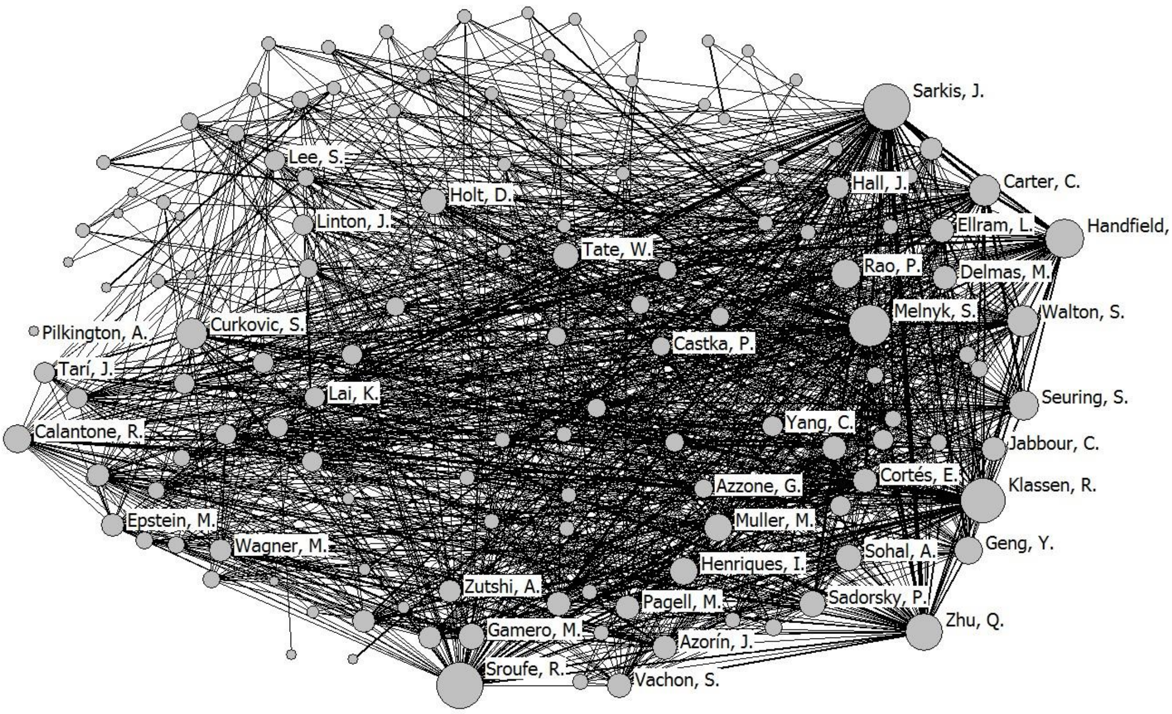


**Fig. 8.** Author citation network (137 authors)

A visual analysis of the network is not enough to determine whether it is strongly or weakly concentrated. Network density (level of network connections) was calculated as the ratio of the current number of connections and the total number of possible connections. This parameter takes the form of the equation L/(N(N-1)/2) [29].

The results depict a community that is dedicated to studying sustainability through a different lens, although it is still poorly integrated. Inserting the values yields a 21% concentration index, which is considered low. According to Hanneman and Riddle [26] a network with a good concentration has density values greater than 50%. Low-density networks have little power and can also indicate poor connections in the network and between its members. This may compromise an acceptable level of information exchange [26, 29]. According to Wasserman and Faust [67] on the other hand, more open networks create favorable conditions for generating new ideas and insights and more opportunities for their members than networks with redundant ties.

Authors with a higher degree centrality are illustrated visually as larger nodes. The twenty authors with the largest CD values are listed in Figure 9.

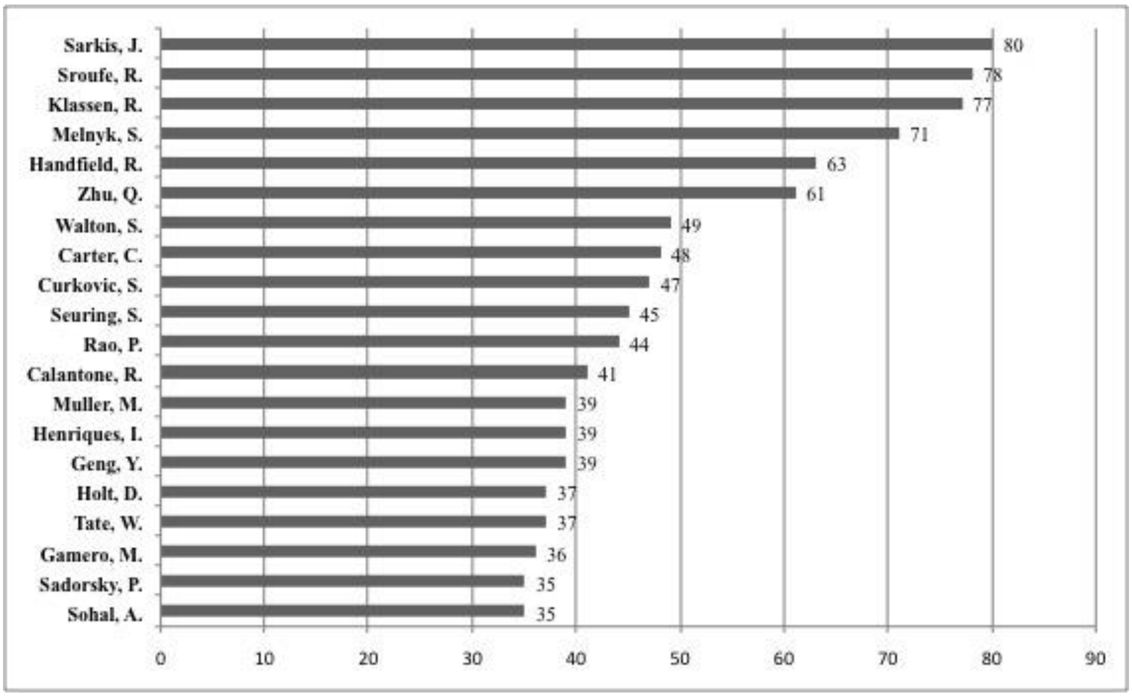


**Fig. 9**. The twenty authors with a higher degree centrality

According to Wasserman and Faust [67], to determine the network importance of an actor it is necessary to examine both the direct and indirect relationships involved. Since one of the goals of this study was to test whether location in the network influenced research development and author productivity, the highest values for each of the variables under study are presented in Table 2.

**Table 2** – The five top authors in each centrality measure

| Degree (CD) | Closeness | Betweeneess | Effsize |
|---|---|---|---|
| Sarkis, J. | Sarkis, J. | Sroufe, R. | Sarkis, J. |
| Sroufe, R. | Melnyk, S. | Klassen, R. | Sroufe, R. |
| Klassen, R. | Gupta, S. | Sarkis, J. | Klassen, R. |
| Melnyk, S. | Geng, Y. | Melnyk, S. | Melnyk, S. |
| Handfield, R. | Carter, C. | Grant, D. | Handfield, R. |

Joseph Sarkis is the author with the highest degree centrality score and structural gap efficiency. Sarkis also has one of the five highest betweenness scores, which means that he can act as a connector, mediating connections between authors and increasing the density/concentration of the network.

The same sample was also subjected to principal components analysis (Figure 10). This algorithm looks for similarities in the distance distributions from one author to the others [26].

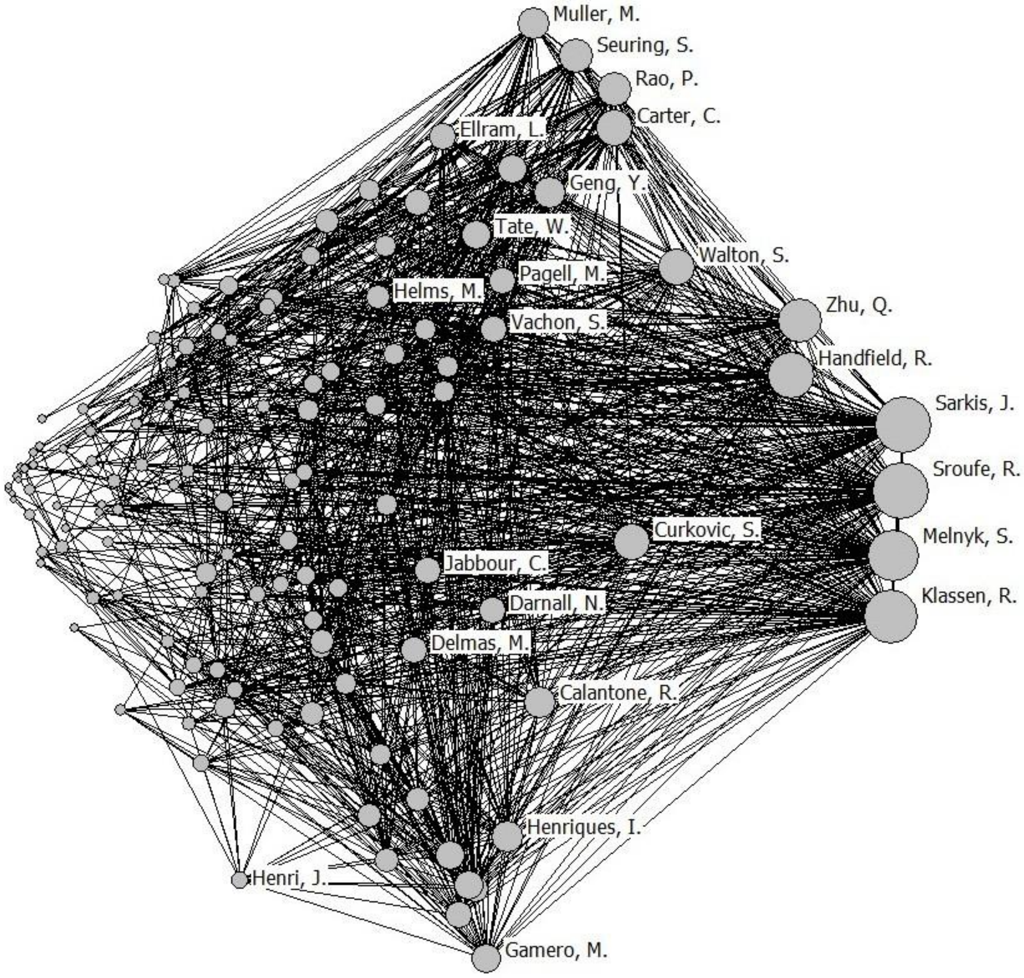


**Fig. 10.** Principal components analysis of the author network

The network illustrates the similarity between the five authors with the highest degree centrality scores in the network. This appears to be the result of the number of studies considered relevant to 'GSCM' (emerging themes in the field), a fact that also favors citation. This presupposition was confirmed by extracting and counting the references of the 70 articles selected in the third phase of research (Table 3).

**Table 3** – The ten most frequently cited references extracted from the sample of 70 papers

| Author/Year | Reference |
|---|---|
| Porter, M.E. and van Der Linde, C. (1995) | Green and competitive: Ending the stalemate [53] |
| Walton, S.V., Handfield, R.B. and Melnyk, S.A.(1998) | The Green Supply Chain: Integrating Suppliers into Environmental Management Processes [124] |
| Hart, S.L. (1995) | A natural resource based view of the firm [27] |
| Min.H. and Galle, W.P. (1997) | Green Purchasing Strategies: Trends and Implications [46] |
| Klassen, R.D. and McLaughlin, C.P. (1996) | The impact of environmental management on firm performance [34] |
| Melnyk, S.A., Sroufe, R.P. and Calantone, R. (2003) | Assessing the impact of environmental management systems on corporate and environmental performance [45] |
| Russo, M.V. and Fouts, P. (1997) | A resource-based perspective on corporate environmental performance and profitability [55] |
| Zhu, Q. and Sarkis, J. (2004) | Relationships between operational practices and performance among early adopters of green supply chain management practices in Chinese manufacturing enterprises [66] |
| Carter C.R., Ellram, L.M. and Ready, K.J. (2006) | Environmental purchasing: Benchmarking our German counterparts [11] |
| Bowen, F.E., Cousin, P.D., Lamming, R.C. and Farukt, A.C. (2009) | The role of supply management capabilities in green supply [8] |

Relevant authors in the network are corroborating the observations of Chalmers [12] and Carlile and Christensen [10], who noted that knowledge might arise from individual research (carried out by a team of researchers) and from interactive cycles of theory development (in which individual research undergoes a process of validation by other research teams).

In order to identify groups in the network, center-periphery and k-core analyses were carried out. The center-periphery analysis highlighted a group of 11 core authors comprised of: Sarkis, J.; Zhu, Q., Klassen, R.; Handfield, R.; Walton, S.; Carter, C.; Lai, K.; Melnyk, S.; Geng, Y.; Sroufe, R. and Calantone, R..

Centrally located authors in the network had high effsize scores, i.e., their position in the network provided better access to gaps in the field, thereby offering opportunities for new contributions. Authors such as Sarkis, Klassen, Melnyk, Sroufe, Handfield, Zhu and others in the central group have established relationship networks that are visually denser than those of other authors and have leveraged these networks to boost productivity, create high-quality publications and drive innovation in scientific research, strongly impacting the rest of the network.

A second strategy for identifying groups was the bottom-up approach of the k-cores algorithm (Figure 11), where groups of authors are connected to other groups, based on the number of related authors. A k-core is a graphically illustrated "group" or "sub-structure" [26].

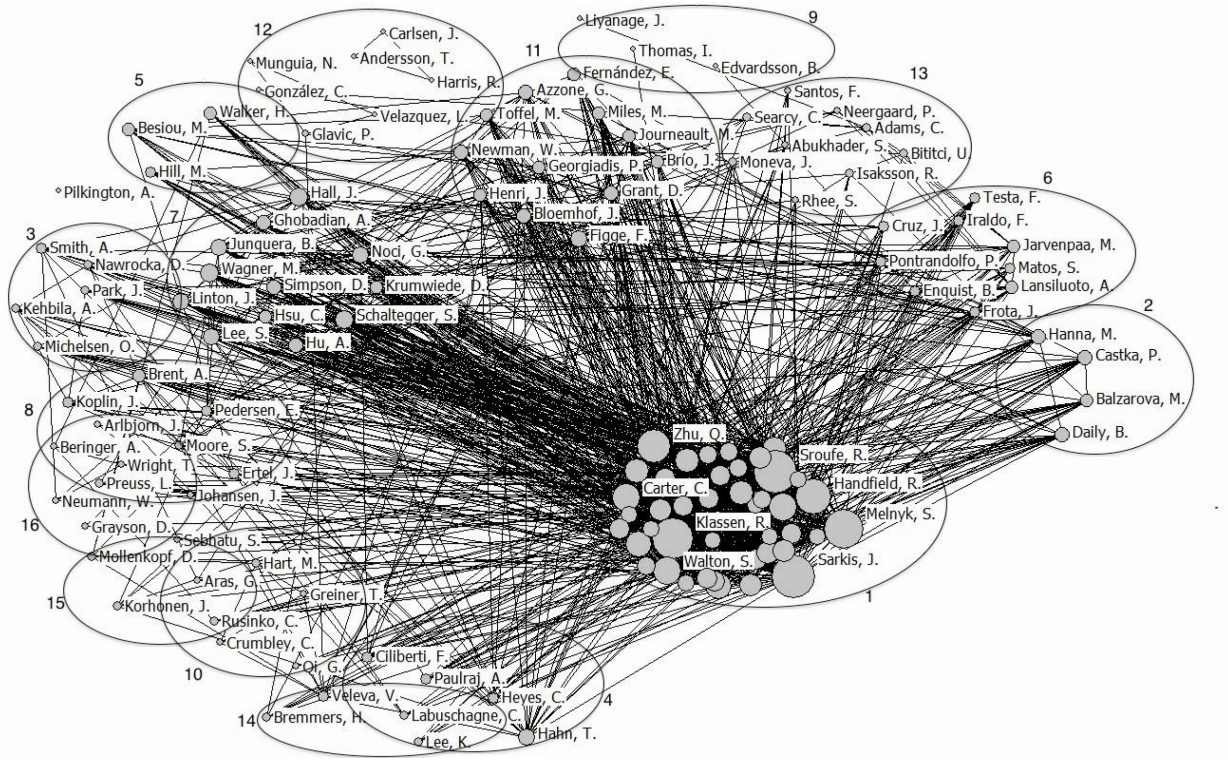


**Fig. 11**. K-core analysis of the author network

Sixteen groups of authors were identified. The largest group, consisting of 42 authors includes the centrally-located authors and those with the highest degree centrality scores and can thus be considered the most influential group in the network (see complete list of author groups in Appendix A). Shared interests or institutions in common as well as co-authorships, may be group-forming variables. The themes 'environmental management' and 'supply chain management' are common to several authors. An example of co-authorship is provided by Sarkis and Zhu, who have co-authored 10 articles accounting for approximately 50% and 80% of the productivity of each author. In addition to Zhu, Sarkis is also a co-author with nine other authors from Group 1.

The identification of sixteen diferent author groups may indicate that this research area in OM offers many opportunities for developing new theories based on multidisciplinary approaches. An analysis of the scientific output of all the groups reveals a preference for issues related to environmental management and green supply chain management, as shown in Table 4.

**Table 4** – Predominant themes among the groups of authors

| Groups | Themes |
|---|---|
| 1 | Green supply chain management; environmental management; sustainable supply chain management |
| 2 | Corporate social responsibility; human resources; operational and environmental management |
| 3 | Corporate social responsibility; design for adaptability; environmental management; supply chain management |
| 4 | Supply chain management; social responsibility; corporate eco-efficiency; sustainable value-added; environmental management; operations management |
| 5 | Environmental supply chain; sustainable procurement; closed-loop supply chain; environmental management |
| 6 | Performance management; green balance scorecard; corporate social responsibility; supply chain management; closed-loop supply chain; sustainable supply chain; environmental management; green supply chain management |
| 7 | Environmental management; green and lean supply chain management; corporate social responsibility; sustainable supply chain; green manufacturing strategies |
| 8 | Corporate social responsibility; supply chain management; environmental and social standards; sustainable supply chain management; |
| 9 | Value-based view; operations and maintenance performance; education for sustainability |
| 10 | Indicators of sustainable production; corporate governance and corporate sustainability; corporate social responsibility and financial performance; green innovation |
| 11 | Green manufacturing strategies; sustainable supply chain; closed-loop supply chain management; manufacturing strategy and environmental management |
| 12 | Innovation; assessment of sustainable development; sustainability accounting and performance; sustainable university; social impact measurement; sustainable development issues and strategies |
| 13 | Corporate sustainability performance measurement; environmental management; corporate environmental and financial performance; eco-efficiency; total quality management; sustainability accounting and performance; performance measures |
| 14 | Assessing sustainability performance; life cycle management; corporate social responsibility; supply chain management; |
| 15 | Green, lean and global supply chain management; closed-loop; green manufacturing; sustainability in higher education; environmental management; sustainability indicators |
| 16 | Sustainability in higher education; manufacturing strategy; environmental management; logistics and supply chain management; corporate social responsibility |

The predominant themes among the group of sixteen authors cover several aspects of sustainability, mainly related to five common macro themes: supply chain strategies; environmental management; manufacturing strategies; corporate social responsibility; and, sustainability performance management and measurement.

The K-core analysis was also applied to the keyword network (Figure 12). Visually it was possible to note the interaction between the two major groups of keywords with the key issues related to sustainability in operations management and the practices associated with them.

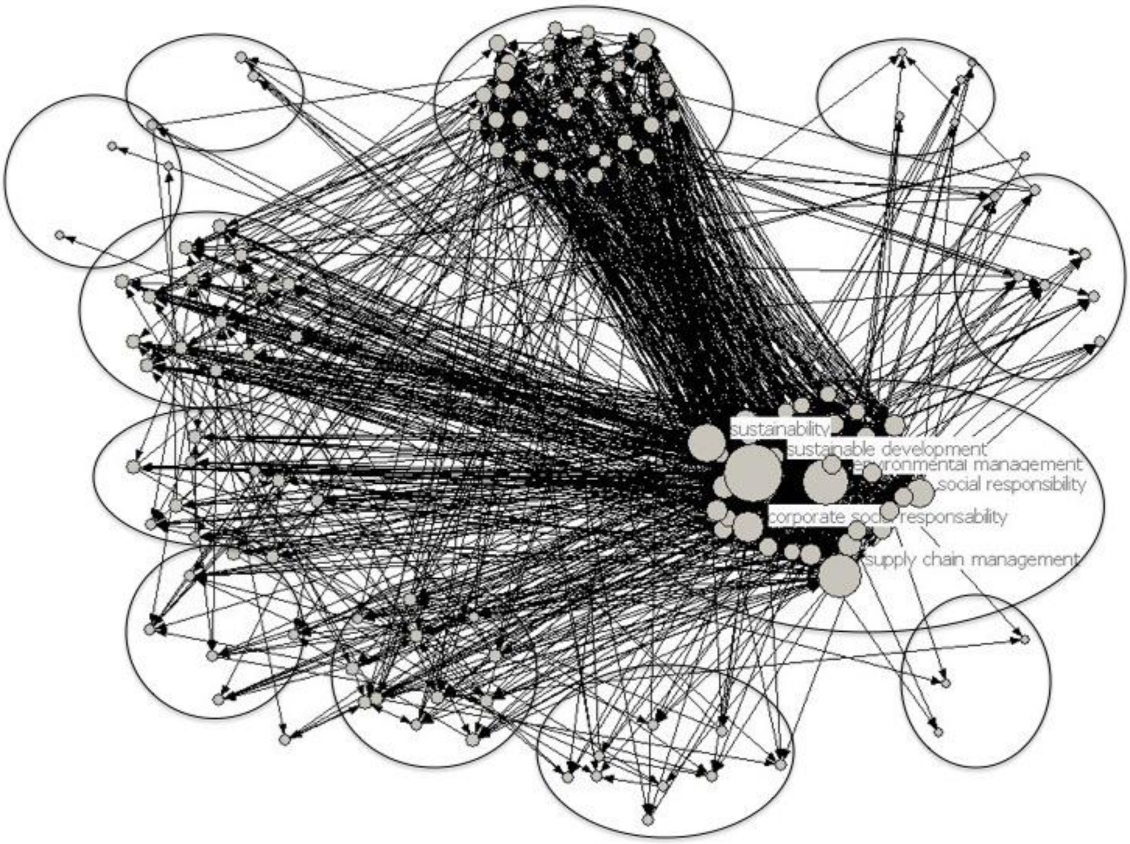


**Fig. 12** – K-core analysis of the keyword network

The largest group, comprised of 36 words, also features the words with the highest CD scores including: environmental management; supply chain management; corporate social sustainability; performance measures; sustainable development; sustainability; green supply chain management; ISO 14001/26000/9001; business excellence; corporate governance; economic sustainability; ecology; performance measures; stakeholders; total quality management; automotive industry and operations management.

The second largest group, comprised of 34 words, shows a strong visual relationship with the largest group and includes the following keywords: accounting; annual reports; sustainability indicators; competitive advantage; corporate sustainability; eco-efficiency; environmental management strategy; life cycle assessment; pollution prevention; reverse logistics; sustainability indicators; lean production; auditing; project management; recycling; and, quality management.

The keyword analysis revealed several theories that have been linked to other field studies in OM. These include Life Cycle Assessment (LCA), Sustainable Manufacturing, Corporate Social Responsibility (CSR), Environmental Management and Cradle to Cradle®.

This shows a greater integration of OM with other disciplines, as noted by Pilkington and Fitzgerald [51] and Linton et al. [105].

The scientific production of the most influential group of authors together with the two k-core analyses carried out indicate that the central focus in OM sustainability research is integrated social and environmental management applied to supply chain management. Also the significant volume of studies on corporate social responsibility reflects efforts in the area to contribute to new sustainable business models and develop processes that are valuable for organizations and for the broader public, as noted by Bayraktar et al. [4], Craighead and Meredith [13] and Gunasekaran and Ngai [22].

Mapping sustainability research in the OM field made it possible to identify relevant themes and problems for researchers and practitioners interested in these studies, e.g. identifying the group of sixteen authors and themes that have been studied by these groups over the last 20 years. This can be useful for understanding the sustainable operations context and for adopting practices. The most commonly explored themes were identified by the theme environmental management; these groups may be candidates for renewing their research efforts through innovative and integrative approaches. Other less studied themes could receive more attention as they are connected to operations, systems and networks, i.e. sustainability strategy coordination and governance.

### 4.2.1 Statitical tests

Tests were carried out using multivariate data analysis methods, suitable for the sample size with SPSS 17 software. Tests were selected based on sample size and parameters that test normality at a significance level of $*p<0.05$ [18]. In order to validate the quality of the sample and the bibliometric outcomes, the tests were conducted based on measurements of degree centrality in the network of 137 authors in order to ensure robust inferences.

The tests showed a relationship between network centrality measures and indicators of author productivity thereby indicating the most influential authors in the network.

#### 4.2.1.1 Tests for normality

Data were first subjected to tests for normality (Kolmogorov-Smirnov), which showed that the data were not normally distributed. This means that non-parametric tests were required (production $D(137)=0.32$ $*p < 0.05$; degree $D(137)=0.12$ $*p < 0.05$; closeness $D(137)=0.32$ $*p < 0.05$; betweenness $D(137)=0.31$ $*p < 0.05$; and effsize $D(137)=0.13$ $*p < 0.05$).

#### 4.2.1.2 Sperman correlation test

The Spearman correlation test was applied in order to verify the type and association level between the centrality measures and author's productivity in the sample of the 137 authors with a higher degree centrality. The results showed a positive and statistically significant association between the centrality measures and author productivity: degree ($r_s$ = .62, p<0.001), closeness ($r_s$ = .54, p<0.001), betweness ($r_s$ = .45, p<0.001), effsize ($r_s$ = .62, p<0.001), in other words, strong correlation for degree and effsize and moderate for closeness and betweness [18].

Thus, hypothesis H1 was supported by the authors' networks. Relationships between authors are associated with better productivity and yield significant contributions to the field of knowledge.

#### 4.2.1.3 Linear regression

To determine which centrality measures can be used as criteria to explain author productivity, linear regressions applying stepwise regression with backward elimination were used.

The presence or absence of multi-colinearity was checked via Tolerance (1/VIF) and Variance Inflation Factor (VIF) scores. If the estimated tolerance score is lower than the 1-$R^2$ relationship, or the VIF score is higher than 10, multi-colinearity is suspected [48]. Betweenness and closeness were not considered statistically significant variables (i.e., the value of the coefficient of determination was not significant in the first two models) and were therefore excluded (Table 5).

**Table 5** – Estimation of linear regression (stepwise regression)

| | Step 1 | Step 2 | Step 3 |
|---|---|---|---|
| effsize | 0,009* | 0,000* | 0,000* |
| closeness | 0,151 | 0,400 | |
| betweness | 0,081 | 0,176 | |
| degree | 0,001* | | |
| F | 31,365** | 34,874** | 100,37** |
| $R^2$ | 0,491 | 0,44 | 0,42 |
| $R^2$ adjusted | 0,475 | 0,43 | 0,42 |

* *p* < 0,05 (*two-tailed*). ** *p* < 0,01 (*two-tailed*).

The results suggest that the effsize variable best explained the variation in author productivity ($R^2$=0.42%). While degree was significant, the results of the VIF indicated multi-colinearity problems with effsize, which showed the best fitting results in the third step. The results show that the efficiency of structural holes (effsize) was strongly correlated with author productivity.

#### 4.2.1.4 Mann-Whitney Test

Hypothesis H3 proposed that there were no statistically significant differences between centrally-located and peripherally-located authors. Mann-Whitney tests were used to test that hypothesis (Table 6).

**Table 6** – Estimation of Mann-Whitney Hypothesis Test[a]

| | Production | Degree | Closeness | Betweenness | Effsize |
|---|---|---|---|---|---|
| Mann-Whitney U | 126.500 | 41.000 | 99.000 | 146.000 | 63.500 |
| Wilcoxon W | 8127.500 | 8042.000 | 8100.000 | 7896.000 | 8064.500 |
| Z | -5.146 | -5.169 | -5.092 | -4.997 | -4.990 |
| Asymp. Sig. (2-tailed) | 0.000* | 0.000* | 0.000* | 0.000* | 0.000* |

a. Grouping Variable: partition;
b. *p < 0.05

The results show statistically significant differences between the measures at the center and the periphery of the network. In other words, H3 should be rejected in favor of the alternative hypothesis, at a significance level of 5%, which means that categorizing authors into centrally-located and peripherally-located groups using the social network can be considered valid.

### 4.3 Content analysis

Based on the 70 papers content analysis, Table 7 presents a timeline that shows the relevant topics associated to sustainability and operations management progression.

The content analysis shows that the sustainability theme in OM has emerged from strong environmental regulatory requirements and competitive pressures. However, there has been a shift from internal to external perspectives and, from reactive to proactive positioning regards to integrate sustainability in companies operations and business models.

**Table 7** – Timeline with relevant topics associated to sustainability and operations management

**Reactive to Proactive**

| Timeline | Topics linked to sustainability and operations management (examples) |
|---|---|
| 1990's | Environmental Management (regulation) |
| 2000-2005 | Environmental Management System (supply chain/human resources/ performance/ISO 14001)<br>Supply Chain Management (socially responsible purchasing/supplier assessment/risk management) |
| 2006-2011 | Environmental Management System and Business Innovation (Green Design/Cleaner Production/LCA/Financial Performance)<br>Green Supply Chain Management<br>Green Lean Supply Chain Management<br>Supply Chain Management (risk management/socially responsible purchasing)<br>Integrated Management Systems (QMS/EMS/OHS)<br>Corporate Social Responsibility and Financial Performance |

The evolution of studies on socio-environmental management, especially on supply chain management, has contributed to research moving beyond a focus on compliance with legal requirements towards innovation processes to promote the improvement and efficiency of processes, as per the trend observed by Gunasekaran and Ngai [22].

## 5. Data analysis and contributions

### 5.1 Research roadmap

The study shows that the evolution of the discussions on sustainability, climate change and the new parameters for sustainable development have been incorporated into the studies in OM. Regarding the evolution and maturation of sustainable OM theories, three aspects were verified:

The initial phase of research on sustainability focused on basic theme discussions, with the aim of describing and understanding it. Key representatives of this phase are: [124, 71, 101]. In the second period, starting in 2005, studies sought to establish theories for the theme sustainability in OM using frameworks and models. Representatives of this phase include: [125, 103]. Also during the second period, studies explored relevant causal relationships in the theme sustainability. Examples include: [104, 123, 134, 135].

As predicted by Craighead and Meredith [13], these periods reflect a more direct interaction of researchers with phenomena using more interpretative approaches, suggesting that this research area has advanced in a healthy fashion and achieved a significant level of maturity.

The sustainability theme also helped to establish OM as a discipline (listed in Table 7). The research area has established strong connections with other fields of study over time (i.e., product design and industrial ecology). The increasing number of publications over time reflects a positive trend in scientific research publications in these inter-related areas. The concentration of papers in relevant journals in the OM field, and the increase in quantitative analysis are also positive factors contributing to the development of a theory regarding sustainable operations management.

To complement and reinforce the analyses, the primary themes covered in the field in terms of degree centrality were selected and their relevance determined. This made it possible to compile a list of four statements that represent the evolution of the research agenda related to sustainability studies in OM followed by some references that reinforce the statements.

# 1 - The sustainable development discussion was initially addressed in OM with a greater focus on the environmental aspect, largely due to pressure from regulations, customer and market demands [90, 117, 115].

# 2 - The environmental perspective requires companies to manage their environmental impacts throughout the supply chain and they must develop greener products and more efficient, safe and socially responsible processes. The evolution in the practices has provided a new approach to supply chain management, namely 'Green Supply Chain Management (GSCM)' [90,120, 121, 93, 105, 103].

# 3 - The green supply chain approach is pushing innovation to the forefront of eco-efficient operational and financial performance [74, 75, 94, 76, 109, 104].

# 4 - The increasing attention to CSR in other areas of study has spurred research in OM from the perspective of creating sustainable value, innovation and new strategies for Global Supply Chains, Socially Responsible Purchasing, Life Cycle Assessment, and as a key component of Corporate Governance, Best Practices and Company Performance [40, 30, 109].

Based on the results presented, it appears that the study of sustainability in the OM field presents an important contribution in response to the push for SD. This is evident in studies aimed at meeting the dimensions of the Triple Bottom Line, summarized in Table 8.

**Table 8** – Sustainable OM research contributions to the Triple Bottom Line approach

| TBL Dimensions | Research theme contributions |
|---|---|
| Economic | Supply Chain Management; Corporate Social Responsibility and Risk Management. |
| Environmental | Environmental Management; Green Supply Chain Management; Green Lean Supply Chain Management; Life Cycle Assessment; Cleaner Production, Closed Loop Supply Chain and Green Product Development |
| Social | Health and Safety Management, Corporate Social Responsibility and Socially Responsible Purchasing. |
| Dimensions' integration | Sustainable Supply Chain Management; Sustainability Performance, Integrated Management System, Sustainable value-added. |

Table 8 shows examples of the dynamic capabilities that represent the foundation for the sustainable OM framework presented by Kleindorfer et al. [33]: modeling and measuring action-outcome links; designing and managing processes to achieve agility, adaptability and alignment; executing strategies; integrating, conceptually and operationally disperse activities need to achieve the goals mentioned; and, building bridges with other functions and disciplines, including strong links to engineering and economics.

### 5.2 Gaps and trends

Sustainable development, in addition to satisfying legal requirements and stakeholder needs, provides opportunities for innovating and generating long-term value for organizations. A fertile ground for sustainable operations is the integrated management of sustainability and innovation, which seeks new models that can lead to a sustainable competitive advantage, thus integrating practices and processes involving production, operations and society.

The new G4 reporting standard (GRI) is a strong example of this trend. It calls for attention to the issue of 'material sustainability' based on identifying and disclosing sustainability issues to meet stakeholder expectations, as well as the social, environmental and economic dimensions [37]. Also, there is a gap between sustainability discourse and practice and where economic activity and growth is expected in the future [58, 37]. Hence, empirical research is strongly recommended.

Kleinforfer et al. [33] warned about the need for establishing strong links between engineering and other fields. The studies analyzed showed a positive response regarding this issue, i.e., Life Cycle Assessment and Cleaner Production studies.

However, sustainability research in the operations management field still calls for multidisciplinary and multi-method studies, since OM theories alone are unable to deal with specific situations such as the integration and study of aspects related to the social dimension.

**5.3 Future Sustainable OM directions**

Opportunities for future research are related to four main directions that represent the integrated approach to sustainability research and practice in operations, considering the three dimensions of TBL and their interrelations to the decision-making and coordinating processes.

- Sustainable supply chain management: green supply chain management and responsible supply chain - such as risk management, global supply chains, socially responsible purchasing.
- Sustainable manufacturing strategies: focused on Eco-efficiency, Life Cycle Assessment, Green and Lean Systems and Cleaner Production.
- Sustainable performance management and measurement systems: development of sustainability indicators and integrated management systems.
- Decision-making models: maturity models to implement and assess sustainable operations management based on corporate social responsibility.

These approaches are relevant to society because they are a proactive way of integrating sustainability for strategically designing enterprise systems and networks.

**6. Conclusion**

Considering the research questions, the analysis revealed that throughout its evolution the OM field has been characterized by its theoretical synthesis through practice, generating a very rich knowledge base that organizes experiences and technical artifacts. The inclusion of sustainability research has expanded the boundaries of OM, both in terms of global operations, as well as environmental and social impacts and meeting the demands of internal and external stakeholders. Moreover, it consolidates the relevance of research conducted in the field to deal with relevant contemporary and future issues involving the entire life cycle of products and processes, enabling long-term strategies, which allow firms to operate in unstable environments with limited resources.

Sustainable operations presents an evolutionary pathway for moving forward focused on innovative, holistic and efficient processes, while facing the challenge of managing and integrating value creation as well as the risks and impacts from operations involving the complete life cycle of products and/or services. This challenge represents a unique opportunity for researchers and practioners alike to contribute to the development of new sustainable business models and business cases.

The second question was addressed, but with some limitations. Although the analyzed sample was attributed to the authors considered the most influential in the network, additional studies with a larger database are recommended, that focus on establishing strong theories with an intedisciplinary and systemic approach to verify and confirm the trend identified, i.e., that this research area is maturing.

For the development of this research area, it is essential that researchers perform both qualitative and quantitative studies in order to identify and characterize causal relationships between phenomena. This integrated research will make it possible to answer broader questions, e.g. an understanding of how the adoption of sustainable operations management affects financial impacts or how operations can contribute to the integration and management of sustainability dimensions in the business model.

The statistical tests reinforced that the social network approach can be a useful tool for mapping a research area or theme. On limitations and further work, the study only mapped sustainability research in the operations management community. In addition, the inference power of analysis is restricted to the theoretical point of view of full academic papers published in scientific journals.

The growing demand for more sustainable products, processes and operations represents a great opportunity for researchers to add new perspectives to the OM field to contribute to sustainable development.

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# APPENDIX A
# COMPLETE AUTHOR'S GROUPS LIST

**Group 1** - Sarkis, J.; Zhu, Q.; Seuring, S.; Klassen, R.; Azorín, J.; Cortés, E.; Handfield, R.; Jabbour, C.; Walton, S.; Carter, C.; Lai, K.; Melnyk, S.; Benito, J.; Benito, O.; Darnall, N.; Gamero, M.; Geng, Y.; Pagell, M.; Rao, P.; Sohal, A.; Rao, P.; Sohal, A.; Sroufe, R.;Tarí, J.;Delmas, M.;Ellram, L.; Henriques, I.; Muller, M.; Sadorsky, P.; Sheu, C.; Tate, W.; Vachon, S.; Wu, Z.; Yang, C.; Zutshi, A.; Brorson, T.; Calantone, R.; Curkovic, S.; Epstein, M.; Gupta, S.; Helms, M.; Hervani, A.; Holt, D.; Holt, D.; Power, D.

**Group 2** - Castka, P.; Balzarova, M.; Daily, B.; Hanna, M.

**Group 3** - Smith, A.; Kehbila, A.; Michelsen, O.; Nawrocka, D.; Park, J.

**Group 4** - Ciliberti, F.; Hahn, T.; Heyes, C.; Paulraj, A.

**Group 5** - Besiou, M.; Hill, M.; Walker, H.

**Group 6** - Enquist, B.; Jarvenpaa, M.; Lansiluoto, A.; Pontrandolfo, P.; Cruz, J.; Frota, J.; Iraldo, F.; Matos, S.; Testa, F.

**Group 7** - Ghobadian, A.; Hall, J.; Hsu, C.; Junquera, B.; Wagner, M.; Hu, A.; Krumwiede, D.; Lee, S.; Linton, J.; Noci, G.; Schaltegger, S.; Simpson, D.

**Group 8** - Brent, A.; Pedersen, E.; Ertel, J.; Koplin, J.; Moore, S.; Preuss, L.

**Group 9** - Edvardsson, B.; Liyanage, J.; Thomas, I.

**Group 10** - Aras, G.; Crumbley, C.; Greiner, T.; Hart, M.; Qi, G.

**Group 11** - Roy, M.; Toffel, M.; Azzone, G.; Bloemhof, J.; Brío, J.; Fernández, E.; Figge, F.; Georgiadis, P.; Grant, D.; Henri, J.; Journeault, M.; Miles, M.; Newman, W.

**Group 12** - Andersson, T.; Carlsen, J.; Glavic, P.; González, C.; Harris, R.; Munguia, N.; Velazquez, L.

**Group 13** - Isaksson, R.; Abukhader, S.; Adams, C.; Bititci, U.; Moneva, J.; Neergaard, P.; Rhee, S.; Santos, F.; Searcy, C.

**Group 14** - Veleva, V.; Bremmers, H.; Labuschagne, C.; Lee, K.

**Group 15** - Rusinko, C.; Korhonen, J.; Mollenkopf, D.

**Group 16** - Beringer, A.; Grayson, D.; Johansen, J.; Neumann, W.; Sebhatu, S.; Wright, T.; Arlbjorn, J.

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**SAMPLE FOR CONTENT ANALYSIS**

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# PAPER II - SUSTAINABILITY INTEGRATION THROUGH AN OPERATIONS MANAGEMENT LENS

Carla Gonçalves Machado[a], Edson Pinheiro de Lima[ab], Sergio Eduardo Gouvea da Costa[ab], Jannis Jan Angelis[c], Leticia Maoski Rocha[a]

[a] Industrial and Systems Engineering Graduate Program, Pontifical Catholic University of Parana, 80215-901 Curitiba, Brazil.

[b] Federal University of Technology - Parana, 80230-901 Curitiba, Brazil.

[c] Department of Industrial Management, Royal Institute of Technology – KTH, 100 44 Stockholm, Sweden.

**Abstract**

*Purpose:* Operations management and sustainability as closely linked. The purpose of this paper is to identify patterns in sustainability integration, including how sustainability is being integrated into operations and what the businesses changes required or indicated by it are.

*Design/methodology/approach:* The study is based on multiple case studies conducted at three companies in Brazil. Sustainable Operations Management (SOM) theory and concepts set a strategic role for enterprises competitiveness, particularly when they are connected to product and process improvements, new markets, and risk management. Three interviews were conducted with seven sustainability experts, including sustainability´s directors, managers and coordinators.

*Findings:* Companies are internally dedicated to sustainability integration, as well as externally forced by regulations or market requirements. Patterns for sustainability integration are emerging and cover most of the SOM boundaries. However, difficulties in integrating sustainability to competitive strategies, business models and value chain remain.

*Research limitations/implications:* The findings are related to large companies operations and strategies. Future research can identify patterns for sustainability integration in small and medium sized companies.

*Practical implications:* The results identify recommendations for the establishment of a sustainable operations management model.

*Originality/value:* The study results confirm the relevance of the sustainable operations management approach for operations management improvement and provide guides for sustainability integration.

Keywords: Sustainable Development, Operations Management, and Performance Management.

## 1. Introduction

According to the Global Corporate Sustainability Report (UN, 2013) “Turning a blind eye to sustainability issues is a ticking time bomb, and hiding missteps – no matter how deep down the supply chain – is no longer an option”. Sustainability can be characterized as a ‘megatrend’, similar to 'quality' and 'information technology' demanding companies to innovate and to adapt their businesses model to stay competitive in theirs served markets. (Lubin and Esty, 2010).

According Epstein and Buhovac (2010) “[…] the challenges of implementing sustainability are still quite significant". Eccles and Serafelm (2013) identify gaps related to companies' sustainable business strategies formulation, indicating that strategy and its implementation are being adapted as their business models evolve.

The MIT/BCG annual survey shows there is a gap between sustainability vision and action for companies around the world. (Kiron et al., 2013b). As Drake and Spinler (2013) argue, the Sustainable Operations Management (SOM) approach contributes to sustainability challenges because many decisions that determine sustainability impact intersect with company operational activities. Sustainable operations encompass the production of goods and services with competitive returns, using non-polluting production processes, conserving energy and natural resources, under healthy and safe conditions for customers and employees, and meeting stakeholders' requirements (Veleva and Ellenbecker, 2001, Krajnc and Glavič, 2005, Kleindorfer et al., 2005).

Operations management (OM) is a key part in building a sustainable business model, as it is responsible for the practical implementation of competitive strategies and its related decisions affect directly the three dimensions of sustainability. Due the complexity of the areas related to sustainable operations, a systemic approach is mandatory design and implementations processes (Drake and Spinler, 2013, Nunes et al., 2013).

This raises two questions that the study seeks to answer: First, (RQ1) how do company operations fit with the sustainability principles? Second, (RQ2) how do sustainable operations impact and change business models? RQ1 analyses the sustainability initiatives through sustainable operations theory while RQ2 identifies the level of change that integration of sustainability requires.

This paper expands on OM theory development by analyzing how company strategy incorporates sustainability demands**.** It also identifies practice patterns and implementation gaps to propose design and implementation recommendations.

## 2. Conceptual background

The number of published papers related to sustainability and operations management has increased during the last few years. This can be linked with the evolution of discussions on Environmental Management Systems (EMS), Supply Chain Management (SCM) and corporate social responsibility (CSR), all driven by regulatory pressures and stakeholders´ demands (Machado et al., 2012; Gimenez et al., 2012). To Bettley and Burnley (2008) SOM represents a boundary expansion, integrating value chain processes with TBL dimensions, e.g., embracing the total life cycle of products including the end-of-life phase and responsibility related to social and labor conditions in various supply chain stages. The closed-system model of sustainability creates opportunities to transform company operations and processes (Linton et al., 2007; Nidumolu et al., 2009). Table 1 presents a set of capabilities that represent the expanded SOM context.

**Table 1 – SOM's capabilities**

| Author | Context |
| --- | --- |
| Kleindorfer et al. (2005) | Green products and process development; Lean and green operations; Remanufacturing and Closed Loop Supply Chains (CLSC). |
| Bettley and Burnley (2008) | Expanded operations model - Product-service system; Product and process design to optimize life cycle performance; Closed loop supply chains; Reverse Logistics (RL); Stakeholder engagement processes; Risk assessment and management. |
| Gunasekaran and Spalanzani (2012) | Closed Loop Supply Chain Management (CLSC); Green Supply Chain Management (GSCM); Cradle-to-Cradle methodology; Green Purchasing or procurement; Carbon footprint mitigation; Quality, Environment and Social system management; RL and remanufacturing/recycling; Lean operations; Life Cycle Assessment (LCA); CSR and ethics. |
| Nunes et al. (2013) | Green buildings; Eco-design (product and process development); Sustainable production; Sustainable supply chains; RL; CSR – internal and external communities; Innovation in business models. |

SOM encompass the TBL integrating economic, environmental and social demands with operations and product/service development/delivering. As seen on Table 1, eight areas represent SOM: Eco-design; Life cycle management; Sustainable supply chain management; GSCM; CLSC and RL; Sustainable and lean production; Integrated management system; and, CSR.

According to Bettley and Burnley (2008) the sustainability integration should be guided by trade-offs and decisions that combine process and technologies sustainably and that are continuously improved.

To Reeves et al. (2012) value creation in the social and ecological perspectives do not provide direct economic returns, but may if connected to an appropriate business model create economic value for companies producing some sort of 'ecosocial' advantage. This is listed in Table 2.

**Table 2 - Ecosocial advantage**

| Spheres | Approach | Requirements | Strategies |
|---|---|---|---|
| Economical | Essential for a company survive, flourish and create social and economic value | Continuously adapt the business model | Business model innovation; Continuous improvement; Performance management; Integrated Management System. |
| | | Build an adaptive ecosystem | Sustainable supply chain; Corporative governance; CSR. |
| Ecological | Manage ecological resources for business model sustainability | Minimize consumption by improving resource productivity | Energetic and hydric efficiency technologies; Cleaner Production. |
| | | Substitute resources | Sustainable product design; LCA; 3R's; Green Purchasing. |
| | | Replenish resources | Renewable energy uses; Water reuse; 3R's. |
| | | Pollution and waste reduction | Cradle-to-Cradle approach; Cleaner Production; LCA. |
| Social | Maintain society's trust attracting customers and talent employees, and also maintain the license to operate. | Help customers and employees realize their ethical and ecological aspirations | Green products and services; Reverse supply chain management; Green label certification; Social Purchasing. |
| | | Access new markets | Stakeholders´ engagement; Sustainable product design; Product-service system (servitization). |

**Source: adapted from Reeves et al., 2012.**

Strategies on corporate governance and business innovation must be highlighted. Aras and Crowther (2008) note that corporate governance encompasses an environment of trust, ethics, moral values and confidence. Business innovation may be adding novel activities or linking activities in novel ways, and by changing one or more elements that perform any of the activities (Amit and Zott, 2012). To support a sustainability strategy it is also relevant to have CEO commitment; communication responsibility; sustainability reporting; sustainability’s KPIs; an executive-level steering group; a separate function for sustainability; linking sustainability performance and financial incentives; a responsible for sustainability per business unit; and an existing Chief Sustainability Officer (CSO) (Kiron et al., 2013b).

## 2.1 Motivations and barriers for sustainability integration into operations

In 2012, KPMG identified ten global 'megaforces’ that will impact businesses over the next 20 years, covering climate change; energy and fuel; scarcity of material resources; water scarcity; population growth; urbanization; wealth; food security; ecosystem decline; and deforestation. These represent a complex and unpredictable system where each factor reinforces the effects of the other. In the OM literature motivations and barriers for sustainability adoption are described, as shown in tables 3 and 4.

**Table 3 – Motivations for sustainability integration into operations**

| Reference | Motivations |
|---|---|
| KPMG (2011); Hannaes et al. (2011); Kiron et al. (2012); Clinton (2012) | New regulations, market share, continuous improvement management, risk reduction |
| Gunasekaran and Spalanzani (2012) | Global demands for more sustainable products, consumer pressure, government industrial policies, politics, economy, employment rates, labor laws, education, natural disasters, terrorism and wars, environmental regulations, competitor´s actions and market opportunities |
| Kiron et al. (2013b) | Customer preferences; political pressure; competitors increasing sustainability commitment; resource scarcity |

Regulation requirements act as a major driver for sustainability adoption (NAEM, 2014).

**Table 4 – Barriers for sustainability integration into operations**

| Reference | Barriers |
|---|---|
| Kiron et al. (2013b) | Competing priorities; difficulties in quantifying sustainability effects; short-term thinking in planning and budgeting cycles |
| Eccles and Serafelm (2013) | Short-term incentives; shortage of expertise; capital-budgeting limitations; investor pressure |
| Global Corporate Sustainability Report 2013 (UN, 2013) | Supplier sustainability; lack of financial resources and lack of knowledge; implementing strategy across business functions; competing strategic priorities; no clear link to business value; extending strategy through subsidiaries |

Table 3 indicates that short-term thinking and budgets are the two main barriers for sustainability integration. These are associated with the barriers ‘no clear link to business value’ and ‘difficulties in quantifying sustainability's efforts. In this sense, developing good measures, including tangible and intangible aspects of sustainability, and integrating them into performance system may be considered a major organizational task.

## 2.2 The regulatory framework

Management systems and standards on sustainability are set on an integrated and comprehensive form covering economic, social and environmental aspects, also referred to as the Triple Bottom Line (TBL) model (Elkington, 1997).

Bettley and Burnley (2008) remark that fully achieved sustainability is still a moot point and a company should not declare itself sustainable in the face of all qualitative aspects related to sustainability management. Sustainability needs to be approached and managed similarly to the concept of quality, i.e. in a continuous improvement basis with decisions and trade-offs guided by the combination of processes and technologies.

Standards are guiding sustainability integration. These include ISO 14000 – EMS

(1993); ISO 14040 – LCA (2001); SA 8000 – social accountability (1997); OHSAS 18001 – health and safety (1999); AA 1000 – corporative accountability (1999); ISO 26000 – CSR (2010); ISO 50001 – energy management (2011) (Castka and Balzarova, 2007; Hundzinski et al., 2013). Ferrer (2008) states that sustainability in internal company processes may be achieved by integrating product and process total quality management, environmental stewardship, and total process safety. Qi et al. (2013) add that the TBL dimensions are related to ISO 9001 (economic goals), ISO 14001 (environmental goals), and OHSAS18001 (social goals).

The Global Reporting Initiative sets the GRI framework for sustainability reporting, now in its fourth version and commonly used for company sustainability reporting (GRI, 2014). Aras and Crowther (2009) note that GRI or the AccountAbility AA1000 are guides for sustainability accounting and were developed to adding stakeholders' expectations and impacts into the reporting. The United Nations Global Compact Office (2013) notes that Global Compact is the largest corporate sustainability movement in the world and its management model a guide for helping companies develop their sustainability efforts. The regulatory framework for sustainable operations is formed by the ISO 9001, ISO 14001 and ISO 26000 standards, and also guided by the principles emerging from voluntary commitments as Global Compact, and organized and reported supported by sustainability reports as GRI.

### 2.3 Best practices for sustainability integration into business and operations

A recent report based on 240 cases from Africa, Asia, Latin America and Central and Eastern Europe describe four steps companies integrate sustainability into their business, covering business analysis (e.g. SWOT analysis); strategy development; strategy implementation; and progress monitor and review (SustainAbility, IFC, Ethos, 2012). Table 5 presents more requirements for sustainability integration.

**Table 5 – Best practices for sustainability integration**

| | |
|---|---|
| Bettley and Burnley (2008) | New business model and a revised competitive strategy. |
| | 'Total-product system' perspective, |
| | Specific legal and regulatory regime. |
| | New performance goals and metrics related to sustainability |
| | Operational performance integrated into a single management system. |
| Nidumolu et al. (2009) | Viewing compliance as opportunity. |
| | Making value chains sustainable. |
| | Designing sustainable products and services |
| | Developing new business models |
| | Creating next-practice platforms |
| WEF and BCG (2011) | Proactively turn constraints into opportunities through innovation. |
| | Embed sustainability in their company culture and operations. |
| | Actively shape their business environments. |
| Eccles and Serafelm (2013) | Identify 'material' environmental, social and governance evidences. |
| | Quantify the relationship between financial and Environmental. Social and Governance (ESG) performance. |
| | Innovate products, processes and business models. |
| | Communicate the company's innovations to its stakeholders. |

The MIT/BCG annual survey has identified over the past years an evolutionary path for sustainability integration (Table 6).

**Table 6 - Evolution pattern for sustainability integration**

| Year | Group | Sustainability' integration focus | Evolutionary triggers for the next level |
|---|---|---|---|
| 2010 | Embracers | Sustainability as condition to be competitive and is on the strategic agenda; Create a sustainability business case | Changes in operations frameworks and strategies driven by sustainable practices financial benefits. |
| 2011 | Harvesters | Sustainability-related actions and decisions added economic value to profits. | Business model changed as result of sustainability opportunities. |
| 2012 | Sustainability-Driven Innovators | Profiting from sustainability efforts and changing business models to sustain profit generation. | Address the significant sustainability issues (material sustainability). |
| 2013 | Walkers | Identifying and addressing significant sustainability issues as a way to mitigate threats and identify powerful new opportunities. | Strong links between relevant sustainability issues and business value creation. Supporting collective action to identify material sustainability in a specific sector. |

Source - adapted from Hannaes et al. (2011) and Kiron et al. (2012, 2013a,b)

The patterns presented suggest that sustainability integration may require a new business model, e.g., Nidumolu et al., 2009, Eccles and Serafelm, 2013, and, Kiron et al. 2013a,b). In Table 6 at the studied companies sustainability was an important element for competitiveness. It has been made a permanent fixture in the business agenda, being integrated to performance objectives, and in a more advanced stage defining the business based on sustainability (Hannaes et al., 2011, Kiron et al. 2012, 2013a,b).

Tables 5 and 6 indicate that developing business cases for sustainability is necessary for supporting a business model innovation. Such cases may be characterized as way to accelerate decisions and actions at corporate level, establishing a strong framework that interconnects environmental and social activities to economic success (Berns et al., 2009, Schaltegger, 2012).

## 3 Research design and process

This is an exploratory study based on multiple cases, following the premise that case studies offer opportunities for a better understanding of contemporary and complex issues (Voss et al., 2002, Gibbert et al., 2008, Barrat et al., 2011). The research design was guided by the suggestions for case research in OM by Voss et al. (2002) on reliability and validity. The decisions encompass multiple sources of evidence, multiple respondents and investigators, replication, triangulation and cross-case patterns, and, research protocol. Table 7 presents the links between the RQs and the conceptual background, which set the research protocol.

**Table 7 – Research questions and the conceptual background**

| Research questions | Conceptual background | References |
|---|---|---|
| (RQ1) how do company operations fit with the sustainability principles? | SOM boundaries (strategies and practices) | Kleindorfer et al. (2005); Bettley and Burnley (2008); Gunasekaran and Spalanzani (2012); Nunes et al. (2013) |
| | Motivations and Barriers | KPMG (2011, 2012); Hannaes et al. (2011); Kiron et al. (2012, 2013b); Clinton (2012); Gunasekaran and Spalanzani (2012); Eccles and Serafelm (2013); UN (2013) |
| | Regulatory framework | Castka and Balzarova (2007); Ferrer (2008); Aras and Crowther (2009); Hundzinski et al. (2013); UN (2013) |
| (RQ2) how do sustainable operations impact and change business models? | Best practices and Business model | Bettley and Burnley (2008); Nidumolu et al. (2009); WEF and BCG (2011); Eccles and Serafelm (2013) |

Interviews were conducted with at least two sustainability experts per company; they also were invited as reviewers of data collected. The seven experts, including sustainability´s director, managers and coordinators, validated the data collect through documental analysis, semi-structured interviews, and direct observations at technical visits to industrial plants and corporate areas. Triangulation was carried out including respondents, documents, technical visits and literature. Four researchers conducted the data collection and, excluding document transcription of recorded interviews (single), other products of evidence gathering (e.g. individual notes) were compiled and validated by researchers in a single report that were submitted to the experts' validation. The research covered nine steps: (1) definition of context and research questions; (2) definition of conceptual background; (3) definition of methodological strategies and research protocol; (4) definition of cases; (5) pilot test; (6) data collection and compilation; (7) expert´s validation; (8) data analysis - cross-patterns; and (9) final report.

The next section presents sample description and synthesis of the collected data and the following analysis.

## 4 Descriptions and Data Analysis

The case selection was defined based on the criteria of business representativeness; public recognition; commitment with a sustainable management (public statements); management system composed by ISO 9001/ISO14001/OHSAS18001/ SA8000 (or equivalent); corporate governance practices; adherence to voluntary commitments (e.g. Global Compact). Table 8 presents a brief description of the cases.

**Table 8 - Cases description**

| Company | Industry | Direct employees * | Headquarter | Visited unit | Market focus |
|---|---|---|---|---|---|
| A | Pulp and Paper | 6.800 | Brazil | Brazil | Internal and External |
| B | Cosmetics | 6.000 | Brazil | Brazil | |
| C | Pulp, Sawn Wood and Panels | 13.227 | Chile | Brazil | |

*According 2012 Firms GRI Sustainability's Reports

Company A is considered one of the largest eucalyptus pulp producers in the world. Company B is one of the leading brands of cosmetics in Brazil. Company C is part of one of the largest forestry companies in Latin America in forest size, pulp production, sawn wood and panels. This section presents a brief description of each case and the identified patterns. The main findings are synthesized by research propositions.

### 4.1 Strategies and Sustainable operations practices

In all companies the LCA principles were being considered in the product design phase, but only in Case company B was the methodology part of the current operations. All studied companies give preference to local suppliers and seek to mobilize key suppliers in dealing with issues related to climate change. The companies also had sustainable practices related to the entire set of value chains or operations network. These practices are connected to compliance issues and risk mitigation. The companies have developed their respective suppliers on training programs, formal procedures for mapping socio-economic and environmental impacts and risks, and sustainability performance assessment.

*Case A*

Company A started implementing sustainability practices in 1996 to be able to compete in new markets. In 2002 a strategic realignment was conducted as a result of external environmental pressures, launching a 'Master Plan for Sustainability' in 2010 with goals to be achieved by 2024 in the dimensions of social, environmental, economic, governance, communication and innovation. The management model that supports the six dimensions is based on three pillars: Corporate Governance (continuous improvement endeavors); Innovation (continuous development); and Socio-environmental Responsibility (sustainability, respect for people and the environment).

Internally, Company A develops programs related to SOM strategies, such as compliance (standards and legal regulations); identifying risks and opportunities; formalizing processes; operational excellence (operational stability); maintenance; innovation (processes and products); continuous improvement (Lean Six Sigma); safety and quality-of-life. The company risk management is supported by COSO (Committee of Sponsoring Organizations of the Treadway Commission) methodology. Externally, the company encourages suppliers to report key actions related to compliance management with the supply chain, conduct programs to incentive GHG emissions control and projects related 'Climate Change', also to improve performance including an award for top performing partners. In addition, there are programs related to engagement with clients and communities and other practices related to the CSR context covering corporative governance; code of conduct for employees and suppliers; sustainability institute; supporting collective actions for developing new policies and regulations based on sustainability's principles.

*Case B*

In 1990 Company B started to implement sustainability practices focused on environmental preservation. In 2012, following a strategic realignment, new guidelines were formalized for the entire value chain and product life cycle to be fully integrated to company operations by 2024 focused on eco-efficiency, raw materials and packaging, and sales channels. Eco-efficiency strategies focus on industrial processes continuously improving the reduction of the use of raw materials and the use of the natural resources. LCA studies show that raw materials and packaging reduce socio-environmental impacts related to the extraction and manipulation, also strategies for design, production and recycling of packing through the value chain. Sales Channels strategies are focus on stimulate entrepreneurship, professionalization and adoption of sustainability standards. According the Director of research and development*"[...] the necessary changes will happen gradually, and that it is necessary to look to reality through new lenses [...]".*

On raw materials and packaging Company B performs SOM strategies related to LCA to measure environmental impacts of production; green design (products and packing); RL; analysis of impacts and supplier risks. Related to eco-efficiency, the company reported strategies on internal productive process and value chain: reduction of the consumption of energy and water; GHG emissions; solid waste; and recyclability. The supplier development program is being conducted through labor issues; rights of children; diversity; health and safety; risk management/social and environmental impacts (products and service); eco-efficiency actions; climate changes; and sustainability in the relationship with business partners.

*Case C*

In Company C, sustainability practices integration started in 2002 in Chile, motivated by environmental problems. The sustainability strategy involves four main topics: license to operate (compliance and requirements for business continuity); securing the basis (results related production, quality, distribution, levels of customer satisfaction and complaining, etc.); growth and continuity (investments, expansion plans, shared value, etc.); and, generating a winning environment (individual goals, working teams, training programs, etc.). The Company developed a risk management framework considered essential for the business continuity.

Company C is a closely held corporation governed by Corporate Governance and CSR programs based on methods of collaboration and supported Shared Value methodology. In Brazil, the company has a history of acquisitions of other businesses, and operations strategies are driven by legal compliance, mainly environmental issues, which according the sustainability director is part of the economics of the forestry industry.

Related to eco-efficiency strategies, company operations use biomass as a fuel, and there is an effort to increase the recyclability rates into operations, emission control and hydric efficiency strategies. Innovation and continuous improvement strategies are related to lean strategies. Occupational Health and Safety internal programs include traditional practices for compliance, and efforts to standardization of practices and procedures, ergonomics and quality-of-life improvements. The company also has extended its occupational health and safety program to third-party service providers.

Table 9 presents sustainability focus areas and strategies for each company. The SOM strategies were identified through the technical visit and the sustainability report analysis.

**Table 9 – Focus areas and strategies**

| | Company A | Company B | Company C |
|---|---|---|---|
| Focus areas | Corporate Governance; Innovation; and, Socio-environmental responsibility | Raw materials and packaging; eco-efficiency; sales channels. | Globalization and efficiency; People of excellence; Occupational Health and Safety; Environmental Performance; Community/participation and dialog. |
| SOM strategies | Regulatory compliance ; GSCM; Suppliers´ development; Risk management; Eco-efficiency strategies; Quality, environmental and social management systems; Lean operations; Continuous improvement; Green Purchasing; Risk management; Suppliers´ development; Stakeholders´ engagement; CSR; Innovation management (products and processes). | Regulatory compliance; RL; Product green design; LCA; Cleaner production; Green Buildings; Eco-efficiency strategies; Quality, environmental and social management systems; Lean operations; Continuous improvement; GSCM; Suppliers´ development; Green Purchasing; Risk management; Stakeholders´ engagement; Innovation management (products and processes); CSR | Regulatory compliance; Quality, environmental and social management systems; Eco-efficiency strategies; Suppliers´ development; Risk management; Quality, environmental and social management systems; Innovation management (products and processes); Stakeholder's engagement; CSR. |

*Proposition 1 - Firms operations strategy are developing a reactive-proactive pattern regarding sustainability aspects, adjusting their strategies and systems to be in compliance with socio-environmental requirements, developing a management component for their internal operations, and expanding their policies to their supply chain or operations network.*

## 4.2 Motivations and barriers

At Company A the founders' commitment to environmental preservation was the initial starting point. Company B also cited founders' commitment, followed by motivations compliance and requirements by the financial partner. Company C had an environmental accident, which called attention for the issues and risks related to sustainability.

*Case A*

The main reasons for the adoption of sustainable practices cited by Company A were commitment to environmental issues; demands of communities affected by operations; and, customer demand for environmental certifications. The main barrier cited is the challenge to improve the level of environmental awareness of managers and employees in carrying out daily routines *"[...] that is, how we can continuously improve our processes incorporating sustainability"* (Sustainability Manager).

*Case B*

At Company B motivations for sustainability practices were integration; environmental and social issues; and, complying with legislation and meeting the requirements of financial partners. The major barrier cited was the difficulty of building procedures and strategies that raise awareness among all those involved and that communicate with the whole business structure.

*Case C*

For Company C the main motivation for sustainability adoption was environmental problems. In Brazil, Company C has a history of acquisitions of other businesses and sustainability practices related to regulatory compliance. The most relevant barrier to establish new practices is represented by the corporate culture of previous administrations, where the issue of sustainability was not part of operations. This meant offering some resistance in changing processes and/or production parameters. Table 10 presents a summary from each case and present also complementary motivations and barriers cited.

**Table 10 – Motivations and barriers**

| | **Company A** | **Company B** | **Company C** |
|---|---|---|---|
| Motivations | Founders' commitment; customer demands for certifications; and society demands. | Regulatory compliance; financial partners' requirements; business growth and continuity. | Environmental issues; and, relationship with communities. |
| Barriers | Internal awareness | Developing strategies which cross all the business chain; and, internal awareness | Previous culture from acquired companies; Resistance in changing processes and/or production parameters. |

*Proposition 2 – Drivers for sustainability integration motivation does not differs significantly from the traditional strategic business drivers, but the difference lies in its scope and motivation 'power' that may vary according to the industry maturity and how companies activities are interconnected to their environments*

*Proposition 3 – The main barrier for sustainability integration is not, in fact, a conceptual or ideological obstacle, but it resides is in the traditional resistance to organizational change or innovation processes.*

**4.3 Regulatory framework**

There is a substantial discussion on how sustainability is reflected in a complex regulatory framework that includes laws, industry regulations, standards, volunteer commitments and reporting practices. The three companies presented regulatory compliance and conformity related to their management system requirements.

*Case A*

The trajectory of the adoption of sustainable practices in the Company A was based on the management systems implementation, starting with the environmental and quality systems and, over time social issues as well. Thus the manufacturing plants are certified by ISO 9001, ISO 14001, OHSAS 18001, Brazilian Forest Certification Program (Cerflor) and Forest Stewardship Council (FSC) for Chain of Custody. The social practices are being implemented and conducted by the guidelines of ISO 26000, Global Compact and Millennium Development Goals (MDG). Certifications are based on the CSR principles presented in the requirements for quality, environmental and social management systems. The GRI report is being used as sustainability report, since "GRI is an *effective communication tool for dialogue with stakeholders and also is alignment with international guidelines (e.g. ONU and ISO standards)"*(Sustainability Manager).

*Case B*

At Company B the certification path is a route for the adoption of sustainability, where *"[...] the logic of certifications is systemic and generates shared benefits for the areas involved [...] they discuss aspects related to the risks, opportunities and trends in the industry and organization"* (Sustainability Coordinator). The sustainability report follows the GRI model. LCA practices have been employed since 2007 in the studies that comprise the steps of the life cycle of packaging and the design of new products by the ISO 14040 series guidelines.

*Case C*

At Company C compliance with regulations and standards is an expected minimum. Certifications are viewed as a trajectory for the sustainability integration. The plants are certified by ISO 9001, ISO 14001, OHSAS 18001 and also FSC Chain of Custody. *"[...] the ideal for a company that is starting up is to try to look at sustainability organically but it is difficult. To start with the certifications can mean a low error rate"* (Sustainability Director). In 2009 the Company C received the 'Carbon Reduction Label' for all its products, which means that all emissions were quantified through product's life cycle. The company sustainability report is compiled by the headquarters in Chile using the GRI model, while the

Brazilian unit started to report some of its sustainability practices in 2012 based on the Global Compact principles own sustainability report. Table 11 presents a summary of certifications and other voluntary commitments in each case.

**Table 11– Regulatory framework**

| | **Company A** | **Company B** | **Company C** |
|---|---|---|---|
| Standards | ISO 9001<br>ISO 14001<br>OHSAS 18001<br>Cerflor<br>FSC<br>SA8000 (initial)<br>ISO 26000 (orientative)<br>NBR 31000 (orientative)<br>PAS 2050 (BSI - Carbon footprint) | ISO 9001<br>ISO 14001<br>OHSAS 18001<br>ISO 26000 (orientative)<br>ISO 14040 (orientative) | ISO 9001<br>ISO 14001<br>OHSAS 18001<br>Cerflor<br>ISO 26000 (orientative)<br>FSC<br>**CARB (California Air Resources Board)** |
| Voluntary Commitments | Global Compact<br>Millennium Development Goals (MDG's).<br>Business Pact for Integrity and against Corruption - Ethos Institute<br>National Pact for the Eradication of Slave Labor - Ethos Institute | Global Compact<br>Millennium Development Goals (MDG's).<br>Business Conduct for the Eradication of Child Labour - Ethos Institute<br>On the Right Track Program - Childhood Brasil<br>Communiqué de Durban | Global Compact<br>Millennium Development Goals (MDG's). |
| Sustainability report | GRI | GRI<br>COP | GRI<br>COP (Brazil) |
| Footprint | GHG protocol | GHG protocol | GHG protocol |

*Proposition 4 - Standards, sustainability reports, and voluntary commitments, have been influencing and guiding sustainability integration, however, the requirements supplied by the same are not sufficient for creating a sustainability integrated management system and to support their deployment at operations level.*

### 4.4 Best practices and business model requirements

In the studied companies sustainability issues in the strategic agenda and governance principles consolidated in organizational structures as councils and committees; ethic and conduct codes that guides their entire set of operations and relationships. All three studied companies have a sustainability management area or an executive board member. The three studied industrial plants present a high degree of automation and adoption of continuous improvement programs, but none have a business case for sustainability that identifies a positive relationship between sustainability and financial performance.

*Case A*

Company A sustainability office was instituted in 2010. Currently it also has a sustainability committee responsible for monitoring the sustainability strategy deployment and the sustainability intelligence management area, responsible for identifying, consolidating and reporting on company's sustainability indicators and linking sustainability practices to its competitive strategy. The company has a sustainability governance structure with a sustainability advisory board, composed of external members from several fields. It is responsible for analyzing trends on best sustainable practices worldwide recognized, evaluating projects and internal processes and permanently guiding. The company has been awarded for its corporate governance.

Currently the company has a 'Sustainability Committee' responsible for monitoring the master plan in the six dimensions of social, environmental, economic, governance, communication and innovation. The 'Management of Intelligence for Sustainability' area is responsible for identifying, consolidating and reporting on company sustainability indicators and also linking sustainability practices with the growth strategy. The company has adopted strict cost management practices, reviewing processes and their respective costs structure to become more productive for efficiency improvement and advising the company in implementing its sustainability policies and strategies. At Company A there is an ongoing long-term initiative focused on assessing the value captured on all management processes, which is firstly approached through a cost management perspective into every single decision-making process.

*Case B*

Company B is a privately held company. There is a 'Sustainability Management Department' divided in two areas, which reports directly to the Vice President, *"[...] one area is responsible for issues related to stakeholders and external matters, the other takes care of internal issues, risks, compliance and everything else"* (Sustainability Coordinator). These topics are managed through practices that involve establishing long-term partnerships with suppliers, making efforts to implement RL's processes, and product green design. In the company green product development and eco-efficiency strategies are established long term goals, streamlining processes with consolidated results for resources consumption in terms of energy, emissions and water. It is also identifying opportunities in inbound and outbound logistics for routes optimization and supplier development process.

*Case C*

In the Brazilian Division, Company C has a sustainability board that reports directly to the CEO and to the committee of corporate affairs. The company has projects involving the application of the shared value concept on new product development, and also redefining productivity measures in its value chain, mainly applied to suppliers in local clusters. Its operations strategy is focused on operational efficiency through cost reduction, and the operations excellence program is an ongoing improvement initiative for engaging workers in improving their daily activities. Table 12 presents a summary of the main topics relate to best practices and business model.

**Table 12 – Best practices and business model requirements**

| | **Company A** | **Company B** | **Company C** |
|---|---|---|---|
| Legal and regulatory regime | (++) | (++) | (++) |
| Sustainability in management agenda | (++)<br>Goals up to 2024 | (++)<br>Goals up to 2024 | (++) |
| Sustainability structure | (++) | (++) | (++) |
| Sustainable value chain | (++) | (++) | (+) |
| Sustainable product design | (+) | (++) | (+) |
| Life cycle management | (+) | (++) | No |
| Embed sustainability into culture and operations | (+) | (++) | (+) |
| New metrics related to sustainability | (++) | (++) | (++) |
| Integrated management system | No | (+) | No (in Brazil) |
| Re-define business based on sustainability | (+) | (++) | (+) |
| Identify ‘material sustainability´ | Biodiversity, water and environmental management, community, certification, growth strategy and impacts on the production chain). | Product´s Life Cycle, RL, Sales channels, resellers, wide eco-efficiency, and value chain. | Biodiversity; economic performance; spills and discharge management; relationships with stakeholders; labor relations; water management; occupational health and safety; landscape and soil management; environmental research; innovation; waste management; carbon footprint; energy management. |
| Business case for sustainability | No. Perceived financial impacts arise from: certifications. | No. Perceived financial impacts arise from: reducing consumption of resources; logistics. | No. Perceived financial impacts arise from: certifications; forest-based operations |
| Innovate products, processes and business models | (++) | (++) | (+) |

(++) Strong adherence / (+) relative adherence

*Proposition 5 - Sustainability is part of companies’ strategic agenda and their organizational design must be reviewed to develop the new required competences, which not only focus on* *compliance and reporting demands, but are oriented to integrate sustainability practices to their business model competitive strategy*

*Proposition 6 - The sustainability mainstream in operations strategy create opportunities for establishing new strategic performance objectives and decision areas policies, based on the conciliation of companies' resources and market needs that demand sustainable products and processes, which cover the whole supply chain and product life cycle*

## 6 Patterns and discussion

The results show that sustainability is being considered a success factor for enterprise competitiveness. In the three studied companies there was a committed leadership and a permanent presence of sustainability issues in the strategic agenda, and also a clear consolidated governance structure. Through the SOM lenses defined in Table 1, companies operations fit with sustainability principles. The level of application and the set of practices vary from one case to another, but several factors were present in all cases (see table 13. Strategies or practices related to Green Product Design and LCA for products and process were identified only on Companies A and B and are not included on the table.

**Table 13 – Patterns for sustainable operations**

| SOM aspects | Practices related |
|---|---|
| Sustainable Supply Chain Management (SSC) | Regulatory compliance; Eco-efficiency strategies; Energy and hydric efficiency; GHG control; Risk management; Suppliers development program (OH&S and GHG emissions); EMS |
| Reverse Logistics (RL) | Regulatory compliance; Eco-efficiency strategies; Waste management; Recycling/reuse/remanufacturing; EMS |
| Closed Loop supply chain management (CLSCM) | Regulatory compliance for the entire value-chain; Risk Management – raw materials and production processes; Stakeholders' engagement (awareness and dialog); RL; Waste management; Recycling/reuse/ remanufacturing; EMS |
| Sustainable and lean production | Eco-efficiency strategies; Lean 6 Sigma methodology (continuous improvement); Risk Management; QMS/EMS; Innovation programs |
| Integrated management system | QMS / EMS / OH&S / Social Responsibility - implemented but not managed in a single management system. |
| Corporate Social Responsibility (CSR) | Stakeholders' engagement (dialog); CSR policies (Conduct and Ethic Codes); Voluntary commitments; Corporate governance structure; Support collective actions; Transparency - Communication - Financial and Sustainability Reports |

Companies A and C belongs to the commodities industry, with cost as a main operational driver. Company B belongs to consumer goods industry and operates in a complex supply chain that covers among other aspects, natural raw materials use and RL. The supply chain management is oriented to develop local suppliers, and adopt a risk management approach with strong focus in eco-efficiency. At the companies, environmental issues were cited as starting point for sustainability integration, mainly related to regulatory compliance and demand for certifications (see Table 2). As shown in Table 2 the legal and political environment is an important driving force for business as a whole, and according to a NAEM report (2014), compliance remains a strong focus or sustainability strategies. The sustainability movement does not begin with a 'sustainable consciousness' by itself, but by regulatory constraints and competitive pressures.

Not considering specific industry standards, companies are using a common set of standards, reports and voluntary commitments to guide and communicate their sustainability practices**.** These are ISO 9001 (QMS), ISO 14001 (EMS), OHSAS 18001 (OH&S), ISO 26000 (orientative), GHG Protocol, Global Compact, Millennium Development Goals, and GRI Report. According to the sustainability managers, the certification approach is a safe path for sustainability integration based on the systemic and continuous improvement approach provided by these standards.

Typically at the studied companies QMS and EMS implementation followed by OH&S and other commitments for sustainable development, as also noted by Qi et al. (2013). SA 8000 and NBR 16000 initially guided social accountability practices, now ISO 26000 and principles from Global Compact and MDG provide orientation for company social management.

At the three studied companies, external markets are prioritized and the decision for using sustainability reports widely accepted reflects it. The GHG Protocol is being used and also replicated for the supply chain to reinforce company commitment with Climate Change and increase awareness. The GRI framework is used to report sustainability practices and also help in the identification of non-tangible indicators and material sustainability. As remarked by Kiron et al. (2013b), material sustainability represents the most relevant sustainability issue related directly to business continuity.

Internal awareness and resistance to change are related topics and key barriers for sustainability integration. As shown in Table 3, these barriers are linked to short-term thinking, difficulties to implementing strategy across business functions and quantifying the effects of sustainability. Internal communication on sustainability is shown to embed sustainability into organizational culture and operations. According to the WEF and BCG (2011) report, companies need to define aspirations and goals for sustainability that move beyond incremental changes looking for a new business model based on sustainability.

With business models managed by strategic scorecards, sustainability has not been integrated into a single management system. This lack of inclusion affects the sustainable practices adoption, resulting in a shortage of sustainable business cases and difficulties in raising awareness and employee engagement in the change process.

Specific legal and regulatory regimes shape their business environments (support associations and other collective actions); embed sustainability in their operations. There are opportunities for developing best practice, mainly related to the establishment of a single management system, quantify of the link between financial and ESG performance, and development of a sustainable business model.

Following the MIT evolutionary framework presented in Table 6, Companies A, B and C fall under the category of 'Embracers' because sustainability is relevant in achieving competitiveness, and is part of their strategic agenda and organizational structure. However, the companies have failed to establish a sustainability business case and promote the integration of sustainability into a single management system effectively. Nonetheless, it is possible to identify some characteristics in company B that points out a transition to become a 'Harvester', in the sense it is revising its business model considering sustainability as a key factor. In terms of strategies to aid sustainability integration, companies sought to:

- Develop a legal and regulatory regime for internal and external operations.
- Define ‘sustainability’ as a strategic item developing a `sustainability strategy´ supported by a strong leadership and a corporate governance structure.
- Establish QMS, EMS, OH&S and Social accountability system.
- Mapping risks and adapting operations based on eco-efficiency strategies and OH&S work conditions.
- Incentive and establish suppliers´ policies relate to eco-efficiency and health and safe work conditions for suppliers.
- Adhere to voluntary commitments related to sustainable development and support collective actions focused on sustainable development.
- Develop performance goals and metrics based on the sustainability regulatory framework.
- Measure sustainability performance and reporting the results using recognized models, as GHG protocol and GRI report.

Comparing the results to the Reeves et al. (2012) business model framework, the company ecological sphere is more mature than the economic and social spheres. Hence, the idea of sustainability is not fully deployed or integrated at the studied companies.

Suggestions on the development of a business model that suppose sustainable operations based on the cases results are summarized as follows:

- Address sustainability in an explicit, coordinated and integrated way considering the entire value chain.
- Define aspirations and goals for sustainability moving beyond incremental change.
- Adapt the performance management model for a comprehensive model including all stakeholders. The Performance Prism by Neely et al. (2002) may be such an option, since it allows for the incorporation of sustainability indicators provided by the regulatory framework to develop a more strong sustainability strategy.
- Develop proactive approaches to anticipate change in the regulatory regime.
- Invest in training for managers improving the internal awareness and establishing links between remuneration and sustainability performance indicators.
- Incentive innovation programs in the value chain.
- Assist customers, employees and suppliers to realize their ethical and ecological aspirations, strengthening RL strategies and consolidating CLSC, and also adopt LCA strategies for Green Product Design and production processes.
- Define links between sustainability practices and economic performance, including tangible and non-tangible results (e.g. financial indicators, productivity results, and reputation). Sustainability business cases may help, and related recommendations can be founded in Schaltegger et al. (2012) and IFC (2012).

**Conclusion**

Addressing the RQ1, this paper demonstrates the relevance of operations management in achieving sustainability integration. The results confirm that company operations fit with existing sustainability principles. Regulatory compliance and market pressures represent the main drivers for sustainability integration and internal awareness the main barrier.

As a key driver, regulatory framework represented by laws, specific industry regulations, standards, voluntary commitments and sustainability reports are guiding practice adoption and set a path for sustainability integration based on the balance of the quality, environmental, health and safe, and social management systems for the entire value chain.

Practices cover most of the SOM capabilities, although companies need to cover aspects related to sustainable product development and LCA for products and processes to establish product disassembly strategies (remanufacturing/reuse/recycling) and to consider product impact during the life cycle, including production. Both approaches are needed to provide resources for more sustainable decisions involving choices in raw materials, technologies and RL.

Exploring the RQ2, the study results also confirmed that corporate governance is important for supporting sustainability integration, mainly through a strong leadership and a separate function for sustainability. An important trigger for evolution in sustainability integration is the effort to link sustainability strategy to economic value and profits and changes the business model accordingly**.** The findings are related to large company operations and strategies. Small and medium sized enterprises may benefit from suggestions on how to improve their operations through SOM**.** This is primarily related to eco-efficiency strategies and regulatory compliance. Future research may help identify sustainability integration patterns in such enterprises.

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# PAPER III - DEVELOPING A MATURITY FRAMEWORK FOR SUSTAINABLE OPERATIONS MANAGEMENT

Carla Gonçalves Machado[a], Edson Pinheiro de Lima[ab], Sergio Eduardo Gouvea da Costa[ab], Jannis Jan Angelis[c], Rosana Adami Mattioda[a]

[a] Industrial and Systems Engineering Graduate Program, Pontifical Catholic University of Parana, 80215-901 Curitiba, Brazil.

[b] Federal University of Technology - Parana, 80230-901 Curitiba, Brazil.

[c] Department of Industrial Management, Royal Institute of Technology – KTH, 100 44 Stockholm, Sweden.

**Abstract**

Business sustainability integration is a complex task and strongly linked to operations management. In fact, sustainability based approaches demand operations management boundaries' expansion, creation and integration of new performance goals into traditional company's performance management system, and new criteria and policies for operations' decision areas development. The challenge is to conduct more sustainable operations through companies' value chain and their operations network. Maturity models have been used in different areas as a process improvement and change management model for complex contexts. In sustainable operations management area, maturity models have been developed for specific purposes, e.g., sustainable production, sustainable supply chain management, corporate social responsibility, and life cycle management. However, there is a lack of models that considers sustainability integration through the evolution of sustainable operations' capabilities in an integrated way. Based on literature review, case studies and expert panels, this paper develops and proposes a maturity framework defined by sustainable operations management theory. The findings pointed out that its is possible to identify an evolutionary path, which goes from an initial approach focused in compliance aspects and firm's value protection to an innovative approach, based on corporate social responsibility supporting operations' integration in a sustainable system, and long-term values development. The experts' panel identified key processes areas that need to be prioritized in each level, and also analyzed the adaptation of some elements from Capability Maturity Model Integration (CMMI) to sustainable maturity framework design and development. The framework represents company's vision regarding its value chain and operations network, and it is indicated for manufacturing companies.

Keywords: sustainability, operations management, sustainable operations, maturity model, and performance measurement.

## 1. Introduction

Companies are looking for guidance in order to develop sustainability competences and to integrate these in a complex, global, distributed, and dynamic operations network (Drake & Spinler, 2013, Gunasekaran & Ngai, 2012, Golini et al., 2014).

Porter and Kramer (2006) say that companies should conduct their operations in a way that guarantees good, long-term economic performance, investing in integrated environmental and social strategies that allow for conformity with various regulatory requirements, exploration licenses, and transparency in business, and other stakeholder demands.

According to Deloitte (2010) *"[...] the goal should be to embed sustainability considerations into a company's strategy and operations in such a way as to enhance business value and derive a competitive advantage."*

In this sense, it is necessary to develop tools to help a company obtain a better understanding as well as define objectives and metrics for the operationalization of sustainable management (Veleva et al., 2001, Singh et al., 2009).

To develop systems aligned with the perspective of sustainability, strategic planning needs to take into account environmental and social principles as well as to translate and institutionalize the definition of sustainability, develop appropriate performance indicators, develop new value-creating approaches, and consider the demands of stakeholders, among others (Labuschagne et al., 2005, Pinheiro de Lima et al., 2008).

Companies that approach sustainability through ad hoc programs or isolated initiatives do not achieve the desired goals as effectively as companies that take an integrated approach (Park & Pavlovsky, 2010). Companies need to develop assessment systems for identifying the starting point and evaluating the progress of sustainability integration. Resources should be continuously assessed in terms of the present and the future from internal and external perspectives (Dao et al., 2011).

According to García-Mireles et al. (2012), companies need *"[...] models that support them in achieving their goals."* However, reports from MIT Sloan Management Review and Boston Consulting Group, from 2010 to 2013, show the *"lack of a model for incorporating sustainability"* and *"difficulty quantifying intangible effects,"* as some of the major barriers for the issue of sustainability in companies (Hannaes et al., 2011, Kiron et al., 2013a, 2013b).

According to Van Looy et al. (2013, 2014), since the 1970's maturity models have been considered relevant improvement tools for companies. To Silvius & Schipper (2010) *"[...] maturity models are a practical way to 'translate' complex concepts into organizational capabilities and to raise awareness for potential development."*

Against this backdrop, a question emerges: How are maturity models for operations management employed in the sustainability context?

Based on literature review, case studies, and expert panels, this study develops a maturity framework defined by sustainable operations management theory, in order to support the sustainability integration process.

## 2. Conceptual Background

Business Process Maturity Models (BPMMs) enable companies achieve high levels of performance. Maturity is expressed in the evaluation and continuous improvement of the capabilities of business processes and requirements so that the company can reach a higher performance in isolated capabilities or in overall performance. The sequence of levels and specifications (a roadmap), with objectives and practices, gradually lead the company through the process of searching for excellence (van Looy et al., 2014).

For van Looy et al. (2014), BPMMs have some limitations, e.g., simplification of complex issues; however, this is attributed to the fact that there is still a lack of theories or comprehensive studies on the maturity of the business process.

In 1995, Carnegie Mellon University published the book, *The Capability Maturity Model (CMM): guidelines for improving the software process.* The CMM defines maturity as the stage in which a process is explicitly defined, managed, measured, controlled, and effective.

The CMMI – Capability Maturity Model Integration – was developed based on the evolution of the CMM. According to CMMI *"[...] organizations can achieve progressive improvements in their maturity by achieving control first at the project level and continuing to the most advanced level — organization-wide performance management and continuous process improvement.* Five levels identify the trajectory of improvement that make up a set of process areas that point to different organizational behavior. In addition, this type of identification contributes to determining the sets of processes (indicators) that will be the focus of improvement (SEI, 2010).

According to CMMI, a maturity model should contain components to facilitate the interpretation of the processes, among them (SEI, 2010):

- Maturity levels: an evolutionary path to improve the processes used to develop products or services.
- Process areas: a set of practices in an area that need to be implemented collectively to improve the area.
- Generic goals: necessary characteristics for institutionalizing processes.
- Generic practices: the important activities for achieving the generic objectives and supporting the institutionalization of the process of change.
- Specific goals: unique characteristics to satisfy the process areas.
- Specific practices: important activities for achieving the specific objectives of the process areas.

The generic and specific targets are considered “required components” of the model, which must be visibly implemented in the organization, while the generic and specific practices are “expected components,” i.e. they describe what should be done to meet required components (SEI, 2010).

The CMMI became a reference for developing other maturity models, including models for sustainable operations. García-Mireles et al. (2012) identified in the literature that most newly developed models are adaptations of CMM and CMMI. The model put forth by Mani et al. (2010), the Sustainability Manufacturing Maturity Model (SMMM), uses guidelines from the CMMI as well as techniques from LCA, and performance indicators and standards, among others.

## 2.2 Sustainable operations management

It is important to have an appropriate approach for sustainability issues in designing, implementing, and running enterprise systems. Sustainability should not be seen as an independent process, but rather as a dynamic and complex system with different components and actors interconnected and interdependent. Organizations need to be viewed through the impact on the whole system (Ueda et al., 2009, Ryan et al., 2012).

Once a company considers sustainability as part of their business model, its operations must reflect this. The operations strategy directs the technologies and production design, and the distribution, as well as the system that will determine the selection and the degree of efficiency of the materials and type of energy used. In addition, it determines the types and extent of waste generated and the sustainability of the ecosystem in relation to society (Drake & Spiler, 2013).

Sustainable operations management (SOM) represents a set of skills and concepts through which companies can structure and manage their business to obtain a competitive return on capital assets without compromising the needs of stakeholders and at the same time considering the impact the operations will have on people and the environment. Thus, SOM can contribute to the company in different aspects, e.g., agility, adaptability, and the balance between profit, people, and the planet, based on the concept of TBL (Kleindorfer et al., 2005).

Sustainability cannot be achieved by a single firm action and, to be truly effective, entire supply chains, not just individual partners, must operate in a sustainable manner (Carter & Rogers, 2008, Bettley & Burnley, 2008).

Companies need to identify the best practice for each activity in its value chain. Some of this could be reflected in more proactive conduct with better results that answer and mitigate issues that may appear in the value chain extension, thus creating a competitive advantage and environmental and social value (Porter, 1998, Porter & Kramer, 2006).

To extend sustainability to the value chain, OM's boundaries need to be expanded (Bettley & Burnley, 2008). Gunasekaran & Spalanzani (2012) identified the main OM capabilities for a sustainable business: Closed Loop Supply Chain Management (CLSC); Green Supply Chain Management (GSCM); Cradle-to-Cradle methodology; Green Purchasing or procurement; Carbon footprint mitigation; Quality, environment, and social system management; RL and remanufacturing/recycling; Lean operations; Life Cycle Assessment (LCA); CSR and ethics.

According to Nunes et al. (2013), two approaches have emerged from the literature on sustainable operations: (1) focused on the decision making processes, adding sustainability criteria to the strategic decisions in OM; (2) adoption of SOM practices, linking green operations and CSR initiatives. Boundary expansion of OM can be represented by some capabilities listed in Exhibit1a and 1b (in alphabetical order).

| SOM's Capabilities | Definition |
|---|---|
| Corporate Social Responsibility (CSR) | *"Corporate sustainability has been defined as ''a business approach that creates long-term shareholder value by embracing the opportunities and managing the risks associated with economic, environmental, and social developments" (DJSI, 2014).* |
| Design for Sustainability (D4S) | *A broad definition of D4S would be that industries take environmental and social concerns as a key element in their long-term product innovation strategy. This implies that companies incorporate environmental and social factors into product development throughout the life cycle of the product, throughout the supply chain, and with respect to their socio-economic surroundings (from the local community for a small company, to the global market for a transnational company) (Crul & Diehl, 2006).* |
| Innovation at business operations models | *Operational innovation should not be confused with operational improvement or operational excellence […] Operational innovation means coming up with entirely new ways of filling orders, developing products, providing customer service, or doing any other activity that an enterprise performs (HAMMER, 2004).* |
| Integrated Management System (IMS) | *"All aspects of operational performance should preferably be integrated into a single management system (e.g., quality, sustainability, health and safety) so as to reduce the administrative overhead and potential confusion arising from multiple systems" (Bettley & Burnley, 2008).* |
| Life Cycle Assessment (LCA) | *[…] Compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle (ISO 14044:2006).* |
| Sustainable Production | *[…] the creation of goods and services using processes and systems that are: non-polluting; conserving of energy and natural resources; economically viable; safe and healthful for workers, communities, and consumers; and, socially and creatively rewarding for all working people (Veleva et al., 2001).* |

Exhibit 1a – Sustainable OM capabilities

| SOM's Capabilities | Definition |
|---|---|
| Sustainable Supply Chain Management (SS CM) | *We are now ready to provide a unified definition for sustainable supply chain management as the management of supply chain operations, resources, information, and funds in order to maximize the supply chain profitability while at the same time minimizing the environmental impacts and maximizing the social well-being (Hassini et al., 2012)* |
| Stakeholder Engagement | *Engaging with stakeholders from the start…enables a proactive cultivation of relationships that can serve as "capital" during challenging times (IFC, 2007)* |
| Reverse and closed-loop supply chains (RL and CLSC) | *Reverse Logistics (RL) involves all the activities associated with the collection and either recovery or disposal of used products […] the closed-loop supply chains, which involve the simultaneous consideration of forward and reverse flows, have become an attractive alternative for the cost-effective management of RL operations" (Ilgin & Gupta, 2010).* |

Exhibit 1b – Sustainable OM capabilities

Explored some characteristics of sustainable operations, it is possible to address some issues related to maturity.

### 2.2.1 The use of maturity models in sustainable operations management

According to Veleva et al. (2001), sustainable systems are a continuous and evolutionary process for measuring performance and different companies are *"[...] starting at different places in the evolutionary process."* This means that a company can adapt its strategies and operations model on an evolving path towards a high level of sustainability.

The concept of sustainability is widely recognized as a multi-level concept where levels are highly interdependent. Genuine progress requires actions at all levels to achieve sustainability at the macro level. Through good practices, skills training, and existing performance metrics and measures, it is possible to move forward through the maturity levels (Cagnin et al., 2005).

A strategy aligned with sustainability meets with a barrier found similarly in traditional strategic models, the difficulty of transforming strategy into action. Driving this transformation represents a great challenge and leads to questioning around how companies can improve sustainability performance; principally, how can companies identify, manage, and measure the indicators for this transformation (Pinheiro de Lima et al., 2008).

In some cases, the first sustainability initiatives in the operations strategy begin by focusing on reducing costs and risks, and then, over time, are directed at new strategies for value creation and valorization of intangible resources such as branding and organizational culture (Lubin & Esty, 2010).

Bititci et al. (2012) emphasize the need to create performance measurement systems that integrate the (TBL) sustainability dimensions, accompanied by models that extend the performance indicators to the supply chain and value chain. Nevertheless, the authors highlight that there is still a need for models that meet the challenge of supplying an integrated vision of sustainability performance in a way that is both broad and in depth.

Based on the academic literature, Pinheiro de Lima et al. (2012) identified the evolution of maturity-based models over the last ten years for managing SOM (Figure 1).

| | | | | | References | Aspects |
|---|---|---|---|---|---|---|
| 2012 | | Total, net and open sustainable innovation | | | Musango and Brent (2011)<br>Marinova and Todorov (2011)<br>van Bommel (2011)<br>Talbot and Venkataraman (2011)<br>Dao et al. (2011)<br>Mani et al. (2010) | Integrated 3BL |
| | 2011 | 3BL integration: IT, HRM, SCM | | | | |
| 2009 | | Sustainable enterprise engineering | Co-evolutionary systems | Sustainable energy management | | |
| | 2008 | 3BL: integration and coordination | | | Hutchins and Sutherland (2008)<br>Seuring and Müller (2008)<br>O'Connor (2006) | 3BL plus Governance |
| 2007 | | | | | | |
| | 2006 | Social sustainable supply chains | Governance | Participative structures | | |
| 2005 | | Supply chain management | Innovation Sustainable nets | Sustainability capabilities | Kleindorfer et al. (2005)<br>Cagnin et al. (2005)<br>Labuschagne et al. (2005)<br>Lamberton (2005)<br>Azapagic (2004) | Extended 3BL |
| | 2004 | Life-cycle models (product and process view) | Life-cycle assessment Value creation | Quality of working life Social aspect | | |
| 2003 | 2002 | Coordination: companies, communities and government (local, regional, national) | | | Veleva and Ellenbecker (2001)<br>Veleva et al. (2001) | 3BL |
| 2001 | | Continuous improvement | Product life-cycle | Evolutionary process | | |

Figure 1 – OM sustainable maturity evolution

The study by Pinheiro de Lima et al. (2013), analyzing professional maturity models based on CMMI (SEI, 2010), and the approach by Pettigrew (1997), identified that maturity models tended to be organized in five levels, from "compliance" positioning to "strategic" operations network integration with capabilities that can be used to describe the "operations vision" associated with the maturity levels. The authors also identified gaps related to the implementation process; SOM scoped delimitation; and, governance structure definitions.

To Dao et al. (2011), maturity is developed in the sense of RBV, that is, OM sustainability competencies evolve over time and resources should be continuously assessed in terms of present and future internal and external perspectives.

Based on the concepts of BPMM and CMM and the application of maturity models in the context of SOM, it is understood that a company can reach maturity in the sustainability integration process through the development and maturation of OM sustainability competencies/capabilities. However, for the macro objective of integrating sustainability in the value chain to be achieved, it is necessary that such competencies are managed in an integrated manner.

## 3. Research Design

The purpose of this study is to develop a framework for evaluating and guiding processes of SOM, structured according to guidelines from Pettigrew's approach (1987, 2012) and the Capability Maturity Model Integration – CMMI.

Pettigrew's approach (1987, 2012) focuses on the processes that drive change. The inclusion of sustainability is a broad change process. The research strategies to define the context of sustainability for OM and its evolutionary pathway, and also the content and processes of the maturity model for SOM are illustrated in Figure 2.

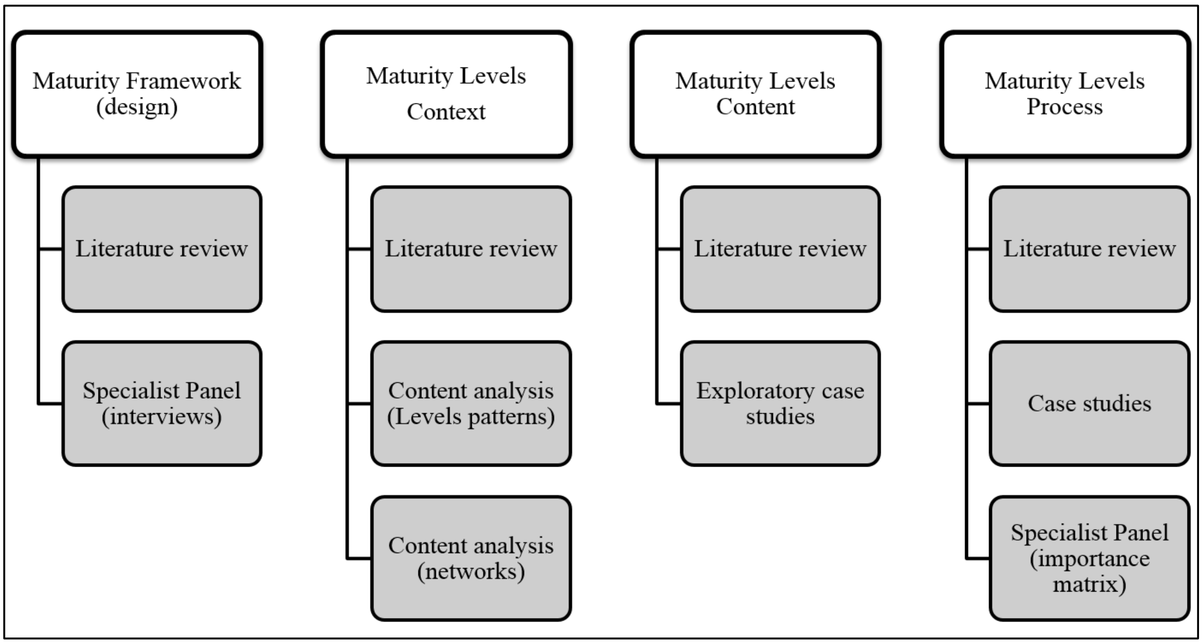

Figure 2 – research strategies

The literature review was conducted on two fronts: sustainability and OM; and, maturity models in OM. The initial results were reported based on previous studies conducted by Machado et al. (2012) and Pinheiro de Lima et al. (2012, 2013).

For content analysis, a set of 29 documents (listed in Paper III) was organized based on the studies carried out by Pinheiro de Lima et al. (2012, 2013) and complemented by additional research from databases and websites, with a focus on sustainability management and companies specializing in business consulting and management systems. The set covers the period 2001-2012 and the following themes: Sustainable production; business sustainability; sustainable supply chain management; corporate responsibility; life cycle management; human resources; project management; the finance function; and, sustainable consumption.

Simultaneously, a content analysis strategy via terms network formation was used. Almeida & Vosgerau (2007) explain that by means of networks, it is possible to get an overview of coded information and allow for the establishment of relationships, subject comparisons, and the creation of theories.

Network analysis was done through the use of Atlas TI software and, due to system requirements, 26 of the 29 models were analyzed in this step. According to Walter & Bach (2009), the Atlas TI offers some advantages: Flexibility in adapting to different research projects; agility and ease in the analysis process; potential to record the steps of the analysis; and facilitation of empirical verification of the interpretations and changes during the process. However, the program does not automate the analysis process, requiring interpretation by the researcher.

Based on the OM approach, the networks were organized in decisional areas in operations and traditional areas of performance objectives, following the classifications customized for manufacturing and service production processes provided by Pinheiro de Lima et al. (2008). Johansson & Winroth (2010) also identified environmental implications for operations decision criteria in manufacturing strategy.

In addition to being formed from the decision and performance objective areas, the networks were organized into five maturity levels, a structure present in most models identified in the literature. Figure 3 illustrates one of the networks formed.

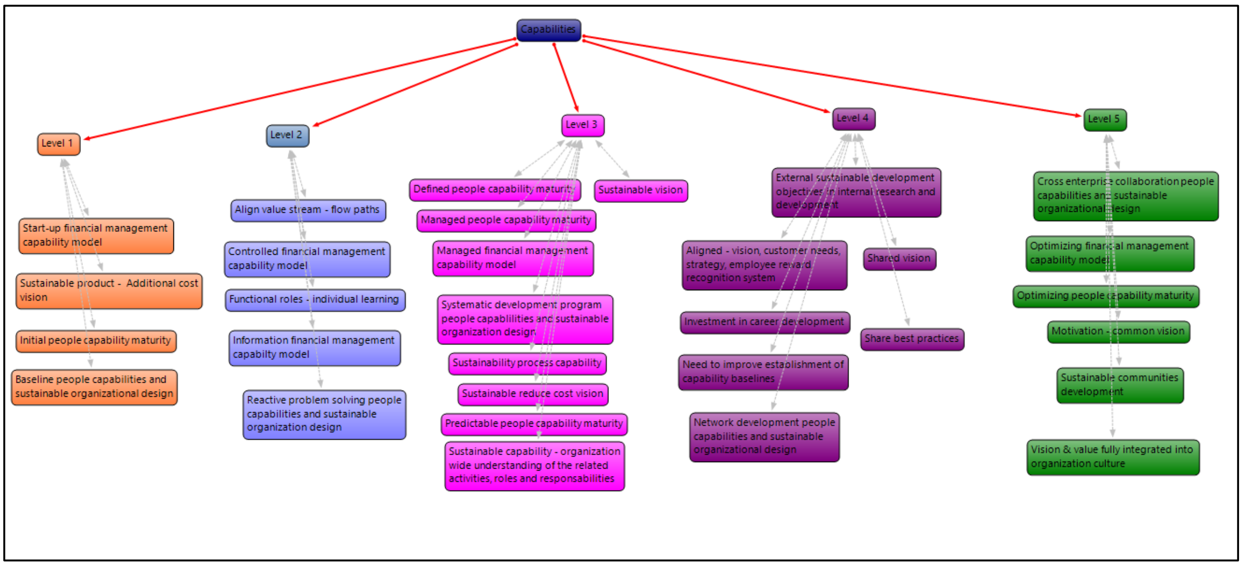


Figure 3 – Decision area network (capabilities)

Case study research design is fully described in Machado et al. (2014). Three companies with operations in Brazil were analyzed in order to identify patterns for sustainability integration. The case studies belong to an earlier phase of the research and will not be described here. However, some of the case study results have been appropriated to be integrated into the discussion as recommendations for the implementation and integration of sustainability.

The second part of the research covers two different expert panels conducted following orientations from Mackenzie et al. (2011). The construct represents the maturity framework for managing sustainable operations, and the items that make up the construct were defined through the literature review (context, content, and processes).

This first panel helped to identify each level's content organization and to determine key processes related to each requirement that integrates the levels. A matrix was developed in which the requirements of SOM were listed at the top of the columns organized, following a sequence of five maturity levels (from compliance to sustainable operations integration), and the processes that attend the SOM requirements were listed in the rows. A pre-test was conducted with a specialist and few adjustments were made.

Eighteen specialists in OM and sustainability rated the extent to which each process needed to be present for each capability, using a six point Likert-type scale ranging from 1 (not important at all/not applicable) to 5 (very important), complemented by 0 (not sure/no opinion). Most raters were in academic/research, with 10-20 years of experience in the operations management field.

The results were organized and clustered using the Minitab and Excel software. Descriptive statistics were used to establish the median of the responses for each variable generated by the matrix. Following the guidelines from the second panel of experts, only the results above "4.5" were considered in analyzing the medians considered as "very important." According to the experts, regarding maturity, companies initially tend to do the minimum and what is mandatory until cultural and organizational change is strengthened.

The clustering was carried out by the Ward's Hierarchical Clustering Method with Euclidean distance. According to Hair (2005), this method forms clusters seeking the minimum standard deviation between each cluster and uses analysis of variance to analyze the distances between them. It provides good results for both Euclidean distances as well as for other distances. It is sensitive to the presence of outliers and tends to combine clusters with few elements.

The second panel was used to validate the maturity framework structure based on CMMI components. Six experts in CMMI and business maturity were interviewed. The strategy adopted was to send an introductory document presenting the research context, the framework structure, and the questions that guided the interview. A pre-test was conducted with a CMMI expert and a few adjustments were made.

**4. Results**

This section presents the results of the content analysis of the list of selected models. Subsequently, the recommendations for the integration of sustainability originating from the case studies are presented, described fully by Machado et al. (2014a, 2104b). Concluding the section are the results from the expert panels.

**4.1 Content analysis**

The analysis of the maturity levels of the 29 models is summarized in Appendix 1. A pattern between the content of the levels is identified; however, the models regarding project management, the finance function, and sustainable consumption were not considered in this step due to these model's context. A summary of the results follows:

- Level 1 - Compliance with regulations and conformity in internal operations, defining policies, and identifying trade-offs in key supplier processes for compliance with regulations.
- Level 2 - Focus on operations (internal and external) efficiency and productivity, ensuring compliance with customers and regulatory requirements, and integrating into operations environmental, social, and governance principles. Reducing impacts related to materials and natural resources in the product design, and defining sustainability goals and policies for inbound and outbound suppliers.
- Level 3 - Operations driven by standards and sustainability gains formal structures and processes, and linked with economic results. External operations are driven by GSCM principles, and the supply chain is included in the performance management system and continuously audited. Customers are engaged in new types of collaboration (e.g., new product design and reverse logistics).
- Level 4 - Sustainability is considered a key business strategy and CSR principles are established. Full sustainability integration into the value chain, with new values defined across the value chain and the knowledge shared with suppliers. Suppliers

are also engaged in the eco-design process based on LCA studies.

- Level 5 - New business model defined. Sustainability integrated into all aspects of the business and managed through change management and process improvement.

The study of terms networks provided insights into the clustering of the required SOM and also into the management guidelines, listed in APPENDIX 2. According to the clustering of networks:

- Level 1 – Focus on reducing pollution and waste generation, in addition to aspects related to occupational health and safety.
- Level 2 – The focus of reducing environmental impacts develops into the concept of eco-efficiency. Quality, environmental, and OH&S management systems are established, supported by knowledge management and performance management. Data from LCA studies are now used in development processes and new products, and to reduce the environmental impact of production.
- Level 3 – New product design is guided by the principles of D4S and LCM, using eco-friendly materials. Operations based on principles of continuous improvement and process optimizations are extended to supply chain management. Eco-efficiency is focused on energy efficiency and the use of renewable resources. Extended to the supply chain, eco-efficiency focuses on risk management, reduction of the carbon footprint, and the viability of closed production systems. Customer engagement becomes part of the strategy.
- Level 4 – LCA and Cradle-to-grave principles integrated across value chain. Products with environmental certifications. Information systems support customer and supply chain engagement, and process activities as well as controlling multiple activities. Energy matrix exchange with focus on renewable resources.
- Level 5 – Full customer and supplier engagement establishing a wide sustainability net. Integrated Management System established with qualitative metrics for social dimensions. LCA inventory validated by a third part.

Based on the management guidelines, it was possible to identify the transition points between levels in view of the decision areas in operations and performance objectives, illustrated in Figure 4.

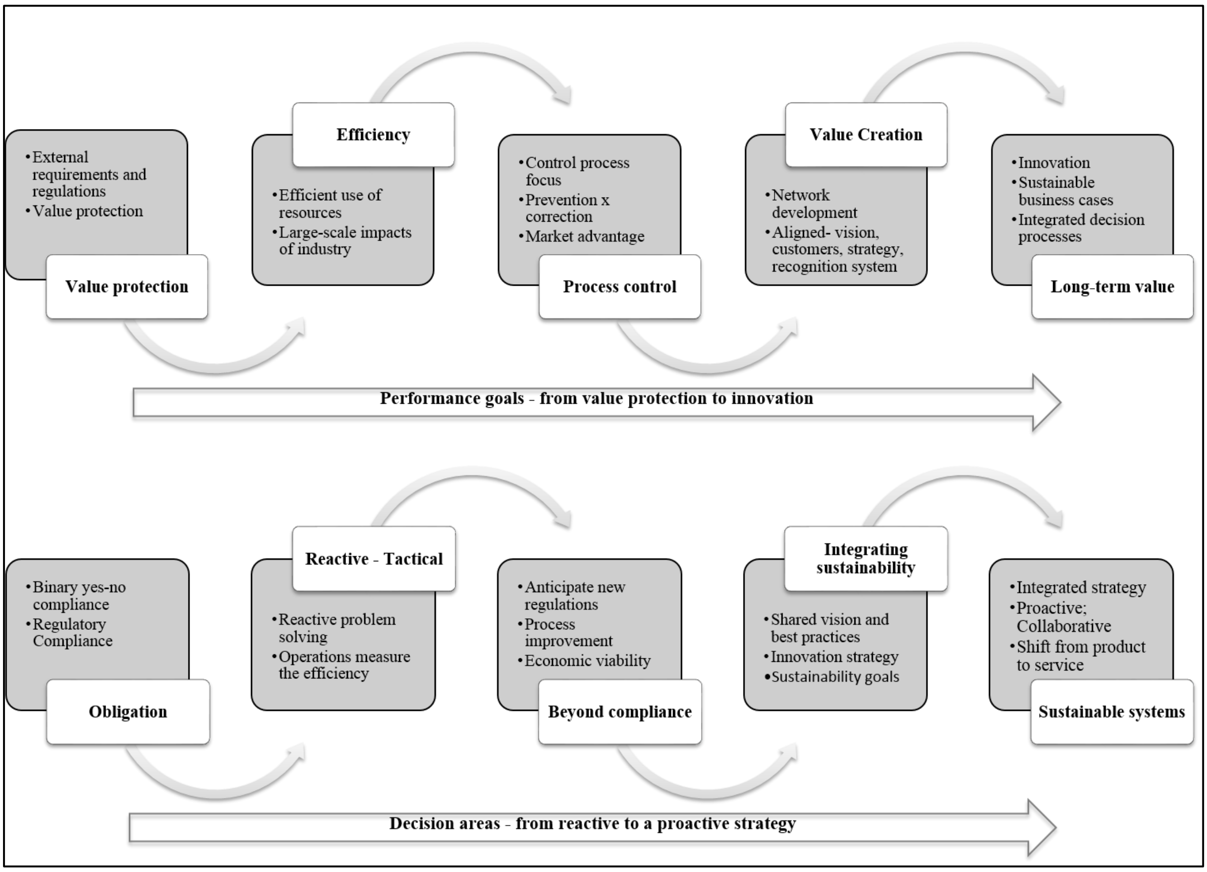

Figure 4 – Requirements for maturity development

Thus, sustainable operations management must be conducted through companies' value chain, guided by strategic performance goals that lead them to: (1) meet regulatory requirements; (2) focus objectives and decisions in operations efficiency considering all systemic impacts in business processes; (3) a transition from tactical-reactive operations approach to a more proactive one, based on process control, continuous improvement, preventive strategies rather than corrective ones, anticipating new business requirements and regulations; (4) to build a collective strategic vision, performance objectives and decision-making processes for stakeholders development, integration and engagement, that is, to create an operations  network that shares strategic visions, best practices and value creation; (5) to enable sustainable operations management conduction in an integrated manner to value chain perspective, to show clearly results that link economic performance to socio-environmental gains (sustainability business cases), and to create a business environment that favor and requires innovation and collaborative strategies among value chain participants and other stakeholders.

**4.2 Expert panels**

The first panel of experts sought to identify the key processes related to the requirements for compliance associated with each maturity level. Initially, the clustering by importance was analyzed using descriptive statistics, considering only the most important processes. The measure considered was the median.

For the formation of clusters, the literature pointed out maturity models containing three to six levels. Thus, this parameter was set for the clustering. However, after analysis of the generated options, the division into five levels presented more consistent results based on the literature review. The key processes identified in each step are described in Exhibit 2.

| Level | Descriptive statistics |
|---|---|
| 1 | Internal operations: D4S; Reverse Logistics and Closed Loop Supply Chain; Eco-efficiency strategies; EMS; OH&SM; Social accountability.<br>Supply chain: LCA; Sustainable Purchasing; Eco-efficiency strategies; EMS; Suppliers Development Program; Stakeholder engagement; Reverse Logistics and Closed Loop Supply Chain. |
| 2 | LCA; D4S; Reverse Logistics and Closed Loop Supply Chain; Eco-efficiency strategies; Lean and green process; Environmental Management System; Cleaner Production. |
| 3 | Lean and green process; Eco-efficiency strategies; Cleaner Production; Quality Management System; Information System. |
| 4 | Suppliers Development Program; Stakeholder engagement; Sustainable Purchasing. |
| 5 | LCA; D4S; Reverse Logistics and Closed Loop Supply Chain; Eco-efficiency strategies; TQM; EMS; Information System. |

Exhibit 2 – Key process identified by the experts

It is noteworthy that the processes assume new aspects as the maturity level increases.

- Level 1, processes should be focused on the plant's internal compliance and supply chain vis-à-vis the legal and industry regulations;
- At level 2, processes should be focused on sustainable product design and eco-efficiency;
- At level 3, the processes are focused on the formalization and optimization of internal and external processes, based on continuous improvement and automation;
- At level 4, the processes focus on the effective value chain integration, supported by engagement and collaboration programs with the suppliers and other stakeholders;
- The full implementation of the core processes at level five points to the effective integration of sustainability in operations and in the business model, based on innovation around products and processes and in the creation of shared value.

The five clusters formed exhibited the following configuration:

- Cluster 1 – LCA; D4S; Reverse Logistics and Closed Loop Supply Chain.
- Cluster 2 – Lean and green process; Sustainable Purchasing; Eco-efficiency strategies; Cleaner Production; Quality Management System; EMS.
- Cluster 3 – OH&S management; Social Accountability; Sustainability Business case.
- Cluster 4 – Suppliers Development Program; Stakeholder engagement.
- Cluster 5 – Information System; Sustainable Marketing.

The generated clusters showed some degree of adherence to the descriptive statistics on levels one, two, and four. Both clustering methods were considered relevant for the development of the framework. The first points to the priority processes that support each maturity level, and in turn, the second points to complementary processes, which can be deployed and managed in an integrated manner. According to the literature review, both also show a development trend.

In the second panel, the experts reviewed applicability and usefulness of the following issues: (1) previous experience with CMMI or other maturity model; (2) the adaptation of the structural elements of the CMMI model to the maturity framework for SOM. Adapted CMMI elements are shown in Figure 5.

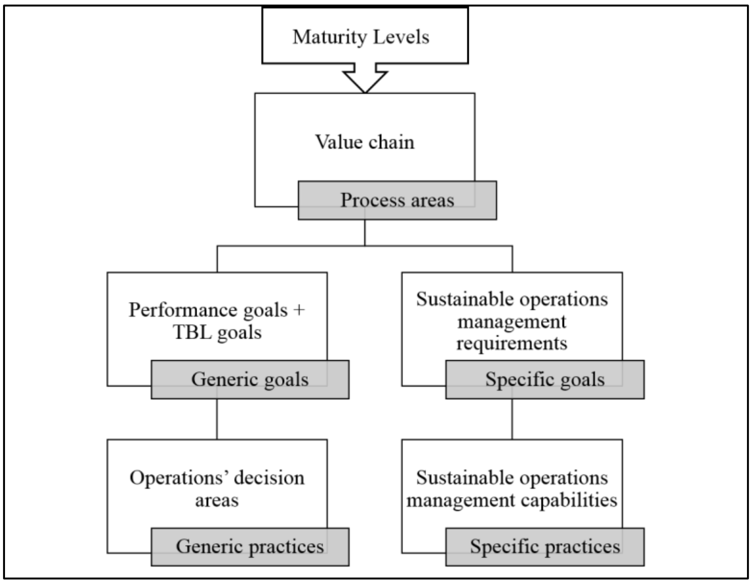


Figure 5 – CMMI´s elements adaptation

The activities that make up the value chain represent the organization of the operations of a company (Porter and Kramer, 2006). In the proposed maturity framework, these correspond to process areas that must be constantly improved.

Generic goals are represented by market requirements related to sustainability, translated into traditional goals of performance, representing economic dimensions (quality; speed; reliability; flexibility; innovation; cost) and into social and environmental performance goals (impact mitigation; pollution prevention; climate change; quality of work life; social justice and community development; ethics and compliance). The generic practices represent the mobilization of organizational resources, i.e. by the operations decision area, representing a set of policies and activities relevant to the fulfillment of the performance goals. The specific goals and practices represent the SOM capabilities implemented in the value chain and processes related to it.

In terms of the use of a maturity model, the experts considered it a good option to address the issue of sustainability integration: *"I think a maturity model can be used as reference to implement new ways of working or to support change/organizational culture or strategy" (Reviewer 3)*. In general, the CMMI model was considered a valid reference. According to one of the experts: *"The CMMI is a basis much considered in the procedural matter, models in Supply Chain Management joined the CMMI in area-specific models" (Reviewer 6).*

The adaptation of the elements was also considered appropriate: *"The structure is relevant to performance management systems" (Reviewer 2).* However, the tendency of companies to do only the minimum required or what is mandatory was pointed out. In conjunction with this, it was highlighted that in some cases pro-activity is not encouraged because it may draw undue attention and force the new approach to become mandatory in the future.

## 5. Framework for maturity in sustainable operations management

Based on the concepts of CMMI and the theory of sustainable operations management, maturity in SOM can be understood as a sequence of capability improvement levels that enable the company to conduct its operations in a sustainable manner.

The following sections present the context of maturity levels, the contents of the expected goals in the value chain, and the key processes that will support the sustainability integration process.

## 5.1 Maturity Levels

Five evolutionary levels define the "Content" of maturity, according to sustainable operations management theory (Figure 6).

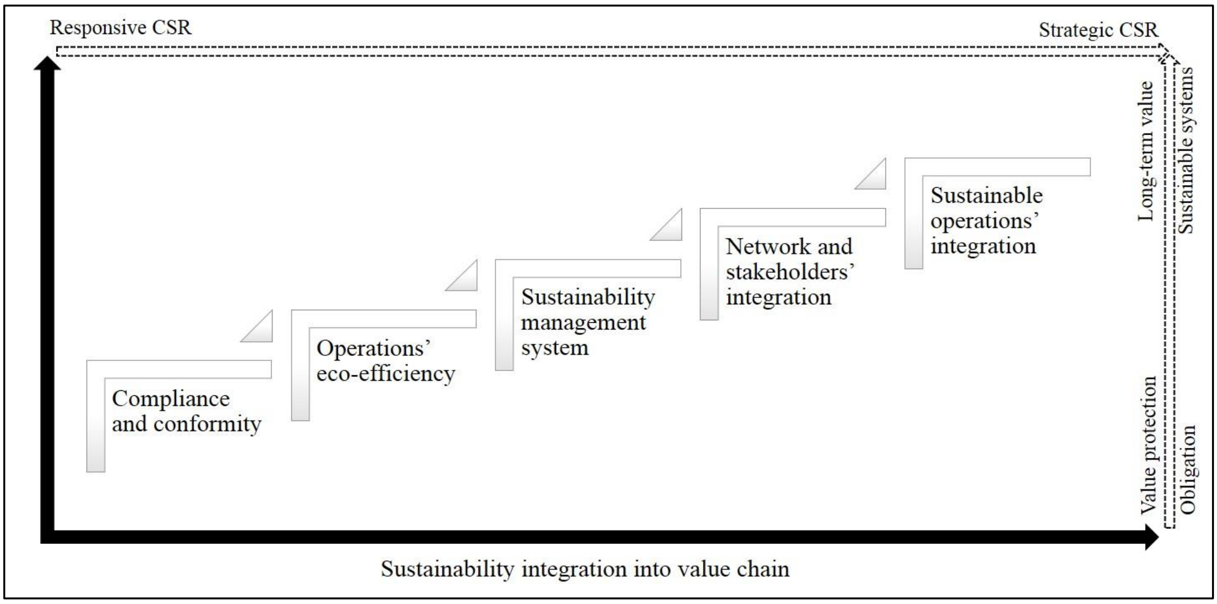


Figure 6 – Maturity levels for sustainable operations management

(1) Compliance and conformity: company recognizes its obligations and responsibilities. Company's facility and internal operations need to be in compliance with general regulations (government laws, license to operate, etc.) and conformity with specific industry requirements. In general, compliance and conformity are focused on all aspects related to license to operate, environmental regulations (identifying and controlling impacts), and ensuring good labor conditions, and human and child rights. This focus is not only on internal operations and facilities, but also to be extended to key suppliers. This approach is reactive and important to the economic dimension, since the company reduces risks with non-compliance, avoiding fines or operational restrictions.

(2) Operations eco-efficiency: company needs to ensure its efficiency and productivity in accordance with socio-environmental requirements; more than identify and control, all impacts need to be reduced. Key suppliers must be included in product design focusing on reducing impacts related to materials, natural resources, and carbon footprint.

(3) Sustainability management system: socio-environmental capabilities become formalized, defined, and managed by continuous improvement and optimized

processes. Company establishes formal processes for sustainable production and sustainable product design, focusing on customer demands. Eco-efficiency strategies are dedicated to energy efficiency and use of renewable resources, including product design and manufacturing processes; extended to the supply chain, eco-efficiency is focused on risk management, reducing carbon footprint, and establishing reverse and closed supply chain systems, considering the entire product life cycle.

(4) Network and stakeholders integration: sustainability principles and processes are integrated across the value chain. Suppliers, customers, and other stakeholders engage and corroborate on company´s sustainability strategies and operations.

(5) Sustainable operations integration: a wide sustainability net is defined, based on an integrated management system established across the supply chain and guided by a new business model based on innovation, looking for more sustainable processes in a continuous improvement system.

Levels four and five emphasize the observation similar to that of Bob Willard (2010) in the 5-Stage Sustainability Journey model: *"[…] About 90% of the behaviours of Stage 4 and Stage 5 companies look the same […] It's the motivation that differs. Stage 4 companies "do the right things" […] Stage 5 companies are successful businesses so that they can continue to "do the right things."*

Thus, in the framework presented here, what differentiates levels four and five is the consolidation of a new business model based on the innovation and continuous improvement of sustainable processes.

### 5.2 Process areas' maturity relationship with specific goals and practices

In the proposed framework, the integration of sustainability in the value chain can be carried out via the development of capabilities related to the scope of sustainable operations management.

Figure 7 shows the proposed framework, relating the process areas, objectives, and specific practices.

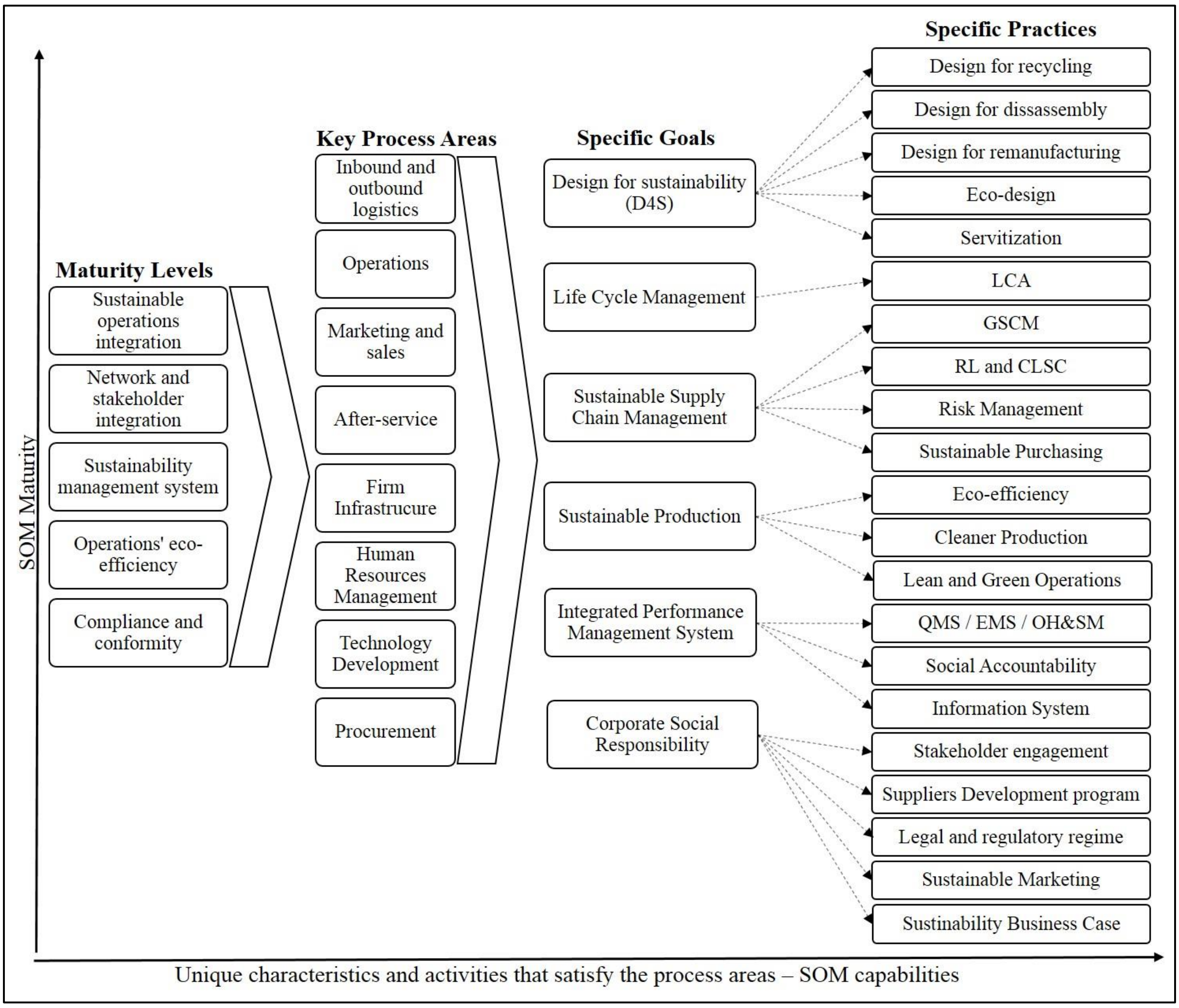


Figure 7 - Maturity Framework – Specific Goals and Practices' context.

Sustainability maturity for inbound and outbound logistics is related to sustainability integration into SCM, i.e. implementing Sustainable supply chain management and Life cycle management, described in Exhibits 8 and 11 in Appendix 2, and complemented by the work of Kocabasoglu et al. (2007), Seuring & Muller (2008), UNEP (2009), Martinez et al. (2010), Hassini et al. (2012), Beuren et al. (2013), and, Drohomeretski et al. (2014). The evolution goes from compliance and conformity to supporting innovative strategies considering the full life cycle of the product and shared value strategies.

After-sales and sustainable purchasing are directly linked to SCM. After-sale strategies need to be linked to product development strategies, creating channels for use and disposal of primary packing, followed by channels for obsolete product disposal, supporting customer engagement, ensuring consumer privacy, trust, and satisfaction, and enhancing collaboration with suppliers (Porter & Kramer, 2006; Subramoniam et al., 2009; Bai & Sarkis, 2010, Gavronski, 2012).

The sustainable purchasing evolution can be summarized by: At Level 1, defining requirements to ensure compliance and conformity and reducing internal operational costs and risks; at Level 2, establishing sustainability policies for minimizing environmental impacts and improving resource efficiency; at Level 3, enhancing suppliers' local network, and defining new material and resource acquisition criteria based on LCA data; at Level 4, alignment with corporate social responsibility social and ethical principles, defined and communicated through a code of conduct; at Level 5, training and support, enhancing longer and closer relationships, defining a set of good business practices and processes considering the value chain and society, as well as promoting industry cooperative efforts (UNEP, 2009; Bjorklund, 2010; Bai & Sarkis, 2010, Sarkis et al., 2010; Miemczyk et al., 2012).

Operations' maturity can be linked with the Sustainable production evolution, described on Exhibit 6, and complemented by the work of Nidumolu et al. (2009), Johansson & Winroth (2010), Drake & Spinler (2012), and Beuren et al. (2013). Operations' maturity goes from internal compliance and conformity to innovation, based on continuous improvement processes.

Firm infrastructure is represented by the evolution of Corporate Social Responsibility, Exhibit 9, Business sustainability, Exhibit 7, Project management, Exhibit 12, and the Finance function on Exhibit 13. Firm infrastructure maturity goes from a responsive to a strategic approach, as describe by Lee & Saen (2011).

Technology development maturity goes from: (1) supporting compliance and conformance in internal operations and facilities; (2) enhancing operations eco-efficiency (e.g., reducing toxic emissions); (3) choices for cleaner and lean production; (4) supporting channels for supplier, customer, and stakeholder engagement; (5) creating an infrastructure for information flow throughout the value chain, and establishing a platform for innovation and new types of collaboration integrating the value chain, the customer needs, and a product-service system, and designing renewable energy source systems (UNEP, 2009; Drake & Spinler, 2013).

A model for human resources evolution is described in Exhibit 10. Requirements for marketing and sales can be identified in some of the analyzed models, because sustainable marketing capabilities support strategies across the entire value chain, For example: At Level 1, identifying customer expectations and regulatory requirements for product development; at Level 2, defining a sustainable products portfolio; at Level 3, developing a marketing strategy and position based on sustainability business cases, and production and marketing linked in the product development processes; at Level 4, customer engagement used as a driver of new value creation and to identify new opportunities. Establishing sustainability criteria for new product development; and, at Level 5, reporting sustainability results to stakeholders and society and exploring sustainability opportunities for new product-service systems.

### 5.3 Generic goals and practices

According to the CMMI (SEI, 2010), generic goals are considered required components, i.e. they represent what the company must do to implement a process area. Figure 8 shows the proposed framework, relating the process areas, objectives, and generic practices.

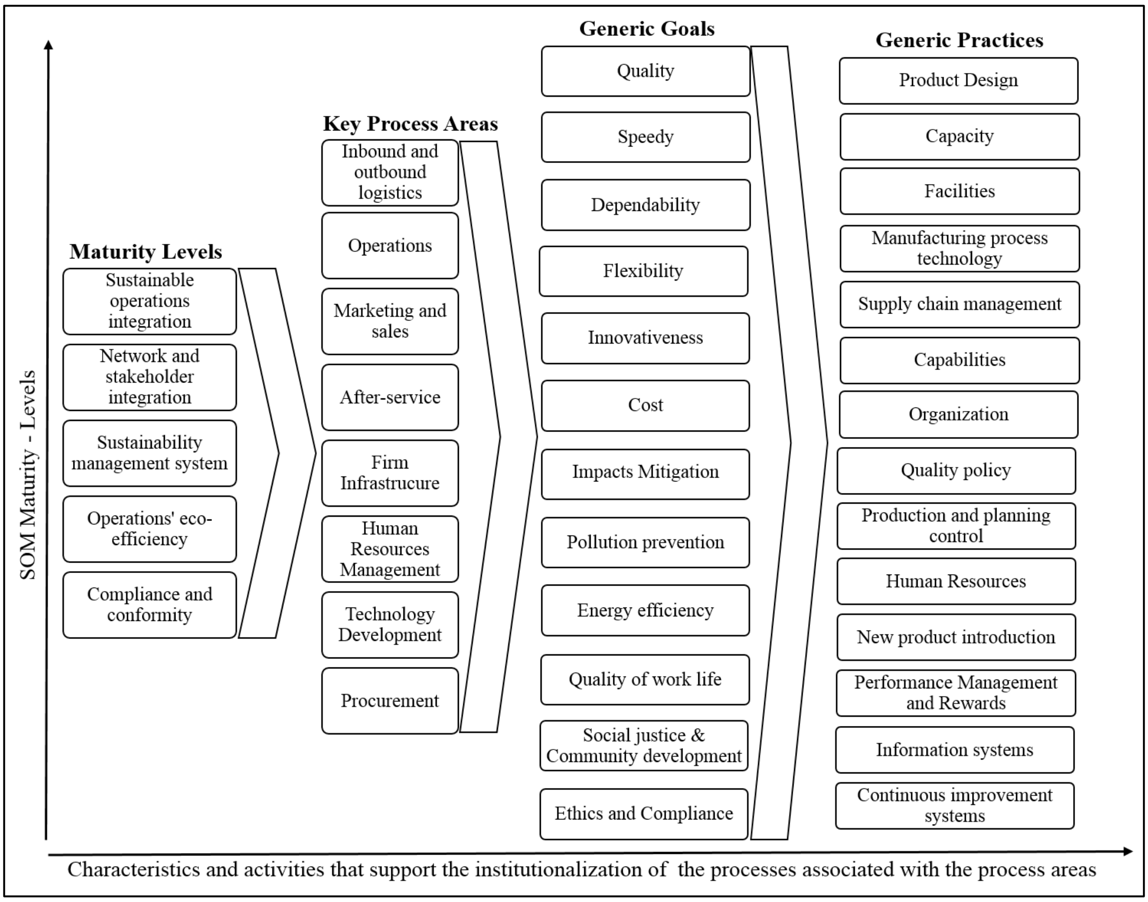


Figure 8 - Maturity Framework – Generic Goals and Practices' context.

Adapted to the context of the management of sustainable operations, performance dimensions represent the generic goals associated with the value chain processes. However, objectives related to the dimensions of sustainability were added. Thus, listed in Exhibit 3 are the guidelines originating from the generic goals that should be associated with the key process areas.

| Performance Dimensions | Dimension | Orientation |
|---|---|---|
| Quality | Economic | Doing the activities right |
| Speedy | | Doing the activities faster |
| Dependability | | Doing the activities on time |
| Flexibility | | Able to change the activities |
| Innovativeness | | Able to produce unique products |
| Cost | | Doing the activities with low costs |
| Impact mitigation on ecosystems (water, air, soil) | Environmental | Doing the activities reducing input and output impact related to manufacturing and product development. |
| Pollution prevention | | Doing the activities reducing or eliminating waste, reducing greenhouse gas emissions, using non-toxic or less-toxic substances, promoting materials reuse, remanufacturing or recycling. |
| Energy efficiency | | Doing the activities reducing energy consumption and using renewable energy sources |
| Quality of work life | Social | Doing the activities in healthy, safe, and decent conditions. Maintaining and improving human capital. |
| Social justice & community development | | Ensuring the respect of human rights, eliminate child and forced labor. Enhancing diversity, equality, and non-discrimination. Doing the activities ensuring the collective rights of local communities. |
| Ethics and compliance | | Doing the activities in compliance, promoting anti-corruption actions, avoiding anti-competitive behavior. Doing the activities in a transparent manner. |

Exhibit 3 – Orientation for generic goals
Sources: Pinheiro de Lima et al. (2008), GRI (2014)

In the CMMI model (SEI, 2010), the generic practices are expected components, i.e. they represent the description of the processes that satisfy the generic goals and contribute to the institutionalization of the processes associated with a process area. In the proposed framework, the decision areas take on the role of generic practices, i.e. adding principles of sustainability to the traditional context, the decisions areas should contribute to meeting the performance dimensions. Thus, the relationships listed in Exhibits 4.1- 4.12 were established:

| Performance Dimensions | Key decision areas | Orientation |
|---|---|---|
| Quality | Quality policies | Quality policies, models, systems, processes, techniques, procedures, and tools. Implementation of ISO 14000, and OHSAS 18001. |
| | Continuous improvement systems | Manufacturing operations processes continuous improvement system, processes and procedures development. Environmental concerns promote improvement in operations. |
| | Information system | Data and information acquisition, analysis, and use processes and systems. |
| | Supply chain management (vertical integration) | Assessments socioenvironmental performance. Support suppliers regarding environmentally-conscious manufacturing or even invest in direct involvement activities at the supplier. |

Exhibit 4.1 – Decision areas related to quality performance dimension
Source: Adapted from Pinheiro de Lima et al. (2008); Johnsson & Winroth (2010).

| Performance Dimensions | Key decision areas | Orientation |
|---|---|---|
| Speedy | Capacity | Shift work management, temporary labor subcontracting policies. |
| | Production planning and control | Materials and production planning and control system, supporting optimized processes. Reduce environmental waste and support remanufacturing processes. |

Exhibit 4.2 – Decision areas related to speedy performance dimension
Source: Adapted from Pinheiro de Lima et al. (2008); Johnsson & Winroth (2010).

| Performance Dimensions | Key decision areas | Orientation |
|---|---|---|
| Dependability | Production planning and control | Materials and production planning and control system, supporting optimized processes. Reduce environmental waste and support remanufacturing processes. |
| | Manufacturing process technology | Automation level, technology selection, layout, maintenance policy, internal process development capability. |

Exhibit 4.3 – Decision areas related to dependability performance dimension
Source: Adapted from Pinheiro de Lima et al. (2008); Johnsson & Winroth (2010).

| Performance Dimensions | Key decision areas | Orientation |
|---|---|---|
| Flexibility | Capacity | Capacity flexibility. Match capacity at multiple manufacturing facilities as a response to environmental demands |
| | Supply chain management (vertical integration) | Make-versus-buy strategic decisions, suppliers' dependence levels. Consider environmental and social issues within the entire supply chain. New supplier relationships may be necessary. |
| | Information system | Data and information acquisition, analysis, and use processes and systems. |

Exhibit 4.4 – Decision areas related to flexibility performance dimension
Source: Adapted from Pinheiro de Lima et al. (2008); Johnsson & Winroth (2010).

| Performance Dimensions | Key decision areas | Orientation |
|---|---|---|
| Innovativeness | Product Design | Design for sustainability – meet consumer needs with less resources. |
| | Capabilities | Manufacturing vision, development paths, and best practices. |
| | Organization | Intensified senior management support and guidance. Roles-responsibilities-autonomy; communication and learning processes. |
| | New products introduction | Manufacturing and assembly design directives. Product development cycles and matrix. |

Exhibit 4.5 – Decision areas related to innovativeness performance dimension
Source: Adapted from Pinheiro de Lima et al. (2008); Johnsson & Winroth (2010).

| Performance Dimensions | Key decision areas | Orientation |
|---|---|---|
| Cost | Manufacturing process technology | Automation level, technology selection, layout, maintenance policy. |
| | Facilities | Size, localization, and manufacturing resource 'focus.' Local and regional environmental regulations may affect the cost structure of the manufacturing facility. The balance between the need to be close to customers and close to material suppliers may be affected by costs related to environmental issues. |

Exhibit 4.6 – Decision areas related to cost performance dimension
Source: Adapted from Pinheiro de Lima et al. (2008); Johnsson & Winroth (2010).

| Performance Dimensions | Key decision areas | Orientation |
|---|---|---|
| Impact mitigation on ecosystems (water, air, soil) | Quality policies | Environmental concern may trigger the capture of different improvement potentials in the operations. Customer safety. |
| | Supply chain management (vertical integration) | The degree of vertical integration is affected by the environmental demands. Suppliers and procurement policies. |
| | Manufacturing process technology | New or modified process technology and equipment based on cleaner production criteria. |
| | Product Design | Design for recycling, disassembly, and remanufacturing. |

Exhibit 4.7 – Decision areas related to impact mitigation on ecosystems performance dimension
Source: Adapted from Pinheiro de Lima et al. (2008); Johnsson & Winroth (2010).

| Performance Dimensions | Key decision areas | Orientation |
|---|---|---|
| Pollution prevention | Facilities | Local and regional environmental regulation compliance. Changes supporting compliance and eco-efficiency processes |
| | New products introduction | Manufacturing and assembly design directives based on LCA data. |

Exhibit 4.8 – Decision areas related to pollution prevention performance dimension
Source: Adapted from Pinheiro de Lima et al. (2008); Johnsson & Winroth (2010).

| Performance Dimensions | Key decision areas | Orientation |
|---|---|---|
| Energy efficiency | Facilities | Layout aspects to improve energy efficiency. |
| | Manufacturing process technology | Automation level, technology selection. |
| | Capabilities | Manufacturing vision, development paths, and best practices. |

Exhibit 4.9 – Decision areas related to energy efficiency performance dimension
Source: Adapted from Pinheiro de Lima et al. (2008); Johnsson & Winroth (2010).

| Performance Dimensions | Key decision areas | Orientation |
|---|---|---|
| Quality of work life | Quality | Ensure safe and healthy operations |
| | Human resources | Organizational culture (a cultural change may be needed), leadership, and management styles. Reward policies. Competencies management model. Encourage employees to take an active part in the integration of environmental concerns in the operations. |

Exhibit 4.10 – Decision areas related to quality of work life performance dimension
Source: Adapted from Pinheiro de Lima et al. (2008); Johnsson & Winroth (2010).

| Performance Dimensions | Key decision areas | Orientation |
|---|---|---|
| Social justice & community development | Organization | Structure, organizational and management processes, roles-responsibilities-autonomy; communication and learning processes. |
| | Human Resources | Recruitment, training, and development policies. |

Exhibit 4.11 – Decision areas related to social justice & community development performance dimension
Source: Adapted from Pinheiro de Lima et al. (2008); Johnsson & Winroth (2010).

| Performance Dimensions | Key decision areas | Orientation |
|---|---|---|
| Ethics and compliance | Organization | Intensified senior management support and guidance. Structure, organizational and management processes, levels of centralization/ decentralization; planning and control systems; roles-responsibilities-autonomy; communication and learning processes. Cross-functional cooperation initiatives involving different competencies within as well as between companies. |

Exhibit 4.12 – Decision areas related to ethics and compliance performance dimension
Source: Adapted from Pinheiro de Lima et al. (2008); Johnsson & Winroth (2010).

Consequently, it appears that the framework includes the two emerging approaches described by Nunes et al. (2013) for sustainable operations: (1) focused on the decision making processes - adding sustainability criteria to the strategic decisions in OM; (2) adoption of SOM practices, linking green operations and CSR initiatives.

### 5.5 Additional orientation

The clusters identified, following the evaluation of the experts, point to the complementarity between specific practices. Thus, it is believed that the company can direct its teams and efforts to integrate sustainability into five major areas: Sustainable Product Design (based on Cradle-to-Cradle methodology) (Cluster 1); Sustainable and Lean Production (Cluster 2); Corporate Social Responsibility (Cluster 3); Stakeholder integration into decision processes (Cluster 4); and, Marketing and ICT-Information and Communication Technology (Cluster 5).

The integration of these areas requires business model changes. Machado et al. (2014b) provided some orientation for this: (1) address sustainability in an explicit, coordinated, and integrated way, considering the entire value chain; (2) define aspirations and goals for sustainability, moving beyond incremental change; (3) adapt the performance management model for a comprehensive model including all stakeholders; (4) develop proactive approaches to anticipate change in the regulatory regime; (5) invest in training for managers, improving internal awareness and establishing links between remuneration and sustainability performance indicators; (5) incentivize innovation programs in the value chain, strengthening RL strategies and consolidating CLSC, as well as adopting LCA strategies for product design and production processes. Define strong links between sustainability practices and economic performance including tangible and non-tangible results (e.g., financial indicators, productivity results, and reputation). Sustainability business case recommendations can be found in Schaltegger et al. (2012) and IFC (2012).

## 6. Conclusion

In answer to the research question, in the area of sustainable operations management, maturity models have been developed for specific purposes, e.g., sustainable production, sustainable supply chain management, corporate social responsibility, and life cycle management. However, the lack of models that look at sustainability through the evolution of sustainable operations capabilities in an integrated way was verified.

The findings pointed out that there is an evolutionary path, which goes from an initial approach focused on compliance and a firm's value protection, to an innovative approach, based on corporate social responsibility supporting operations integration into a sustainable system, and long-term value development.

The proposed framework does not intend to be an instrument for implementing sustainability in itself, but together with the norms and guidelines for sustainability and other initiatives, form an integrated sustainability management system that involves the company and its value chain, extending the results and actions to all of society.

The five levels represent an evolving and cumulative process of practices and experiences that propel a company to seek standards of excellence in operations with a focus on long-term gains, innovation, and continuous improvement.

Inside companies, it is understood that there are areas and processes at different stages of evolution. The objective then, should be to direct efforts assertively to promote the strategic alignment of operations at the company to reach a superior standard of sustainability management.

The framework application can be used to guide the strategy, auditing of sustainability, or to support the development of a sustainable performance management system.

For future research, we recommend a survey with a significant number of companies recognized for their sustainability approach, or the conducting of in-depth case studies. Thus, new emerging results will be faced with the refinement of this conceptual framework and integrating theory and practice.

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**Appendix 1**

| Model | Reference |
|---|---|
| Indicators of sustainable production - LCSP | Veleva et al. (2001)<br>Veleva and Ellenbecker (2001) |
| Business Sustainability Maturity Model - PREST | Cagnin et al. (2005) |
| Assessing the sustainability performances of industries | Labuschagne et al. (2005) |
| Sustainable Operations Management | Kleindorfer et al. (2005) |
| The Next Sustainability Wave | Willard (2005) |
| The Corporate Responsibility and Sustainability Capability Maturity Model | CSRQUEST (2005) |
| Sustainability stages in business* | IBGC (2007) |
| A Maturity Model for the Strategic Design of Sustainable Supply Network | Kirkwood et al. (2008) |
| Sustainable Enterprise Maturity Model / Sustainability's Staying Power - The Results Group | Schneiderman (2008) |
| Sustainability as Corporate Strategy | Nidumolu et al. (2009) |
| Atos’s Sustainability Maturity Assessment Model | SAP (2009) |
| The Sustainability Management Maturity Model: Version 2.0 - FairRidge Group | Scott (2009) |
| The GAIA Supply Chain Sustainability Maturity Model | Boone et al. (2009) |
| A Maturity Model for Integrating Sustainability in Projects and Project Management | Silvius and Schipper (2010) |
| CMMI | SEI (2010) |
| The Strategic Management Maturity Model/ Link Sustainability to Corporate Strategy Using the Balanced Scorecard | Rhom and Montgomery (2010) |
| Developing a Sustainability Manufacturing Maturity Model | Mani et al. (2010) |
| Sustainability in business today: A cross-industry view | Deloitte (2010) |
| Redesigning Business Value: A Roadmap for Sustainable Consumption | WEF and Deloitte (2010) |
| Maturity level towards sustained success* | ISO 9004:2010 |
| Maturity progression model for sustainable supply chains* | Reefke et al. (2010) |
| Creating a better future with the right Business Sustainability Management Framework | von Rosing and von Scheel (2010) |
| Sustainability Maturity Model (IRI) | Hynds et al. (2011) |
| Life Cycle Management Capability Maturity Project - UNEP/SETAC | Swarr et al. (2011) |
| A Research Report by SHRM, BSR and Aurosoorya - Society for Human Resource Management | Cohen et al. (2011) |
| Sustainability: Moving from compliance to leadership (PWC) | Baya and Gruman (2011) |
| Corporate Responsibility and Sustainability | Ainsbury and Grayson (2012) |
| Integrating Sustainability with Corporate Strategy: A Maturity Model for the Finance Function | Campbell et al. (2012) |
| ERP and sustainability | Sustainable dynamics (2013) |

Exhibit 5 – Set of documents for content analysis
* not considered for the networks’ development

## Appendix 2

| References: Veleva et al. (2001); Veleva and Ellenbecker (2001); Kleindorfer et al. (2005); von Rosing and. Scheel (2010); Brandt et al. (2011); Sustainable dynamics (2012) | | |
|---|---|---|
| | Internal | External |
| Level 1 | Focused on internal operations and based on compliance with regulations and conformity with industry standards. Starting with understanding which processes/activities are connected with sustainability. Green process would be ad hoc. | Suppliers' policies driven by specific regulations and directives. |
| Level 2 | Focused on efficiency and productivity of a facility with extended compliance based on green processes. | Extended compliance for key suppliers (inbound and outbound) with supplier assessment of supplier's Sustainability and OH&S policies. Key suppliers are engaged in product design that relate to trade-offs of materials and processes, guided by sustainability and environmental responsibility. |
| Level 3 | Managing and reducing impacts of design and production. Identifying triggers to move from a tactical approach to a strategic one supported by management systems (e.g. ISO standards). Established cleaner production capabilities. LCA are used to assess overall environmental impact. | Sustainability policies established for supplier selection (inbound and outbound). Defined green supply chain management. |
| Level 4 | Defined strategic sustainability policy. Defined sustainability process in product design and operations (based on LCA studies). Leader in innovation in design for sustainability (D4S). Integrated Management System. | Closed loop supply chain management involving the entire value-chain. Suppliers engaged in the eco-design process. |
| Level 5 | Defined the new business model. Continuous improvement of sustainability through innovation. The effects on the long-term quality of life and human development within the ecological capacity might measure production. | Suppliers' engagement innovation based on new types of partnership or collaboration. |

Exhibit 6- Maturity models for sustainable production

| References: PREST (2005); Cagnin et al. (2005); Willard (2005); AMR (2008); Schneiderman (2008); Atos (2008); Johnson (2009); Nidumolu et al. (2009); Rhom and Montgmery (2010); SEI (2010); Park and Pavlosky (2010); Deloitte (2010); ISO 9004: 2010 | | |
|---|---|---|
| | Internal | External |
| Level 1 | Initial motivations relating sustainability and strategy based on compliance and conformity with regulations and industry standards. Process managed ad hoc and reactively. Basic processes. End-of-pipe solutions. | Drivers for partnerships are price and cost reduction. |
| Level 2 | Processes planed and executed in accordance with policy but do not have a formal sustainability function. Focus on customers and regulatory requirements. Initial efforts for green product design. Reduce impacts with better of use of materials and natural resources. | Sustainability starts to integrate operations and processes across the value chain in an isolated way focused on compliance, license to operate, reduction of reputational risk and efficiency. Relevant stakeholders are involved and monitored. Driver for partnerships is process efficiency. |
| Level 3 | Idea for integration. Formal sustainability department. Standards driven sustainability formal structures and processes, and sustainable product design. Defined sustainability business cases based on eco-efficiency. Focus on people engagement and training. Sustainable products portfolio. | Structuring new stakeholder types of collaboration and extending existing ones. Driver for partnerships is quality. |
| Level 4 | Sustainability linked with strategic goals and strategies and new business model development based on innovation. Quantitative measures for quality and process performance. Operational processes and activities are autonomous and flexible. Use of renewable resources. Continuous improvement is emphasized. Governance structure is supported by the right infrastructure. | New values defined across the value chain. Balancing the needs of identified interested parties. Driver for partnerships is social-environmental existing impact, focused on values and capabilities creating ‘multi-dimensional’ communities. |
| Level 5 | Sustainability integrated into all aspects of the business and managed through change management and process improvement. | Balancing the needs of emerging parties. Stakeholders engagement in the decision making process. Driver for partnership is mutual collaboration from a long-term perspective. |

Exhibit 7 - Maturity Model for business sustainability

| References: Kleindorfer et al. (2005); Kirkwood et al. (2008); Reefke et al. (2010); Porteous et al. (2012) | |
|---|---|
| Level 1 | Alignment of customer requirements and strategy, considering the impacts in the full lifecycle of product and basic level of compliance and conformity with regulations and industry standards. TQM and JIT applied to developing new products and managing supply chain. |
| Level 2 | Full compliance and conformity with regulations and industry standards. Defined sustainability goals and full integration across the supply network. Optimized logistics with Efficient Consumer Response (ECR) between producers and distributors. |
| Level 3 | LCM establish throughout the value chain and performance management system extended for the supply chain. Customer Relationship Management implemented. |
| Level 4 | Full sustainability integration into value chain including the TBL elements and governance. Triggers to reactive to proactive measures. Transition from lean operations-lean enterprises- lean consumption. |
| Level 5 and 6 | Integration of profit and efficiency with considerations of external stakeholders and environmental impact. Process management based on continuous improvement and supply chain collaboration embracing sustainability leadership. Sustainable R&D programs established through value-chain. Corporative engagement in the development of national and global regulatory and fiscal standards. Consolidate green product and process development; lean and green OM, and remanufacturing and closed-loop supply chains. |

Exhibit 8 - Maturity models for sustainable supply chain management

| References: CSRQUEST (2005); Labuschagne et al. (2005); GESE (2007); Grayson (2012) | | |
|---|---|---|
| | Internal | External |
| Level 1 | The company accepts its business responsibility and defines corporate sustainability policies. Compliance with regulations and industry standards. | |
| Level 2 | Compliance with regulations and Corporate Sustainability methodologies including operational and societal activities. | Extended compliance to supply chain management. |
| Level 3 | Full Corporate Sustainability integration including process, system, and services integration. Strong links between sustainable development and commercial success based on eco-efficiency, risk management and reputation. | Suppliers audits |
| Level 4 | Compliance with all Corporate Sustainability policies and reports. Sustainability is considered key business strategy and the business case is extended to the value chain. Shared value strategies. | Shared knowledge with suppliers. |
| Level 5 | New business model defined. | Collaborative partnerships with different players including suppliers, NGO's, Universities etc. |

Exhibit 9 - Maturity model for corporate sustainability and responsibility

| References: Cohen et al. (2011) | |
|---|---|
| Level 1 | Compliance with socio-environmental regulations and codes of conduct. |
| Level 2 | Integration of environmental, social, and governance drivers into operations. |
| Level 3 | Business model and processes redesigned considering socio-environmental factors. |

Exhibit 10 - Maturity model for human resources management

| References: Swarr et al. (2011) | |
|---|---|
| Level 1 | (Project) – compliance trade-offs in the process outputs. |
| Level 2 | (Enterprise) – rules-based trade-offs in process inputs and outputs guided by eco-efficiency. |
| Level 3 | (Value chain) – fact-based trade-offs integrated across value chain. |
| Level 4 | (Society) - value-based trade-offs to achieve company and society goals. |

Exhibit 11 - Maturity model for life cycle management

| References: Silvius et al. (2010) | |
|---|---|
| Level 1 | Sustainability is not considered. |
| Level 2 | More sustainable business processes. |
| Level 3 | New business model. |
| Level 4 | New design considered for products and services. |

Exhibit 12 - Maturity model for project management

| References: Campbell et al. (2012) | |
|---|---|
| Level 1 | Sustainability is not considered in the risk-management portfolio. |
| Level 2 | Reactive considering short-term financial trade-offs. |
| Level 3 | Initial connections between sustainability outcomes and long-run financial performance. |
| Level 4 | Strong links between sustainability, strategic goals, and long-term financial performance. Sustainability is included in the risk-management portfolio. |

Exhibit 13 - Maturity model for finance function

| References: WEF and Deloitte (2010) | |
|---|---|
| Level 1 | Sustainability strategy is integrated into business. |
| Level 2 | New business model’s development. |
| Level 3 | Sustainability is integrated across the entire value chain. |
| Level 4 | Establish new balanced system based on innovation and new values for all stakeholders. |

Exhibit 14 - Maturity model for sustainable consumption

**Appendix 3**

| | **Managerial** | **Capabilities** |
|---|---|---|
| Level 1 | • Regulatory Compliance; Legal and regulations; Obligation - do the minimum; Binary yes-no compliance; External driver and regulations<br>• Baseline resource utilization; No formal research process<br>• Internal human resources; Diversity regulation<br>• Sustainability not considered in risk-management portfolio; Value protection<br>• Initial management implementation<br>• Operational process and business strategies are not linked; Ad hoc processes; Inertia of organization<br>• Suppliers – specific regulations and directives; Auditing function | • OH&S<br>• Few support tools – technology is not a priority<br>• Initial understanding of LCA<br>• Reduce pollution; Toxic release inventory; Greenhouse gas control (GHG)<br>• Waste minimization |
| Level 2 | • Operational processes are structured; Operations measure-monitor the efficiency<br>• Reactive problem solving – resource utilization; Tactical approach<br>• Alignment value stream<br>• Supply chain – sustainable design; manufacturing practices of suppliers; Labor practices of suppliers; Diversity<br>• Information for general support; Stand-alone claims<br>• Customers' requirements and expectation; Consumer engagement – end-of-life treatment<br>• Sustainable product design; Green product design<br>• Corporate sustainability methodologies followed; Internal trust; Organizational change<br>• Good communication – regulatory and policy issues; Sustainability reports | • Knowledge Management<br>• Data-based (Technology) – decision process/interface concepts<br>• Eco-efficiency; Functional integration<br>• LCA considered in NPD process – reduce manufacturing impact; LCA for some products<br>• Establish management systems; OH&S policy and training; Few improvement models; TQM – repeatable; SIX SIGMA; Metrics for inputs/outputs<br>• Reporting metrics (emissions, energy consumed, toxic inventory, occupational injuries) |
| Level 3 | • Anticipate new regulations; Beyond compliance<br>• Integration - Sustainability vision; Align business strategy and workforce competencies; Employee accountability; Internal integration – network governance<br>• Sustainability capability – organization-wide understanding related activities, roles, and responsibilities; Operations' sustainability<br>• Consolidation processes – consistent implementation-defined process – formal; Process change; Process improvement<br>• Facility – economic viability, environmental effects/ worker, and public health<br>• Industrial process innovation<br>• Defined strategic marketing & positioning | • Change in specific local resources; Coordinate resources<br>• Energy efficiency and waste minimization; Prevention; Using renewable resources<br>• Risk Management; Carbon footprint analysis and reduction goals<br>• Sustainable design; Improve tools and management systems for product design; DfE; Develop eco-friendly raw materials<br>• Technology-information-based; Formal sustainability data<br>• Innovate technology – value chain<br>• LCM; Life Cycle Cost;<br>• Product Quality; TQM; Standardized<br>• Lean and green operations; Just in time |

| | | |
|---|---|---|
| | • Economic viability; Improve business efficiency<br>• External trust; Industry collaboration<br>• Value chain sustainable; Defined supply/partner integration strategy; Suppliers – EHS policies<br>• Community development | • Closed-loop system<br>• CRM |
| Level 4 | • Sustainability; Integrating sustainability; Aligned- vision, customer needs, strategy, employee reward, recognition system; Shared vision and best practices<br>• External sustainable development objectives; Macro-social performance<br>• Information – strategic resource<br>• Profitability leadership; Economic sustainability; Growth leadership; Excellence at corporate level<br>• Innovation strategy – service, product, process and activities, technology)<br>• Sustainable Governance – transparency<br>• Supplier's regional network; Logistics; Value-chain partners – performance reviewed; Network development – suppliers policies<br>• New regulatory requirements<br>• Sustainability goals – quantified and measured – accountability for sustainable performance – improve focus and performance; | • Communication – technological channels in use (stakeholder engagement/dialogue)<br>• Improving technologies<br>• Cradle-to-grave integrated across value chain<br>• LCA; Supply chain- LCA and costs of energy and carbon; Quantitative metrics<br>• Eco-labels<br>• Cross-functional planning teams; Focus on controlling multiple activities<br>• Flexible process/activities/ infrastructure to information flow through the firm/communication<br>• Renewable resources; Energy supply; Carbon cost |
| Level 5 | • Integrated strategy; Cross enterprise collaboration; Sustainable systems; Partnership between business, customers, and government<br>• Reflect true cost of resources in all pricing decision of resources<br>• Vision and values fully integrated into organization culture<br>• Sustainable value chain innovation; Suppliers aligned with global initiatives<br>• Increasing value; Shift from product to service<br>• Innovative business – leader in innovation in design for manufacturing to reduce life-cycle environmental impact<br>• Resiliency<br>• Influence business decisions<br>• Global Report Initiative – annual report<br>• Proactive; Collaborative – regulatory and legislative compliance<br>• Sustainable communities development; Global and local communities quality of life | • Design teams work with suppliers and customers to develop materials; Zero waste; Continuous improving and learning<br>• Human health metrics; Qualitative metrics<br>• Technology – cooperative sustainability net<br>• Contributions to LCA inventory databases and registered and approved by third party; NPD processes use sustainability at each phase<br>• Leading in Integrated Management System |

Exhibit 15 – Networks Atlas ti - Decision Areas

| | Managerial | Capabilities |
|---|---|---|
| Level 1 | • External requirements and regulations<br>• Regulatory compliance; Conformance; Governments regulations; Environmental regulation; Legal requirements<br>• Value protection | • Few support tools (technology)<br>• OH&S; EMS<br>• Initial understanding of LCA<br>• Greenhouse gas control (GHG) |
| Level 2 | • Comply with requirements; Corporate obligation<br>• Operational efficiency; Efficient use of resources<br>• Large-scale impacts of industry<br>• Sustainable product design; Manufacturing practices of suppliers<br>• Competitive advantage; Sustainable Business case for internal operations<br>• Customer expectation; Customer engagement | • Six Sigma; Lean; Lead Time<br>• TQM<br>• Metrics for inputs/outputs<br>• End-of-life treatment<br>• Develop greener products; LCA considered in NPD process – reduce manufacturing impact; Product specification |
| Level 3 | • Anticipate new regulations<br>• Selecting partnerships for new products and services<br>• Sustainable product design; Product design – suppliers are involved<br>• Control process focus – consolidation processes; Product Quality<br>• External trust; New markets; Consolidate sustainability vision<br>• Innovation adoption (manufacturing operations and facilities); Prevention x correction<br>• Customers satisfaction and engagement<br>• Corporate image – firm image; Market advantage | • Just in time; Lean and green operations<br>• LCM; Life cycle cost<br>• Improve tools and management systems for product design<br>• QMS; EMS; OH&S<br>• Carbon footprint<br>• Closed-loop system |
| Level 4 | • Formal supplier requirements and audits; Supply chain – LCM, cost of carbon and cost of energy<br>• Aligned – vision, customer needs, strategy, employee reward, recognition system<br>• Customer engagement as driver; Value creation; New opportunities<br>• Network development; Supplier's regional network | • Energy supply<br>• LCM<br>• Flexible process/activities/ infrastructure for information flow through the firm/communication |
| Level 5 | • Increase value – long-term value/innovation in value creation; sustainable business cases<br>• Integrated strategy; Integrated decision processes;<br>• Cross-enterprise collaboration; Connect to the regulators and policy makers<br>• Innovation<br>• Encourage personal accountability | • Renewable energy sources<br>• NPD processes use sustainability at each phase; Contributions to LCA inventory databases<br>• Leading in Integrated Management System; Performance management and continuous improvement<br>• Full DfE implementation; Design teams work with suppliers and customers to develop materials |

Exhibit 16 - Networks Atlas ti – Performance

# PAPER IV – CAPABILITIES' ORGANIZATION FOR SUSTAINABLE OPERATIONS MANAGEMENT

Carla Gonçalves Machado[a], Edson Pinheiro de Lima[ab], Sergio Eduardo Gouvea da Costa[ab], Luciana Rosa Leite [a], Rosana Adami Mattioda

[a] Industrial and Systems Engineering Graduate Program, Pontifical Catholic University of Parana, 80215-901 Curitiba, Brazil.

[b] Federal University of Technology - Parana, 80230-901 Curitiba, Brazil.

**Abstract**

*Purpose:* This paper seeks to verify the presence of a set of sustainable operations capabilities in manufacturing and infrastructure companies, and their level of implementation. Also, to identify strategic patterns for integration of sustainability into companies' value chain.

*Design/methodology/approach*: This is an exploratory/descriptive research, which was conducted with professionals belonging to companies recognized for their sustainability approach. To guide the analysis, a conceptual maturity framework for sustainable operations management was developed. The empirical data were analyzed via multivariate strategies and PLS method.

*Findings*: Sustainability integration can be deployed in six dimensions of sustainable operations capabilities. Evolutionary patterns about sustainability integration were identified. Two groups of companies emerged to confirm these patterns. PLS tests indicated that a deliberate strategy dovetailed with sustainability integration processes supported by upper-level management.

*Research limitations/implications*: The external generalization is limited. Findings are derived from a no probabilistic sample of professionals from companies that operate in Brazil. It is difficult to identify appropriate professionals to address the wide range of aspects considered.

*Practical implications*: Built on theoretical and empirical findings, the maturity framework for sustainable operations management is able to drive companies on the path of sustainability adoption and integration.

*Originality/value*: Findings indicate different maturity levels on the path toward becoming more sustainable companies. The results contribute to the field of operational management, since they reduce gaps related to models and frameworks to support sustainable operations management strategies and to incorporate sustainability into company operations.

*Keywords:* sustainable operations, maturity model, performance management, survey.

## 1. INTRODUCTION

Sustainability issues have increased the complexity of business decisions and strategies. According to Hasna (2010), sustainability is "an engineering responsibility." It is necessary to change the reductionist thinking of process mitigation and remediation in order to create new, cleaner, and more efficient processes that do not create pollution in the first place. Sustainability considers the system as a whole, across all its main doctrines (i.e., economic, political, social, cultural, institutional, technological, and spiritual), while sustainable development is the process of capital and economic management on a truly sustainable basis.

For Todorov and Marinova (2011), sustainable development requires that paradigms be reviewed and realistic solutions be created. The KPMG (2012) presents ten “sustainability megaforces” which function as a complex and unpredictable system that will affect businesses in many ways (e.g., bringing new regulations, changing consumer preferences; increasing resource constraints on production, increasing prices and volatility, and promoting physical and weather changes).

For Eccles et al. (2012), what differentiates sustainable companies from traditional ones is that the former engage with the needs of their stakeholders and collaborators and promote a culture of innovation and continuous transformational change. An organization should identify best practices in all the activities in its value chain, some of which will be reflected in a more proactive approach to address and mitigate problems, enabling competitive advantages and creating economic, environmental, and social value.

This type of scenario requires a new configuration of the operations model, which should consider the impact of all the activities involved in its value chain (Bakshi and Fiksel, 2003; Elkington, 2004; Ueda et al., 2009; KPMG, 2012; Nunes et al., 2013).

For Bettley and Burnley (2008), “sustainable operations management could become a core competence of the organization, and as such, a driver of business strategy rather than merely the vehicle for its implementation.” Achieving this goal requires new business models, the “total product system” perspective, the proper legal and regulatory regime, new performance objectives and indicators, and attention to the sustainability issues arising from the strategic decision areas. Thereby, for sustainability to be extended to the value chain, the operations management (OM) boundaries need to be expanded.

Gunasekaran and Spalanzani (2012) identified the main OM capabilities for a sustainable business: closed loop supply chain management (CLSC), green supply chain management (GSCM), a cradle-to-cradle methodology, green purchasing and procurement, carbon footprint mitigation, quality, environmental, and social system management, reverse logistics (RL) and remanufacturing/recycling, lean operations, life cycle assessment (LCA), corporate social responsibility (CSR), and ethics.

According to Nunes et al. (2013), two approaches have emerged from the literature on sustainable operations management (SOM): (1) a focus on decision-making processes, adding sustainability criteria to the strategic decisions in the OM; and (2) the adoption of SOM practices, linking green operations with CSR initiatives.

To Gavronski (2012), strategic decisions in the sustainable operations context require new categories, which must be integrated with the traditional ones of decision and value chain activities. The competitive dimensions should also incorporate sustainability issues. A set of capabilities and resources are proposed:

- Environmental: reduce, remanufacture, recycle, reuse, and dispose.
- Social: health, safety, diversity, and well-being.
- Economic: cost, quality, flexibility, delivery, and innovativeness.
- Sustainable operations value chain resources: pyramid base, design for disassembly, design for the environment, disassembly systems, environmental management systems, green logistics, worker health and safety, industrial ecology, life cycle analysis, pollution control and prevention, reverse logistics, recognition and sorting systems, and socially responsible sourcing.

To Veleva et al. (2001), an organization progresses from one degree of maturity to the next following a model based on total quality management; as a result, its behavior should progress according to its responsibility to nature and society in general.

According to Ferrer (2008), achieving sustainability requires adopting a continuous improvement approach with measureable performance objectives. Companies need to integrate the “components of sustainable operations”: total quality for products and processes, environmental protection, and total process safety. To the KPMG (2012), “Standards and regulations can promote sustainable practices on the production and supply side, such as standards for pollution control or energy standards.”

For over 30 years, companies have used maturity models as an instrument for improvement, contributing to the development of organizational capabilities in complex environments (Silvius and Schipper, 2010; van Looy et al., 2013).

Among the benefits that maturity models provide for management, Fraser et al. (2002) state that they help describe a company's behavior more objectively and simply, relating it to maturity levels for each aspect analyzed and thus identifying sets of best practices. Maturity models provide direction on how and where to start improvement processes, creating a foundation on which managers can develop activities and analyze their processes (SEI, 1995; Tesmer et al., 2011).

Maturity is defined as "full development" (Merriam-Webster, 2014). The Capability Maturity Model (CMM) defines as the extent to which a process is explicitly managed, defined, controlled, and effective (SEI, 1995). For Tesmer et al. (2011), maturity represents the company's ability to respond and adapt to circumstances appropriately.

Nascimento et al. (2013) synthesized the concept of maturity into three perspectives: maturation, moving from an early stage to an advanced stage over time (Sousa and Voss, 2001); capability, full development or a perfect condition for a process or activity (SEI, 2010); and evolution, whereby a process may go through intermediate stages until it reaches maturity (Lahti et al., 2009).

To Dao et al. (2011), the maturity of sustainable is achieved through the evolution and continuous evaluation of organizational resources and skills. It is thus assumed that the maturity of sustainable operations can be evaluated insofar as a company responds appropriately to the challenges of sustainability—by establishing effective processes that ensure the fulfillment of economic objectives while contributing to the improvement of environmental and social objectives throughout the value chain.

Pinheiro de Lima et al. (2012) found that maturity models have contributed to the development of capabilities and processes related to sustainable operations management. These models are related to some specific areas as: sustainable production; sustainable supply chain; CSR; sustainable product design; life cycle management; business sustainability maturity; energy; human resources; and, project management.

However, the literature also shows that there is a lack of models or frameworks to support SOM strategies in an integrated way, guided by a performance management system that allows an assessment of the level of sustainability integration (Liyanage, 2007).

To Lubin and Esty (2010), most sustainability initiatives are implemented in an isolated way, without a vision or plan. Park and Pavlovsky (2010) argued that companies that approach sustainability through *ad hoc* or isolated initiatives cannot achieve better results than companies pursuing an integrated approach. According to Parisi (2013), studies have not explicitly addressed how companies adopt sustainability performance measurement systems, which include social and environmental goals.

Survey reports from 2009 to 2014 point out that companies consider sustainability relevant for competitiveness; however there is a gap between the vision and action. One of the barriers cited is "*lack of a model for incorporating sustainability*" (Kiron et al., 2013b).

Pinheiro de Lima et al. (2012) observed that "maturity levels do exist and a trajectory of developed capabilities could be traced for a company and their operations networks". The challenge is to develop evaluation systems capable of identifying the starting point and evaluating the progress of the integration of sustainability into strategies and operations (Hannaes et al., 2011).

The present research aims to identify the level of implementation of sustainable operations practices in a sample of manufacturing/transformation and infrastructure companies. It also looks to verify the organization of a maturity framework for sustainable operations and the presence of strategic patterns for sustainability integration.

## 2. A MATURITY FRAMEWORK FOR SUSTAINABLE OPERATIONS

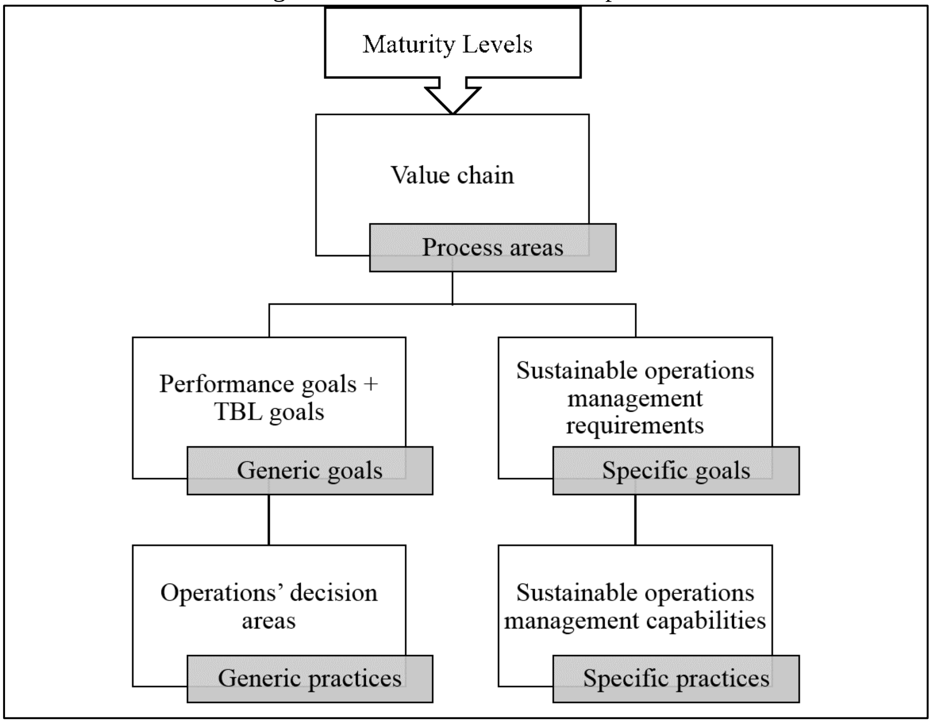
The issue of sustainability is complex and involves decisions related to various objectives and values. The move from a traditional resource-based economic vision to one that includes inter-organizational approaches and social innovation represents a high level of complexity in sustainability implementation (Ueda et al., 2009; van Bommel, 2011). To Silvius and Schipper (2010), maturity models help to " 'translate' complex concepts into organizational capabilities and to raise awareness for potential development."

As stated in Machado et al. (2015), a sustainable operations maturity framework was developed based on the emerging literature, case studies, and contributions from experts. Maturity in SOM can be understood as a sequence of capability improvement levels that enable the company to conduct its operations more sustainably.

Some elements of the Capability Maturity Model Integration – CMMI (SEI, 2010) were adapted for the operations management context, following directions provided by Bettley and Burnley (2008), Johansson and Winroth (2010), Dao et al. (2011), and Gavronski (2012), who all agree that sustainability issues must be integrated into the traditional operations' decision areas and performance goals.

Figure 1 presents the CMMI's element adaptation (CMMI elements are represented by the highlighted text box).

Figure 1 – CMMI's elements adaptation



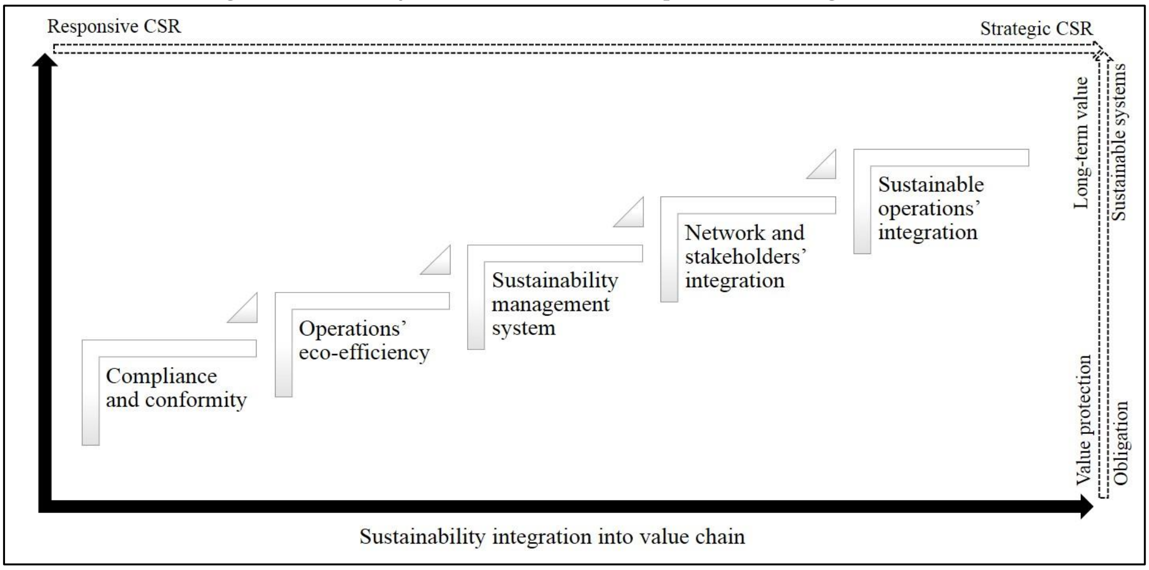

Source: Machado et al., 2015.

Performance and Triple Bottom Line goals are represented by market requirements related to sustainability, translated into the traditional goals of performance, representing economic dimensions (i.e., quality, speed, reliability, flexibility, innovation, cost) and into social and environmental performance goals (i.e., impact mitigation, pollution prevention, climate change, quality of work life, social justice and community development, ethics and compliance). The operation's decision areas represent the mobilization of organizational resources representing a set of policies and activities relevant to the fulfillment of the performance goals. The specific goals and practices represent the SOM capabilities implemented in the value chain and related processes.

Five evolutionary levels define the "content" of maturity according to the sustainable operations management theory (Figure 2). The levels represent an evolving and cumulative process of practices and experiences that propel a company to seek standards of excellence in operations with a focus on long-term gains, innovation, and continuous improvement.

The content for each level integrates SOM into the entire value chain, as described in Table 1.

Figure 2 – Maturity levels for sustainable operations management



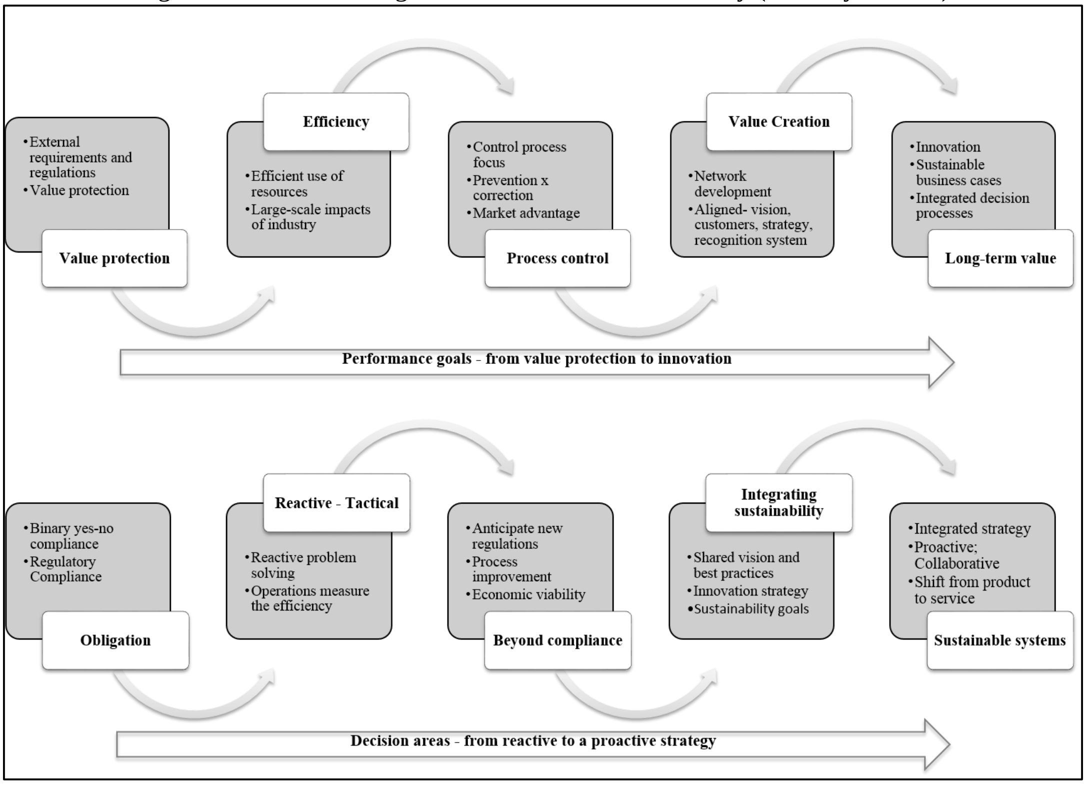

Source: Machado et al., 2015.

Table 1 – Maturity level context

| Level | Scope |
|---|---|
| Level 1 Compliance and conformity | Focused on obligations and responsibilities. The company's facility and internal operations need to be in compliance with general regulations and conform to specific industry requirements. In general, compliance and conformity are focused on all aspects related to permission to operate and environmental regulations, ensuring good labor conditions and human and children's rights. This focus should also be extended to key suppliers. This approach is reactive and important to the economic dimension since the company reduces risks with non-compliance, avoiding fines and operational restrictions. |
| Level 2 Operations eco-efficiency | Focused on ensuring efficiency and productivity in accordance with socio-environmental requirements, in addition to identifying and controlling all impacts that need to be reduced. Key suppliers must be included in product design, focusing on reducing impacts related to materials, natural resources, and carbon footprints. |
| Level 3 Sustainability management system | Socio-environmental capabilities become formalized, defined, and managed through continuous improvement and optimized processes. The company establishes formal processes for sustainable production and sustainable product design, focusing on customer demands. Eco-efficiency strategies are dedicated to energy efficiency and the use of renewable resources, including product design and manufacturing processes; when extended to the supply chain, eco-efficiency is focused on risk management, reducing the carbon footprint and establishing RL and CLSCS throughout the entire product life cycle. |
| Level 4 Network and stakeholder integration | Sustainability principles and processes are integrated across the value chain. Suppliers, customers, and other stakeholders engage and collaborate in the company's sustainability strategies and operations. |
| Level 5 Sustainable operations integration | A wide sustainability net is defined, based on an integrated management system established across the supply chain and guided by a new business model based on innovation, seeking more sustainable processes in a continuous improvement system. |

The model presented in Figure 2 also presents the evolutionary trajectory related to performance objectives and decision areas. The main objective of the generic goals and practices is to direct the evolution of SOM strategies and processes representing the unique characteristics of the sustainable operations implemented in value chain activities (see Figure 3).

Figure 3 – Performance goals and decision areas maturity (maturity content)

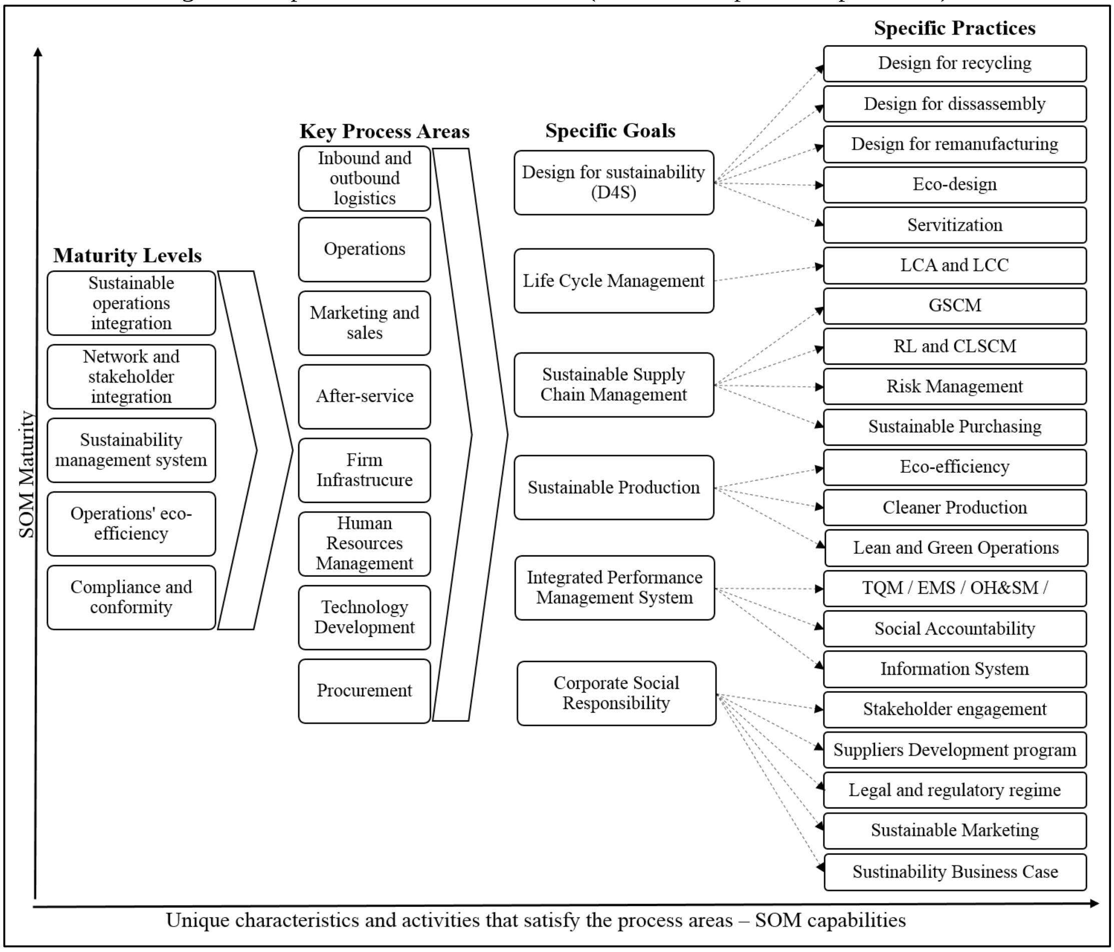



Thus, sustainable operations conducted in the value chain should be guided by performance objectives and strategic decisions that

1. initially, direct activities to meet regulatory requirements in order to meet mandatory business requirements;
2. then expand the objectives and decisions to include operational efficiency, considering all the impacts of the business processes;
3. lead the transition from tactical–reactive operations to a new management level based on process control, continuous improvement, and preventive rather than corrective strategies, creating an environment in which new regulations can be anticipated;
4. ensure that the strategic vision, performance objectives, and decision-making processes become the foundation for developing, engaging, and integrating the stakeholders, creating a network that shares visions and best practices guided by sustainability objectives and value creation;
5. and, allow sustainable operations management to be conducted in an integrated manner from the perspective of the value chain, generating sustainability business cases that clearly demonstrate the economic results aligned with socio-

environmental results and create an environment conducive to innovation and collaborative strategies between value chain participants and other stakeholders.

Figure 4 – Specific Goals and Practices (sustainable operations processes)




The proposed framework does not intend to be an instrument for implementing sustainability in itself but to help form an integrated sustainability management system along with the norms and guidelines for sustainability and other initiatives that involve the company and its value chain, extending the results and actions to all of society.

Companies understand that functions and processes occur at various stages of evolution. The objective should thus be to direct efforts assertively towards promoting the strategic alignment of operations in the company to reach a superior standard of sustainability management.

## 3. RESEARCH DESIGN

According to Forza (2002), a survey approach can consist of exploratory, confirmatory, or descriptive research. This study has exploratory characteristics, as research on maturity in sustainable operations management is in the early stages (Machado et al., 2012). More broadly, it can also be classified as descriptive survey research, focusing on understanding the relevance and patterns of sustainability management and describing how companies are dealing with sustainability challenges.

The goal was to identify the level of implementation of the sustainable operations practices in a sample of manufacturing/transformation and infrastructure companies in order to compare and refine the conceptual model. It was also considered important to verify the existence of a strategic pattern in sustainability integration, i.e., through "deliberate" or "emergent" strategies.

For Mintzberg (1995), a deliberate strategy issues from a strategic intent and is explicit and controlled by formal systems, defined by leadership. It appears in reaction to uncertain and complex environments, opportunities, unexpected threats and challenges, or even learning processes. By contrast, an emergent strategy results from actions or decisions, initially unplanned or unintended, that were implemented in isolation and became consistent over time. Both strategies result in a "conducted strategy"— a strategy that is actually followed, unlike "unconducted" strategies.

Below is a list of propositions that guided the development and analysis of the survey questionnaire, which were formulated throughout the process of developing the maturity framework for sustainable operations.

### *3.1. Propositions*

According to the data presented in the introductory section, such as that from Liyanage (2007), Machado et al. (2012), Kiron et al. (2013b), and Parisi (2013), research on maturity in SOM is in the early stages, and there are few models or frameworks to support SOM. According to Oppenheim (1992), formulating hypotheses may not be the best decision, as it is still impossible to have a broad knowledge of the phenomenon, and the variables that comprise it cannot be clearly determined.

It was thus decided to define a central question and a list of propositions drawn from case studies and the development of the conceptual model as described in the preliminary studies of Machado et al. (2014; 2015) and verify them using the collected data:

- RQ1. What are the sustainable operations capabilities and their respective implementation levels for a company manage its maturity evolution for sustainability integration?
- Proposition 1: Firms' operations strategies are developing a reactive–proactive pattern regarding sustainability aspects, adjusting their strategies and systems to be in compliance with socio-environmental requirements, developing a management component for their internal operations and expanding their policies to their supply chain or operations network.
- Proposition 2: The drivers of sustainability integration motivation do not differ significantly from the traditional strategic business drivers; their difference lies in their scope and motivation "power," which may vary according to the industry's maturity and how the companies' activities are connected to their environments.
- Proposition 3: Standards, sustainability reports, and voluntary commitments have been influencing and guiding sustainability integration; however, their requirements are not sufficient for creating a sustainably integrated management system or supporting their deployment at an operations level.
- Proposition 4: Sustainability is part of companies' strategic agenda, and their organizational design must be reviewed to develop the newly required competences, which not only focus on compliance and reporting demands but are oriented to integrating sustainability practices into their business model's competitive strategy.
- Proposition 5: the SOM's main capabilities can be viewed as complementary processes, which can be deployed and managed in an integrated manner:

➢ Dimension 1: Sustainable Life Product Management: LCA; D4S; RL and CLSC;

➢ Dimension 2: Sustainable Production: Lean and green process; Sustainable Purchasing; Eco-efficiency strategies; Cleaner Production; Quality and Environmental Management Systems;

➢ Dimension 3: Social Responsibility and Accountability: OH&S

management;

- Dimension 4: Value-chain integration: Suppliers Development Program; Stakeholder Engagement; Information System;
- Dimension 5: CSR: Sustainability Business Case; Sustainable Marketing.

- Proposition 6: The implementation/integration of sustainability is an emergent strategy with a reactive pattern, and, as the company's management processes mature, it evolves to a level of proactivity, represented by the definition of strategies and formal systems.

*3.2. Survey design and strategic decisions*

Data for this paper were collected during February and March 2015 using an online survey emailed to professionals working for manufacturing and infrastructure companies with operations in Brazil and from various sectors. The data were collected through an e-survey (internet-based survey) conducted using Qualtrics.

Klassen and Jacobs (2001) and Petchenik and Watermolen (2011) indicate that Web response rates are lower than rates for traditional survey models (i.e., mailed or paper-and-pencil surveys). According to Klassen and Jacobs (2001), "if Web surveys become commonplace, reviewer expectations for response rates may need to be adjusted downward from 20% (Malhotra and Grover, 1998) to possibly 10% (i.e. Web response rate was approximately half that of other technologies)."

To assess the construct of SOM capabilities, the questionnaire explores a range of issues related to the sustainable operations management context. The SOM issues were organized in six dimensions, presented in Proposition 6, based on studies by specialists (Machado et al., 2015).

The six dimensions encompass 93 statements, complemented by 16 initial questions related to the companies' contexts and respondent characteristics. The questions and statements were developed based on benchmarking using relevant sustainability surveys, including the Sustainability and Innovation Global Executive Study-MIT/BCG (Berns et al., 2009; Hannaes et al., 2011; Kiron et al., 2012; Kiron et al., 2013a,b), the sustainability maturity assessment tool (IRI, 2011), the High-performance Manufacturing Project 2012 (Schroeder; Flynn, 2001), and the EFQM 2010.

Each statement was associated with one of the three dimensions of the contextualist model of Pettigrew et al. (2012) and one of the SOM capabilities or aspects related to best practices and sustainable business models drawn from studies by Bettley and Burnley (2008), Nidumolu et al. (2009), WEF and BCG (2011), Eccles and Serafelm (2013), and Hannaes et al. (2011).

The emerging challenges for sustainability can be related to the drivers of the processes of organizational change (Stoughton and Ludema, 2012). The contextualist model of change proposed by Pettigrew et al. (2012) considers that the process of change in companies involves actions, reactions and interactions from and between the various parties of interest, involving multilevel and continuous processes (see Table 2).

Table 2 - Pettigrew´s approach

| Strategic Changes | Description |
|---|---|
| Content "What" of change | The content of the area of transformation, i.e., the content of the strategic change linked to the context inside and outside the company. |
| Context "Why" of change | Macro and microenvironment and political context in which the company operates, and through which the ideas of change will occur. |
| Process "How" of change | Identification and explanation of the process standards to demonstrate how the processes model the outcomes. |

Source – adapted from Pettigrew (1987) and Pettigrew et al, 2012.

Annual surveys conducted by the Massachusetts Institute of Technology and the Boston Consulting Group-MIT/BCG (Kiron et al., 2012, 2013a,b) have identified an evolutionary path for sustainability integration, which was considered relevant to the survey design and analysis. The MIT/BCG results showed four levels of sustainability integration: Embracers, where sustainability is seen as a condition for competitiveness; Harvesters, where operation frameworks and strategies are changed based on sustainable practices that add economic value to profits; Sustainability-driven Innovators, where the companies obtain profits from sustainability efforts and change business models to sustain profit generation; and Walkers, who address significant sustainability issues (material sustainability) as a way to mitigate threats and identify powerful new opportunities.

To evaluate the adoption/implementation level of practices, an unbalanced, itemized six-point Likert-type scale was used, with **0** corresponding to nonexistent practices and **1** to **5** reflecting the processes' maturity levels. The scale represents the "stage representation" applied in the CMM and CMMI models (SEI, 2010). Its application was verified in other studies, such as Gomes et al. (2010), Araujo and Rodrigues (2011), and SustainValue (2013).

According to the SEI (2010), using stage representation allows the processes' implementation level to be analyzed. Locating a particular practice at a certain level assumes the implementation of the same practice in previous levels. The scale adopted has the following levels: Nonexistent (0), Initial (1), Managed or Repeated (2), Defined (3), Quantitatively Managed (4), and Optimized (5).

To Frohlich (2002), a pre-test survey is important for improving scale readability, verifying the order of the questions, and removing ambiguous questions. A pre-test was conducted with a heterogeneous sample comprised of professionals in continuing education courses and companies that had participated in earlier stages of the research ($n \approx 150$). In all, 42 questionnaires were returned (28%), but only 20 (13%) were considered valid (i.e., were fully answered).

To evaluate internal consistency, the Cronbach's alpha coefficient was chosen to evaluate each block (dimension) of the questionnaire (Cronbach, 2004; Field, 2010). The first block of questions concerning the characterization of the company and respondent was not included in the evaluation. Table 3 presents the Cronbach's α for each dimension:

Table 3 – Cronbach's α pre-test

| Dimensions | Variables | Cronbach's α |
|---|---|---|
| Corporative Strategy | 18 | .987* |
| Process/Practices – Cluster 1 | 16 | .926* |
| Process/Practices – Cluster 2 | 18 | .924* |
| Process/Practices – Cluster 3 | 4 | .683 |
| Process/Practices – Cluster 4 | 12 | .885* |
| Process/Practices – Cluster 5 | 4 | .685 |

* Coefficient of .70 or higher is considered "acceptable" (Forza, 2002).

The lower rates in Groups 3 and 5 have been attributed to the low number of items evaluated. This factor was improved when the final questionnaire was compiled. However, as the results were close to the value indicated as acceptable by the literature (0.70), they were also considered acceptable for the pre-test.

The pre-test also pointed out the need for further improvements in the questionnaires, such as reordering/reallocating questions, removing redundant items, and providing more information about the contents of each block of items to be evaluated. The results also indicated that there could be difficulties in obtaining a significant return, given the broad scope of the questionnaire and of the topic of "sustainability," which is still considered incipient by some companies. To mitigate the problems related to the questionnaire's breadth, the respondents were informed that they could answer the questionnaire in stages and that their data would be automatically saved.

Some of the strategies suggested by Frohlich (2002), Monroe and Adams (2011), and Melnyk et al. (2012), were adopted: subject interest (channeling the survey to the appropriate and/or interested manager); pre-notice (a brief advance letter or phone call); using messages to each person by name, with a personalized survey link; including contact information for collaborators and project organizers; multiple mailings (i.e., in multiple waves); appeals (direct/sincere requests for help); steady pressure (periodic reminders by phone and/or mail).

In the first wave, the questionnaire was sent to 314 professionals (*n*=314) working for companies directly aligned with the research context and identified by a set of characteristics, as directed by Miguel and Ho (2010).

The first wave of companies was identified by their adherence to the following requirements: Global Pact or another voluntary commitment; ISE/BOVESPA participants; GRI Reports (versions G3, G3.1, and G4, 2013 and 2014), Report on ETHOS indicators; and certified by the ISO 9001, ISO 14001, and OHSAS 18001 standards.

A second wave was sent to a wider sample (*n*=884), comprised of professionals selected according to managerial position and the scope of the companies (*n*=214); the largest 100 companies and companies with more than 150 employees as identified by the 2012–2013 FIEP industry catalogue (*n*=386); professionals participating in an approved education program (Lean Logistics, Lean Manufacturing, Lean HealthCare, Lean Six Sigma, Production Engineering, Quality Management, and Project Management) with a functional bond with manufacturing companies of around 60% (*n*=284). Some questionnaires were forwarded to other potential respondents; these could not be included in the sample.

Based on the approximate number of questionnaires sent in the two waves, the overall rate of return, 5.34% (*n*=64), was considered low. However, the first wave's rate of return is worth noting (professionals from companies that are more publicly engaged with sustainability): of the 64 valid questionnaires, 41 adhered to the criteria of the first wave, representing a return of 64.06%. The rest of the respondents

(35.94%) presented characteristics related to the initial requirements, although not in their entirety.

Comparing the two waves, it appears that companies that are more engaged with sustainability may be more willing to share information on their activities and best practices.

### *3.2.1. Data collection and analysis*

Initially, cross-tabulation tables were generated using the SPSS software to analyze the distribution of the variables. The tables were created using questions about the characterization of the companies and respondents in order to evaluate and identify possible patterns of behavior among the cases.

The first step in the data analysis was assessing the internal consistency of each of the six dimensions. This occurred in three steps: (1) defining the Cronbach's alpha coefficient (Flynn et al., 1995; Forza, 2002; Mackenzie et al., 2011); (2) identifying the correlation between the dimensions through the Spearman coefficient, which does not depend on assumptions of a parametric test (Field, 2010); and, (3) in the event of a correlation between the dimensions, defining a composite average of the Cronbach's alpha coefficients.

For Hair Jr. et al. (2005), a construct is a concept formed in theoretical terms that cannot be measured directly but only by variables. These tests were also used to identify the degree of consistency of the set of SOM capabilities and their relationship with corporate strategy.

Cluster analysis was used to determine whether the cases and variables would group consistently. Clustering was carried out using Ward's Hierarchical Clustering Model with Euclidean distance. According to Hair (2005), this model forms clusters seeking the minimum standard deviation between each cluster and uses the analysis of variance to analyze the distance between them; this provides good results for both Euclidean distances as well as for other distances and tends to combine clusters with few elements.

Partial least squares (PLS) was used to test the scale's validity and reliability, supported by the SmartPLS Software (Hair Jr. et al. 2012). The PLS is a second-generation structural equation modeling (SEM) technique, used when the research intends to predict or explain the variance of key constructs by various explanatory constructs and when the research deals with theory in the early stages of development (Hair Jr. et al., 2012; Sosik et al., 2009; Henseler et al., 2014; Sarstedt et al., 2014).

Three different frameworks were subjected to the validity and reliability test through PLS. Table 4 presents the three frameworks and their characteristics, based on the classification in Edwards and Bagozzi (2000).

Table 4 – Classification of frameworks' constructs and measures

| | Framework | Attributes of construct | Type of measure |
|---|---|---|---|
| 1 | Original conceptual framework | Direct reflective model* | Reflective |
| 2 | Deliberate strategy framework | | |
| 3 | Emergent strategy framework | Direct formative model** | Formative |

*Direct effects from a construct to its measure    ** Measures as correlated causes of construct

Framework 1 considers that SOM practices, grouped by experts to meet the maturity requirements for sustainable operations, form dimensions related to product life cycle management, sustainable production, social accountability, value-chain integration, and corporate management, which are guided by a corporate strategy for sustainability. In this sense, it is considered an emergent approach for the formation of dimensions and a deliberate approach related to the influence of strategy on the dimensions of practices.

Framework 2 also considers the SOM dimensions, but considers that the deliberate strategy of sustainability is what forms and directs sustainability practices.

Framework 3 considers an opposite approach, whereby integrating sustainability into strategy is reactive, influenced by practices adopted to respond to unexpected or unplanned demands.

According to Henseler et al. (2014), "PLS can be a valuable tool for exploratory research because it estimates a less restricted model (the composite factor model), because it reliably provides estimates even in situations in which other methods fail, and because as a limited-information approach, it is less prone to consequences of misspecification in subparts of the model."

Following Peng and Lai (2012), the PLS algorithm was generated by the path coefficient and bootstrap resampling 500 times.

## 4. SURVEY FINDINGS

First, the descriptive results related to the first set of questions will be presented; these are related to the characteristics of the respondents and their respective companies. Table 16 (see Appendix 1) presents the general characteristics of the respondents generated by the cross-tabulation table (with absolute numbers).

According to the results, most respondents belong to the managerial and operational/technical levels and have been in a position related to sustainability for up to 10 years; they have knowledge of the subject and are informed about the sustainability strategies of their companies. These characteristics can be related to Stoughton and Ludema (2013) which affirms that "[…] middle managers were "catalytic" for bringing sustainability into their organizations […] senior leadership involvement was needed to deploy sustainability throughout the organization [...] middle management in these companies "activated" but did not "lead" sustainability initiatives".

In terms of the companies' characteristics, 72% (*n*=46) of the respondents stated that sustainability is embedded in their business' strategic management agenda. Cross-tabulation Tables 17 to 20, seen in Appendix 2, present the results considered relevant to the research objectives.

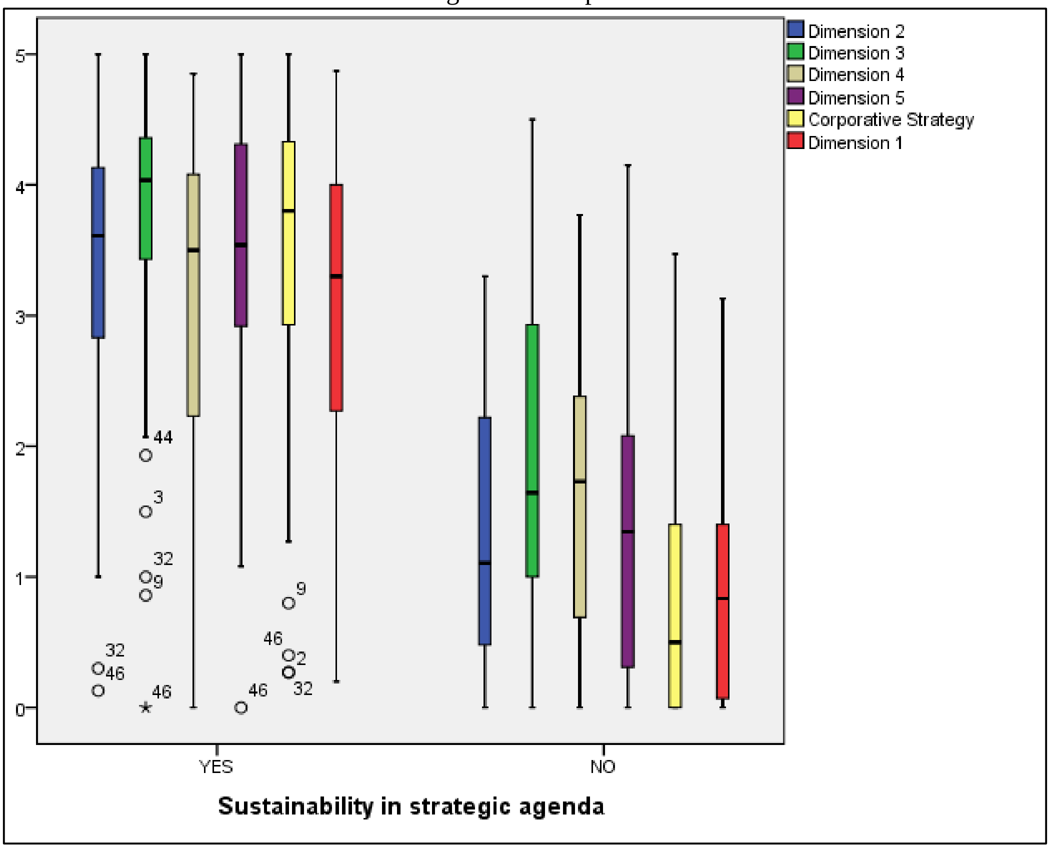
Overall, the results indicate that the companies identified by the respondents have the following characteristics: large companies, headquartered in South America (mostly in Brazil), with operations and business in Brazil and abroad. Sustainability has been integrated into the strategic agenda, particularly in the last decade, and management systems are aligned with the dimensions of TBL. Most of them already publish some kind of sustainability report, and around 50% already support some kind of voluntary commitment.

In the cases analyzed, companies that have been integrating sustainability into their strategic agenda for at least two years and have management systems related to the three dimensions of TBL report their practices through sustainability reports and support voluntary commitments. Furthermore, companies where sustainability has been integrated into their strategy for more than 10 years have a set of management systems based on expanded TBL, including the dimension of corporate governance. Table 20 complements this by showing that these characteristics are more evident in larger companies.

In cases where the respondent indicated that sustainability is not part of the strategy, the companies are generally smaller but have operations and businesses in both domestic and foreign markets. For all of them, at least one aspect of TBL is being treated by their management systems: four have systems related to three dimensions of TBL; five address more than one aspect of TBL; two publish sustainability reports; and three support voluntary commitments.

Analysis of the boxplot graph Figure 5 indicates that, for most respondents who claim that sustainability is part of the company's strategy (*n*=46), corporate strategies and practices and processes related to sustainability operations management are defined and have quantitative indicators for their management.

Figure 5 – Boxplot




In cases where sustainability is not considered part of the company's strategy, issues related to social management (Cluster 3), suppliers and customers (Cluster 4), corporate responsibility (Cluster 5), and sustainable problems (Cluster 2) already have some level of implementation. However, these practices do not seem to be aligned to a strategic orientation, which the data indicate is still incipient (Strategy).

*4.1. Internal Consistency*

The reliability of each dimension was considered satisfactory (see Table 5), according to the accepted guidelines requiring Cronbach's alphas of at least 0.70 (70%).

Table 5 – Cronbach's α

| Dimension | Items assessed | Cronbach's α |
|---|---|---|
| Corporative Strategy | 15 | .983* |
| Process/Practices – Dimension 1 | 15 | .980* |
| Process/Practices – Dimension 2 | 23 | .978* |
| Process/Practices – Dimension 3 | 14 | .967* |
| Process/Practices – Dimension 4 | 13 | .958* |
| Process/Practices – Dimension 5 | 13 | .977* |

* Coefficient of .70 or higher is considered "acceptable" (Forza, 2002).

The dimensions were also tested through correlation analysis using Spearman's correlation coefficient for non-parametric data. Table 21 in Appendix 3 shows the correlation coefficient. All dimensions are positively correlated. The composite average of the dimensions' Cronbach's α was α= 0.974.

*4.2. SOM capabilities organization*

Cluster analysis was performed for both variables and cases. Clusters 2 to 5 were generated in order to evaluate them, but only those considered relevant to the research context have been reported.

Table 6 presents the five clusters formed by the variables for the dimensions related to SOM practices and processes.

Table 6 – Cluster of variables

| Clusters | Questions and related SOM capabilities | Organizational change aspects associated |
|---|---|---|
| 1 | Q19.1, Q19.2, Q20.6, Q20.15, Q20.20, Q21.2, Q21.3, Q21.5, Q21.6, Q21.7, Q21.8, Q21.9, Q21.10, Q21.11, Q21.13, Q22.3, Q22.4, Q22.5, Q22.13, Q23.1, Q23.2, Q23.3, Q23.11 | Context, content and process |
| | Related capabilities: reverse logistics, product design, lean and green processes, cleaner production, OH&S, sustainable purchasing, social purchasing social accountability, information system, stakeholder engagement, and sustainable marketing. | |
| 2 | Q19.3, Q19.4, Q19.5, Q19.6, Q19.7, Q19.8, Q19.9, Q19.10, Q19.11, Q19.12, Q19.13, Q19.14, Q19.15, Q20.1, Q20.2, Q20.4, Q20.5 | Context, content and process |
| | Related capabilities: life cycle management, reverse logistics, product design, closed loop supply chain, cleaner production, EMS, eco-efficiency, and sustainable business. | |
| 3 | Q20.3, Q20.7, Q20.8, Q20.9, Q20.10, Q20.11, Q20.12, Q20.13, Q20.14, Q20.16, Q20.17, Q20.18, Q20.19, Q20.21, Q20.22, Q20.23 | Process |
| | Related capabilities: sustainable purchasing, QMS, lean and green processes, cleaner production, and eco-efficiency | |
| 4 | Q21.1, Q21.4, Q21.14, Q22.2, Q22.6, Q22.7, Q22.8, Q22.9, Q22.10, Q22.11, Q22.12 | Context, content and process |
| | Related capabilities: social accountability, sustainable purchasing, information system, suppliers' development program, and stakeholder engagement. | |
| 5 | Q22.1, Q23.4, Q23.5, Q23.6, Q23.7, Q23.8, Q23.9, Q23.10, Q23.12, Q23.13 | Content |
| | Related capabilities: suppliers development program, sustainable business case, sustainable marketing | |

In the groupings by respondents, the organization in three clusters presented the most distinct patterns. Table 7 presents the results of the groupings, including the respondents' statements about their company's position regarding sustainability (*n*=48).

Table 7 – Clusters of respondents

| Cluster cases | Main Characteristics |
|---|---|
| 1 *n*=38 | Qualified respondents (as measured by length of time spent in the position related to sustainability and level of experience and knowledge about the company's sustainability strategy); strategy embedded in the management agenda (in 50% of cases for over 10 years); management systems related to all dimensions of TBL; publication of sustainability reports; signatories of voluntary commitments; and practice implementation levels concentrated among levels 3 (Defined), 4 (Quantitative Management), and 5 (Optimized). |
| | Position regarding sustainability: "compliance strategy", "innovative", and "from compliance to innovative" |
| 2 *n*=14 | Practice implementation levels concentrated among levels 1 (Initial) and 2 (Managed or Repeated). In this grouping, only two respondents consider themselves an expert/leader in sustainability; most say they are a beginner or have some knowledge but are not an expert. In terms of how long sustainability has been part of the strategic agenda, there were two distinct groups: six respondents stated that the topic is not part of the agenda, and six stated that sustainability has been integrated into the business for a short time (1 to 5 years). |
| | Position regarding sustainability: "compliance strategy", and "innovative" |
| 3 *n*=12 | They can be considered "outliers," even though, in some cases (*n*=4), the respondents state that sustainability is embedded in the company's strategic agenda. The cases differ from the other groupings mainly in the smaller number of employees (between 50 and 1000), incipience in the level of implementing sustainability, and the fact that they do not publish sustainability reports or even support voluntary commitments. It is important to highlight some of the respondents' characteristics: most stated that their position is not related to sustainability and that they have little or no knowledge of how sustainability affects the business. |
| | Position regarding sustainability: "none" |

Another distinctive aspect of the groupings is the region where the companies' headquarters is located, as well as that of the companies with which they negotiate. In Cluster 3, most of the companies have headquarters and focus their operations and business in Brazil. In Cluster 2, five cases have headquarters outside Brazil, in countries in Europe/Scandinavia and North America, and global operations and businesses (in more than three countries). In Cluster 1, 12 cases have international headquarters, and 19 cases (most of which are in the Global category) have operations and businesses in foreign countries.

*4.3. Capabilities organization test through PLS*

The three frameworks described above were analyzed using SmartPLS software. The constructs and relationships established in each model are illustrated in Appendix 4 (see Figures 6 to 8). Tables 8 to 11 present the structural estimates.

In Framework 1, with the exception of the loadings referring to variables Q20.11 (0.528), Q.20.15 (0.412), Q22.4 (0.494), and Q.22.5 (0.539), the loadings of all indicators on their corresponding constructs reached acceptable values (greater than 0.6). The items were removed, and the framework was re-tested; it was found that the parameters were not affected by the variables' removal. In this case, the tests did not generate the values of communality (AVE), Cronbach's α, or Composite reliability.

Table 8 – Framework 1 - PLS analysis

| Framework 1 | $R^2$* | t-Stat. |
|---|---|---|
| Strategy – Cluster 1 | 0.938 | 59.580 |
| Strategy – Cluster 2 | 0.931 | 78.677 |
| Strategy – Cluster 3 | 0.886 | 39.883 |
| Strategy – Cluster 4 | 0.858 | 31.620 |
| Strategy – Cluster 5 | 0.950 | 84.344 |

In Framework 2, which represents the deliberate strategic approach, the loadings of all indicators on their corresponding constructs reached acceptable values (greater than 0.6). The framework showed strong convergence between its constructs, generating the values of communality (AVE), Cronbach's α, and Composite Reliability.

Table 9 – Framework 9 - PLS analysis (a)

| Framework 2 | $R^2$ | T-Stat. |
|---|---|---|
| Strategy – Cluster 1 | 0.901 | 28.865 |
| Strategy – Cluster 2 | 0.855 | 24.638 |
| Strategy – Cluster 3 | 0.775 | 12.657 |
| Strategy – Cluster 4 | 0.767 | 15.028 |
| Strategy – Cluster 5 | 0.895 | 39.219 |

Table 10 – Framework 2 - PLS analysis (b)

| Framework 2 | $R^2$ | T-Stat. |
|---|---|---|
| Strategy – Cluster 1 | 0.901 | 28.865 |
| Strategy – Cluster 2 | 0.855 | 24.638 |
| Strategy – Cluster 3 | 0.775 | 12.657 |
| Strategy – Cluster 4 | 0.767 | 15.028 |
| Strategy – Cluster 5 | 0.895 | 39.219 |

*AVE values greater than 0.50 suggest convergent validity at the construct level

** CR values greater than 0.70 indicate acceptable reliability

In Framework 3, the $R^2$ of the strategic construct is $R^2$=0.954. As with Framework 1, the tests did not generate the values of communality (AVE), Cronbach's α, or composite reliability. The framework showed severe multicollinearity (VIF) among the clusters and the strategy, with all loadings above 3.3 (Diamantopoulos and Siguaw, 2006).

Table 11 – Framework 3 - PLS analysis

| Framework 3 | $R^2$ | T-Stat. |
|---|---|---|
| Cluster 1 | 0.346 | 1.449 |
| Cluster 2 | 0.226 | 0.679 |
| Cluster 3 | 0.022 | 0.136 |
| Cluster 4 | -0.113 | 1.213 |
| Cluster 5 | 0.512 | 2.206 |

The absence of construct quality indicators indicates that Frameworks 1 and 3 do not converge. Framework 2 showed the best results in general and suitable convergence indicators.

## 5. DISCUSSION

The results generated by the cross-tabulation tables were considered relevant for defining the scope of the respondents' characterization and qualification, which was considered appropriate. It is believed that the strategy of qualifying respondents before sending the questionnaires had a direct impact on that qualification.

The PLS tests were corroborated, as the integration of sustainability into operations and business is based on a top–down approach that can be significantly characterized as a deliberate strategy (Framework 2). However, the good results of Framework 1 may indicate that integration is based on top–down planning and definitions, but they are also influenced by reactive demands, effectively resulting in the strategy.

For Bettley and Burnley (2008), SOM should be seen as a core competence of the company. The analyses confirm that the cluster of capabilities is suitable for the sustainable operations management construct. In addition, the analysis of the variables cluster indicated that the SOM capabilities were grouped based on evolutionary levels.

Table 12 presents considerations on the focus of each cluster formed and the relationships that were identified based on the sustainability integration standard identified by the MIT/BCG studies (Kiron et al., 2012; Kiron et al. 2013a,b).
The grouping of variables is also supported by the set of capabilities and resources proposed by Gavronski (2012).

Eccles et al. (2012) state that what differentiates sustainable companies from traditional companies is engagement with the needs of stakeholders and collaborators, promoting a culture of innovation and transformational change. The variables present in the first three clusters point to the gradual changes in motivated operations, primarily from the financial benefits provided by adopting sustainable practices. Beginning with cluster 4, the company adopts an extramural posture, supporting and contributing effectively to collective actions that contribute to sustainable development, as pointed out by Kiron et al. (2013a,b).

The analysis of the organizational aspects, listed in Table 6, corroborates the perception cited above. In Clusters 1 and 2, the external environment is primarily represented by the demands of industry regulations and laws incident to business, causing areas and processes to be modified internally and externally for compliance. In Cluster 3, formalized processes consolidate the changes promoted in Clusters 1 and 2. The engagement of the value-chain demands strategic changes and deeper processes (Content and Process) to meet new demands and satisfy stakeholders involved in the business (Context). Cluster 5 characterizes the consolidation of the strategic change, which clearly establishes the relationships between the company and its supply chain with the market and society as a whole.

In respondents' clusters, the organization in three clusters is the one with more distinct patterns. Based on the evolutionary pattern presented by MIT/BCG, Table 13 presents considerations on the respondents' clusters 1 and 2.

Table 12 – Clusters of variable

| Cluster | Evolution | Evolution focus | Capabilities | Evidence |
|---|---|---|---|---|
| 1 | Embracers | Sustainability as a competitive condition and on the strategic agenda. | Compliance<br><br>License to operate | The variables point to processes that ensure compliance in the dimensions of TBL, including the compliance by key suppliers. Some variables, even though they seem to belong to other groupings, are aimed at compliance issues, such as: Q21.11, Q21.13, Q.22, and Q.23.11. The variable 21.9 indicates that the sustainability strategy should be developed based on the values, mission, and vision defined by the company. |
| 2 | | Changes in operations frameworks and strategies driven by sustainable practices' financial benefits.<br><br>Creating a sustainability business case. | Eco-efficiency | The variables point to the identification, necessary negotiations, and mitigation of environmental impacts in both internal and supplier products and manufacturing processes. Definition of criteria for managing the product life cycle, including decisions for facilitating reverse logistics and closed-loop supply chain. The variables Q19.9, Q19.10, and Q.19.11 represent triggers for the next level. |
| 3 | Harvesters | Sustainability-related actions and decisions adding economic value to profits. Business model changing because of sustainability opportunities. | Processes management and control<br><br>Performance management | The variables point to the definition of systems and processes that formalize procurement processes and internal processes for sustainable production and eco-efficiency. |
| 4 | Sustainability-driven Innovators | Profiting from sustainability efforts and changing business models to sustain profit generation. Addressing the significant sustainability issues (i.e., material sustainability). | Value-chain engagement | The variables indicate the consolidation of sustainability criteria in the value chain, based on the engagement of customers and suppliers<br>The variable Q.21.12 represents a trigger for the next level. |
| 5 | Walkers | Significant sustainability issues are used as a way to mitigate threats, identify powerful new opportunities, and value creation. Supporting collective action to identify material sustainability in a specific sector. | Sustainability integration | The variables indicate the consolidation of the strategic sustainability management and the positioning of the company and its value chain as agents of sustainable development. |

Source: adapted from Kiron et al., 2012, 2013a,b.

Table 13 – Clusters of respondents

| Cluster | Evolution Level* | Description | Evidence (average of responses) |
|---|---|---|---|
| 1 | Harvesters to Sustainability-driven Innovators | Strategies and practices are defined, but not all of them are quantitatively managed and optimized. It can therefore be said that there are strong signs that, in these cases, sustainability is being integrated into the operations and business model. Strong support from senior management | Q18.7 = 3.73<br>Q18.8 = 3.31<br>Q18.9 = 3.68<br>Q18.10 = 3.28<br>Q18.14 = 4.21 |
| 2 | Embracers | Sustainability is being integrated into the business but is still in an initial stage. It is considered important for competitiveness but not defined in the context of the operations and business model. | Q18.7 = 1.71<br>Q18.8 = 2.00<br>Q18.9 = 1.85<br>Q18.10 = 1.00<br>Q18.14 = 2.42 |

*Source: adapted from Kiron et al., 2012, 2013a,b.

The cases from Cluster 3 were considered outside the group of companies engaged in integrating sustainability, still incipient on the topic, or with low quality ratings due to the respondents' perception or lack of knowledge, as the statements about the companies' positioning exemplify (e.g., "*None*" was indicated by respondents 23, 29, 37 and 39; *"intends to include sustainability in the agenda"* was indicated by respondent 32; and "*I have no information on this subject"* was indicated by respondent 61).

The "outlier" cases identified in the boxplot graph (see Figure 5) corroborate the analysis cited earlier. Three cases (9, 32, and 46) were grouped in Cluster 3, and three other cases (2, 3, and 44) were grouped in Cluster 2 (Embracers). Thus, for cases where sustainability is integrated, corporate strategies and the practices and processes related to sustainability operations management are defined and have quantitative indicators for their management.

Most companies in cluster 3 have headquarters, operations, and business focus in Brazil. In Cluster 2, five cases showed headquarters outside Brazil (Europe/Scandinavia and North America), with global operations and business (more than 3 countries). In cluster 1, twelve cases pointed an international origin and nineteen cases pointed operations and business with foreign countries, mostly in Global operations. Based on these data, it can be said that there is a tendency that the level of integration of sustainability is higher in multinational companies or companies, which are developing operations and business with other countries. One of the causes can be the legal and market requirements related to these regions.

The cross-tabulations and clusters of cases indicated that, in general, larger companies tend to present a broader set of implemented sustainability practices. This does not mean that this tendency was not also seen in smaller companies. Companies that are part of more structured and regulated chains, such as automotive and pulp and paper firms, and even those that identify market gains through the adoption of practices tend to have a higher level of sustainability integration.

Table 14 analyzes the results from the perspective of the central issue and the propositions to be evaluated.

Table 14 – Proposition validation

| | |
|---|---|
| RQ1 | In order to achieve a high maturity level in implementing sustainability, a company needs to have strong leadership that defines the overall sustainability strategy. Sustainability integration can be deployed in six main dimensions, formed by SOM capabilities. These capabilities can be viewed as complementary processes that can be deployed and managed in an integrated manner according to the variables' cluster results. |
| Proposition 1 | Validated. According to the evolutionary patterns identified in the variables' cluster results, there is a reactive–proactive pattern to sustainability integration, proceeding from Embracers to Walkers. |
| Proposition 2 | Validated. The results support this proposition. There is an indication that the duration of sustainability integration and company size influence the scope and level of sustainability integration. |
| Proposition 3 | Validated. The clusters of cases corroborate the validation of this proposition, mainly in Cluster 1 (Harvesters to Sustainability-driven Innovators) and confirm the second part of the proposition with Cluster 2 (Embracers) |
| Proposition 4 | Validated. The boxplot results support this proposition. See Figure 5. |
| Proposition 5 | Validated according to RQ1 |
| Proposition 6 | Denied. The analyses of the frameworks' convergence and reliability indicated that the best results for sustainability integration begin with a deliberate strategy, supported by senior management. |

The three perspectives on maturity presented by Nascimento et al. (2013) were identified in the generated results: (1) the results corroborate Maturation, in which sustainability integration evolves over time as the subject is being treated and disseminated within the company (Kiron et al., 2012, 2013a,b); (2) Capability is corroborated, as sustainability integration can be carried out through the maturity of the SOM capabilities (Dao et al., 2011, Pinheiro de Lima et al., 2012); (3) and Evolution is corroborated, as sustainability integration can be carried out through five evolutionary levels, moving from the initial stage of compliance to the integration of sustainability (Veleva et al., 2001, Hannaes et al., 2011).

**CONCLUSION**

The model's internal consistency and the reliability of its measurements validate the organization of SOM capabilities into a maturity model for sustainable operations management that considers the evolution of organizational skill resources to be integrated with the value chain.

The groupings illustrated by the boxplot graph and the clusters indicate the acceptability and reliability of the maturity levels proposed in Figure 2 as well as the levels of evolution for operations' decision areas and performance goals presented in Figure 3. The results also support the organization of specific goals and practices in the proposed framework.

These results contribute to studies on OM by helping to reduce the gaps concerning the models and frameworks for supporting SOM strategies and by helping companies incorporate sustainability.

The study's limitations include the number of cases examined, the sample size, the average time spent to complete the questionnaire, the difficulty of identifying the professionals in each company who could answer the questionnaire's broad questions, some firms' policies to not participate in surveys, and some companies' refusal to discuss sustainability since it seems to be a strategic topic. Even so, it is worth noting that some of the respondents praised the questionnaire's scope.

As suggestion for further research, it is indicated to analyze differences among industry sectors and size. In addition, future research may consider: expanding the number of cases to increase the model's explanatory and generalizing power and enable more robust analysis; including the "I don't know/Not applicable" option on the scale (as suggested by the respondents in the first round); using a sample balanced between the manufacturing and infrastructure sectors to identify patterns and practices, and conducting qualitative studies that allow the issues identified in this exploratory study to be more deeply examined.

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# Appendix 1

Table 16 – Respondent Characteristics

| Job position | Time working with sustainability, or in a related function? | | Experience related to how sustainability affects business | | How well informed are you about your organization's sustainability strategy | |
|---|---|---|---|---|---|---|
| Executive 3 | < 5 years | 0 | expert/leader in this subject | 1 | fully informed | 3 |
| | 5 to 10 years | 0 | some knowledge, but not expert | 2 | a bit informed | 0 |
| | 10 to 20 years | 0 | beginner | 0 | not very informed | 0 |
| | > 20 years | 1 | no experience | 0 | not informed | 0 |
| | work is not related | 2 | | | | |
| Manager 28 | < 5 years | 8 | expert/leader in this subject | 10 | fully informed | 17 |
| | 5 to 10 years | 6 | some knowledge, but not expert | 11 | a bit informed | 7 |
| | 10 to 20 years | 1 | beginner | 3 | not very informed | 2 |
| | > 20 years | 1 | no experience | 4 | not informed | 2 |
| | work is not related | 12 | | | | |
| Operational and technical 33 | < 5 years | 11 | expert/leader in this subject | 9 | fully informed | 14 |
| | 5 to 10 years | 5 | some knowledge, but not expert | 17 | a bit informed | 15 |
| | 10 to 20 years | 6 | beginner | 4 | not very informed | 3 |
| | > 20 years | 0 | no experience | 3 | not informed about anything | 1 |
| | work is not related | 11 | | | | |

# Appendix 2

Table 17 – Companies' Characteristics 1

| | Employees | | | | | Company´s Headquarter* | | | | Major Operations** | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | < than 50 | 50 to 200 | 200 to 1000 | 1000 to 10,000 | > than 10,000 | SA | EU and SCAN | NA | AS | BR | GL | EU | LA |
| Yes (46) | 0 | 7 | 12 | 22 | 5 | 31 | 9 | 6 | 0 | 27 | 14 | 2 | 3 |
| No (18) | 1 | 5 | 6 | 2 | 4 | 14 | 3 | 0 | 1 | 8 | 6 | 4 | 0 |

* SA– South America / EU – Europe / Scan – Scandinavia / NA – North America / AS – ASIA
** BR - Brazil / GL – Global (more than 3 regions) / EU - Europe / LA – Latin America

Table 18 – Companies' Characteristics 2

| | How long sustainability in strategic agenda | | | | Management Systems related to TBL* | | | | | | | | Report | | Voluntary Commitments** | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | < 2 years | 2 to 5 | 10 to 20 | No | Ec | E | S | Ec and E | Ec and S | S | TBL | TBL (exp.) | Yes | No | E | S | SE | No |
| Yes (46) | 4 | 23 | 19 | 0 | 5 | 1 | 1 | 7 | 1 | 1 | 21 | 9 | 33 | 13 | 6 | 4 | 15 | 21 |
| No (18) | 0 | 1 | 0 | 17 | 6 | 1 | 2 | 2 | 3 | 0 | 3 | 1 | 2 | 16 | 1 | 1 | 1 | 15 |

* Ec – Economic / E – Environmental / S – Social / TBL – Triple Bottom Line / TBL (exp.) – Expanded Triple Bottom Line
** E – Environmental / S – Social / SE – Socio-environmental

Table 19 – Companies' Characteristics 3

| How long in strategic agenda | Company´s Headquarter* | | | | Management Systems related to TBL** | | | | | | | | Report | | Voluntary Commitments*** | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | SA | EU and SCAN | NA | AS | Ec | E | S | Ec and E | Ec and S | S | TBL | TBL (exp.) | Yes | No | E | S | SE | No |
| < 2 years | 3 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 2 | 0 | 3 | 1 | 1 | 0 | 2 | 1 |
| 2 to 5 | 16 | 5 | 3 | 0 | 3 | 1 | 1 | 2 | 1 | 1 | 11 | 4 | 16 | 8 | 2 | 3 | 7 | 12 |
| 10 to 20 | 13 | 4 | 2 | 0 | 1 | 0 | 0 | 4 | 1 | 0 | 8 | 5 | 14 | 5 | 3 | 2 | 7 | 12 |
| No | 13 | 3 | 0 | 1 | 6 | 1 | 2 | 2 | 2 | 0 | 3 | 1 | 2 | 15 | 1 | 0 | 1 | 15 |

* SA– South America / EU – Europe / Scan – Scandinavia / NA – North America / AS – ASIA
** Ec – Economic / E – Environmental / S – Social / TBL – Triple Bottom Line / TBL (exp.) – Expanded Triple Bottom Line
*** E – Environmental / S – Social / SE – Socio-environmental

Table 20 – Companies' Characteristics 4

| | Sustainability in strategic agenda | | Management Systems related to TBL* | | | | | | | | Report | | Voluntary Commitments** | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Yes | No | Ec | E | S | Ec and E | Ec and S | S | TBL | TBL (exp.) | Yes | No | E | S | SE | No |
| < than 50 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 |
| 50 to 200 | 7 | 5 | 5 | 2 | 2 | 0 | 2 | 1 | 0 | 0 | 1 | 11 | 1 | 0 | 0 | 11 |
| 200 to 1000 | 12 | 6 | 3 | 0 | 0 | 4 | 1 | 0 | 8 | 2 | 8 | 10 | 2 | 2 | 4 | 10 |
| 1000 to 10,000 | 22 | 2 | 1 | 0 | 0 | 4 | 0 | 0 | 14 | 5 | 20 | 4 | 4 | 2 | 8 | 10 |
| > than 10,000 | 5 | 4 | 1 | 0 | 1 | 1 | 1 | 0 | 2 | 3 | 6 | 3 | 0 | 1 | 4 | 4 |

* Ec – Economic / E – Environmental / S – Social / TBL – Triple Bottom Line / TBL (exp.) – Expanded Triple Bottom Line
** E – Environmental / S – Social / SE – Socio-environmental

# Appendix 3

Table 21 – Correlations among six dimensions of variables

| | | Strategy | Cluster 1 | Cluster 2 | Cluster 3 | Cluster 4 | Cluster5 |
|---|---|---|---|---|---|---|---|
| Strategy | Correlation Coefficient | 1,000 | ,875** | ,841** | ,756** | ,741** | ,863** |
| | Sig. (2-tailed) | | ,000 | ,000 | ,000 | ,000 | ,000 |
| Cluster 1 | Correlation Coefficient | ,875** | 1,000 | ,855** | ,694** | ,756** | ,823** |
| | Sig. (2-tailed) | ,000 | | ,000 | ,000 | ,000 | ,000 |
| Cluster 2 | Correlation Coefficient | ,841** | ,855** | 1,000 | ,855** | ,848** | ,875** |
| | Sig. (2-tailed) | ,000 | ,000 | | ,000 | ,000 | ,000 |
| Cluster 3 | Correlation Coefficient | ,756** | ,694** | ,855** | 1,000 | ,831** | ,823** |
| | Sig. (2-tailed) | ,000 | ,000 | ,000 | | ,000 | ,000 |
| Cluster 4 | Correlation Coefficient | ,741** | ,756** | ,848** | ,831** | 1,000 | ,875** |
| | Sig. (2-tailed) | ,000 | ,000 | ,000 | ,000 | | ,000 |
| Cluster 5 | Correlation Coefficient | ,863** | ,823** | ,875** | ,823** | ,875** | 1,000 |
| | Sig. (2-tailed) | ,000 | ,000 | ,000 | ,000 | ,000 | |

** Correlation is significant at the 0.01 level (2-tailed).

# Appendix 4

Figure 6 - Framework 1 – Constructs

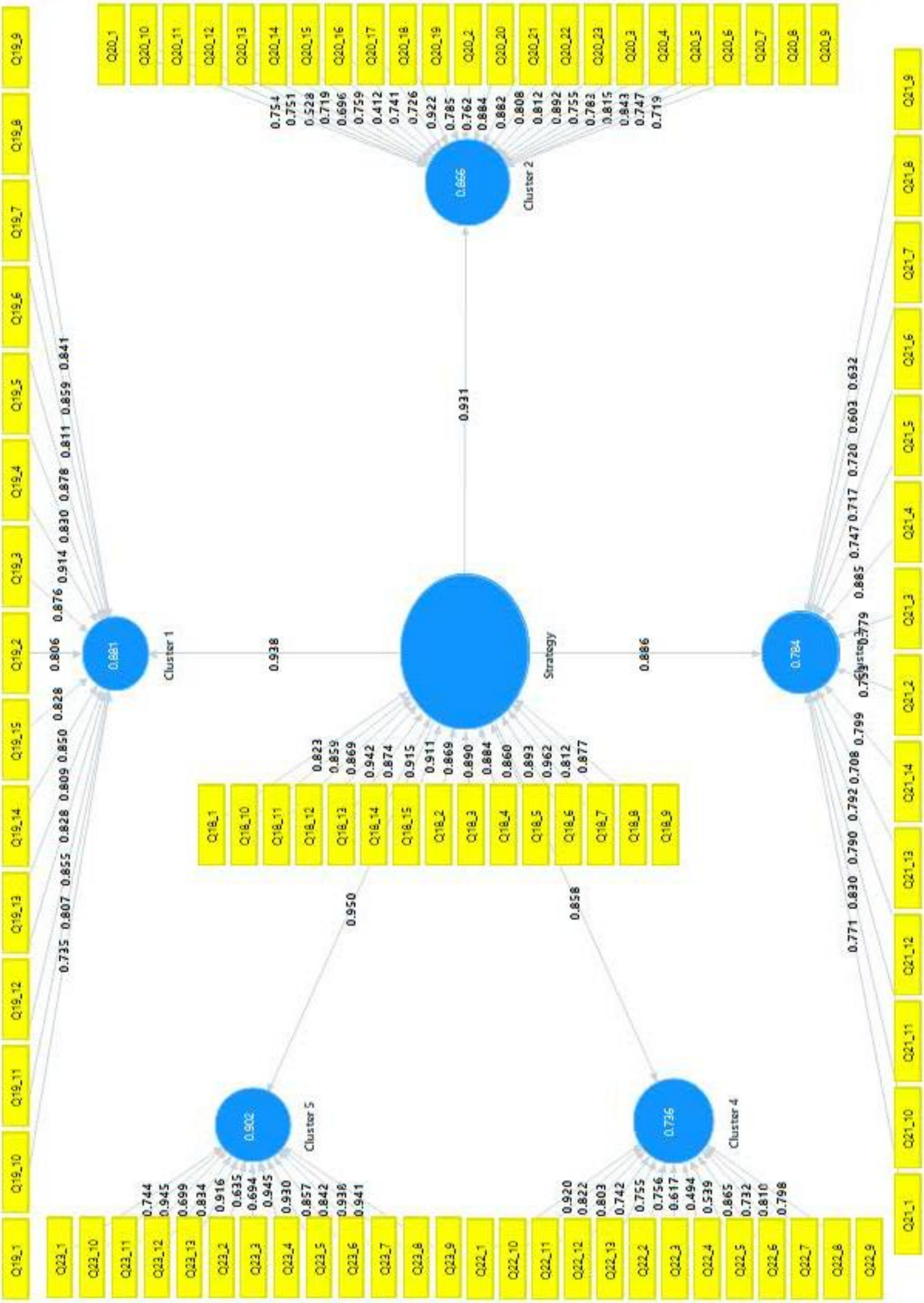
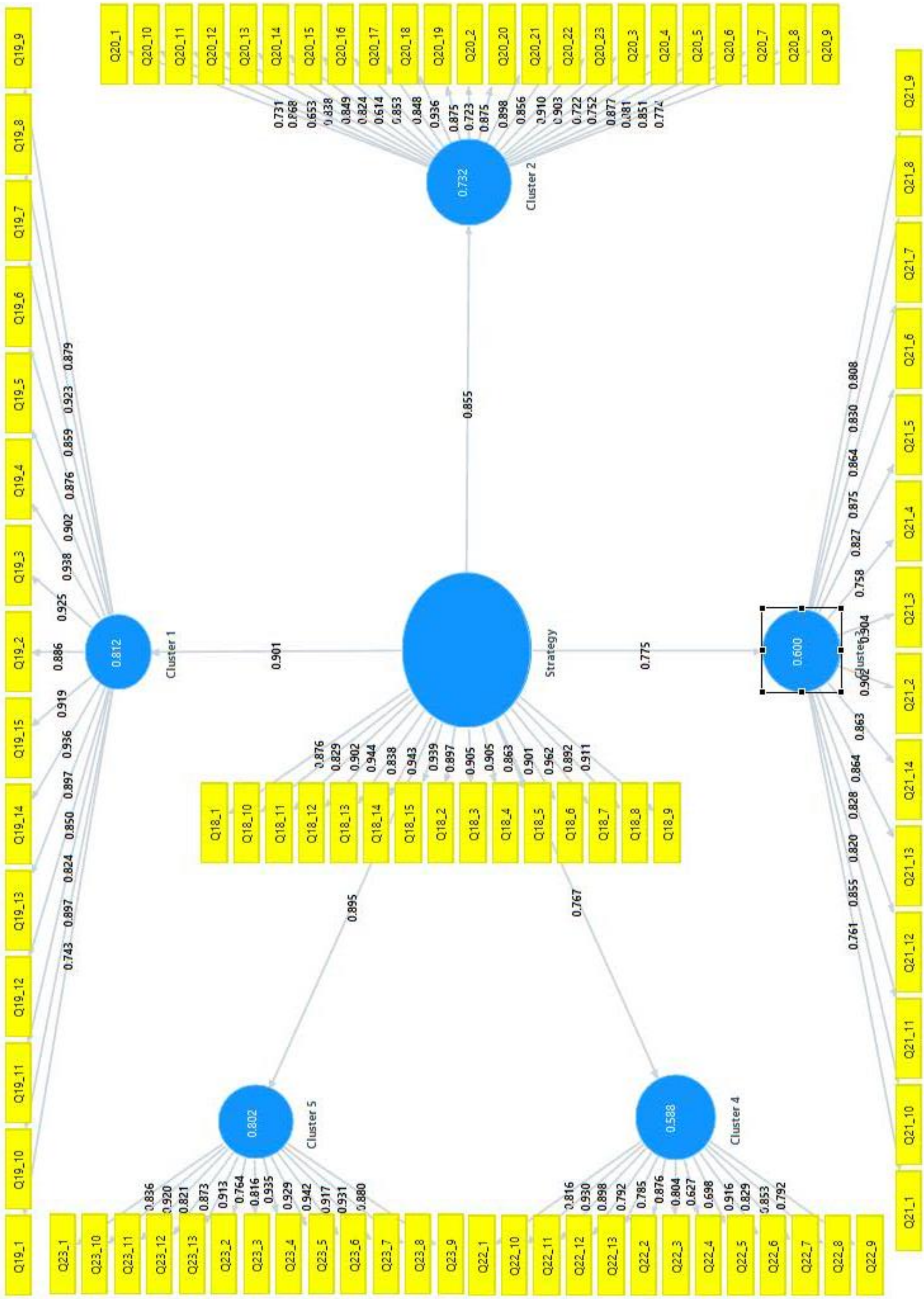


Figure 7 - Framework 2 – Constructs



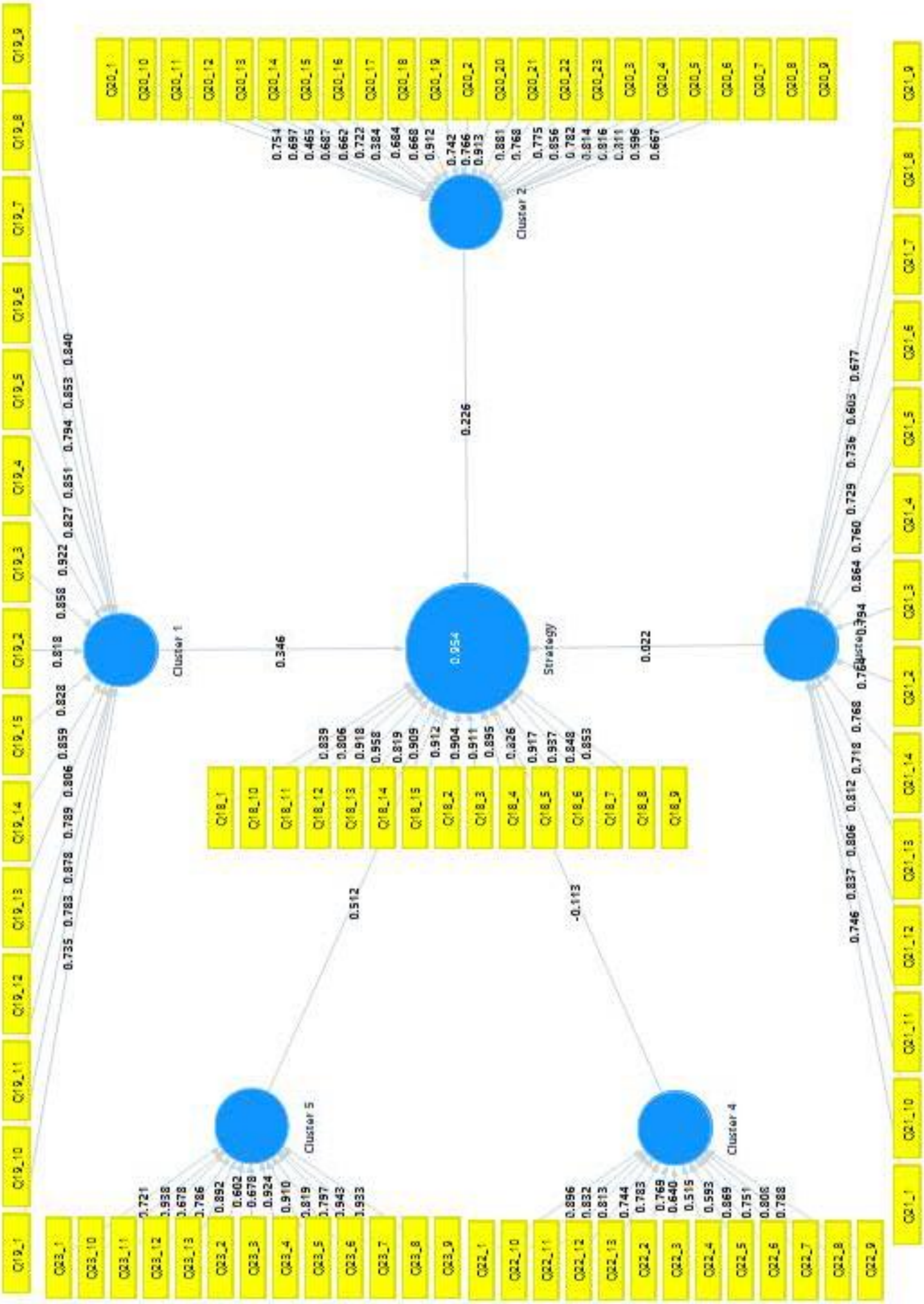



Figure 8 - Framework 3 – Constructs

# PAPER V - IMPLEMENTING A SUSTAINABILITY INDICATORS DESIGN PROCESS FRAMEWORK

Edson Pinheiro de Lima[ab], Carla G. Machado[b], Rafael A Kluska[c], Leandro N. Hundzinski[d], Letícia M. Rocha[b], Elias H D. Ribeiro da Silva[b], Sergio E Gouvea da Costa[ab]

[a] Industrial and Systems Engineering Graduate Program, Pontifical Catholic University of Parana, 80215-901 Curitiba, Brazil.

[b] Federal University of Technology - Parana, 80230-901 Curitiba, Brazil.

[c] Control and Automation Engineer

[d] Industrial Enginner

**Abstract**

Sustainable development is defining the competitive context in the last decade forcing companies to review their business model for incorporating sustainability requirements. Stakeholders demand more transparency that is being reflected in present regulatory framework, which is formed by standards, guidelines and performance reports. These elements provide information for markets and the society in general respect to sustainable behavior, which is certified or formally agreed by companies. Organizations operations performance information could be related to an evolutionary performance indicators set, which could represent sustainability present performance, and also could orient companies in reaching higher sustainability performance levels, following for that purpose a maturity trajectory. The objective of this paper is to develop a process for designing an integrated set of performance indicators for managing sustainability at operations system level. An applied research was conducted based on 'Cambridge Process Approach', and managed in a research BPM cycle. Sustainability performance indicators are formally defined and detailed as metadata. Process application not only allows a better understanding on how sustainability indicators could be integrated and related to a maturity model, but also created an information system that could be used for auditing, assessment and reporting sustainability performance.

Keywords: Sustainability performance indicators, sustainability maturity models, value chain, extended triple bottom line, process approach, BPM

## 1. Introduction

Business stakeholders are demanding more transparency related to companies' results and performance, particularly in those aspects connected to sustainability.

Some evidences point in that direction as companies' shareholders and stockholders look for evidences that support governance best practices, customer and clients are demanding information related to product raw materials and components origins and suppliers labor conditions, employees are looking for opportunities in companies that are social responsible and aware of their environmental duties, governments and the society in general are creating 'global' requirements for companies to report their economic, environmental and social performance (Leyh and Demez, 2014, Reuter et al., 2012, Gold et al., 2010, Aras and Crowther, 2008, Castka and Balzarova, 2007; Keeble et al., 2003).

The last three decades cover a significant evolution of the regulatory framework for 'sustainability', which encompass economic, environmental and social aspects. Table 1 summarizes it.

Sustainability standards also experimented an interesting evolution in the last decades, and are responsible for guiding implementation in sustainability regulatory framework. Some standards could be cited as representative for sustainability implementation: ISO 14000 - environment (1993); ISO 14040 - life cycle assessment (2001); SA 8000 - social accountability (1997); OHSAS 18001 – health and safety (1999); AA 1000 – accountability (1999); ISO 26000 - corporate social responsibility (2010); ISO 50001 - energy management (2011) (Leyh and Demez, 2014, Hundzinski et al., 2013, Castka and Balzarova, 2008).

Accountability and reporting are also important activities for companies showing their sustainability initiatives. The Global Report Initiative (GRI), created in 1997, proposes a framework that provides metrics and methods for measuring and reporting sustainability-related impacts and performance. In its version GRI 4.0, the report also helps companies to identify material sustainability issues, i.e., those considered most relevant to the company's continued ability to function (Hundzinski et al., 2013, Kiron et al., 2013, Tate et al., 2010).

It was shown that sustainability regulatory framework is complex and following an evolutionary path, so companies should comply with these requisites to attend local and global demands (Leyh and Demez, 2014).

Hart and Milstein (2003) highlight that sustainability metrics and indicators should be approached as 'instruments' used for value creation, that is, benefits should be cleared defined when adopting sustainability based business model. In addition, according to Singh et al. (2009) and Bititci et al. (2012) there is a demand for people, organizations, and society to find the models, metrics, and tools needed to operationalize sustainability, because progress and gaps need to be measured and monitored for sustainability to have more optimized and efficient stages.

Table 1 – Regulatory framework for sustainability

| Aspects | Regulatory examples |
| --- | --- |
| Corporate Social Responsibility (CSR) | United Nations Universal Declaration of Human Rights; International Labour Organization (ILO) Declaration on Fundamental Principles and Rights at Work and its Follow-up; ILO Tripartite Declaration Concerning Multinational Enterprises; Organization for Economic Co-operation and Development (OECD) Guidelines for Multinational Enterprises; United Nations Rio Declaration/Agenda 21 on environment, sustainable development and poverty eradication. |
| Social - Labor relations | Freedom of association and protection of the right to collective bargaining' (ILO Conventions 87, 98, complemented by ILO Convention 135); Abolition of forced and compulsory labor (ILO Conventions 29 and 105); Abolition of child labor (ILO Conventions 138 and 182); Abolition of discrimination in respect of employment and occupation (ILO Conventions 100 and 111), and Conventions 87 and 98 (complemented by ILO Convention 135). |
| Environment and sustainable development | OECD Guidelines for Multinational Enterprises (1976); Vienna Convention for the Protection of the Ozone Layer (1985); United Nations Environment Programme (UNEP) and the World Meteorological Organization (WMO) Intergovernmental Panel on Climate Change (IPCC) Report (1988); Earth Summit, Rio de Janeiro (1992); Convention on Biological Diversity (1992); Aarhus Convention (1998), through which human rights and environmental rights were for the first time related to each other; Kyoto Protocol (1997-2005); Rotterdam Convention on the Prior informed Consent (PiC) Procedure. (1998); Biosafety Cartagena Protocol (2000); Stockholm POPs (Persistent Organic Pollutants) Convention (2001); Stern Report (2006). UN Assembly voted in 2007 on the Norms on the Responsibility of Transnational Corporations and other companies concerning human rights, represented and compiled by the following documents: United Nations Universal Declaration of Human Rights; United Nations Charter; Tripartite Declaration of Principles Concerning Multinational Enterprises and Social Policy; ILO Declaration on Fundamental Principles and Rights at Work; OECD Guidelines and Global Compact. |

Source: Louette, 2008.

Park and Pavlovsky (2010) said that companies that take an *ad hoc* approach to sustainability or use isolated initiatives may not achieve better results than companies using an integrated approach. Some companies are putting great effort for developing integrated systems for managing sustainability, that is, coordinating all aspects related to sustainability in terms of economics, environmental and social issues. These companies are approaching their operations considering their operations network that covers multiple supply chains, and the sustainability capabilities are been organized in maturity-based models, which are guiding companies for developing their systems over time (Maas and Reniers, 2014, Looy et al., 2013, Cabezas et al., 2003).

Chee Tahir and Darton (2010) presented a method for selecting sustainability indicators. According to the method, the possible indicators can be identified in published lists, e.g. the GRI Report. The main driver for decision-making is to link issues identified through internal and external impacts to an indicator. In this matter, the authors pointed out that the method is useful for selecting a basic set of indicators for a particular business process. Martinet (2011) presented algorithm for a bottom-up approach to characterize sustainability through indicators, focusing on identifying thresholds.

Operations Management (OM) literature is full of sustainability metrics, measures/indicators, and measurement systems studies. Taking some representative papers, it could be traced an evolutionary trajectory on how sustainability is been assessed and related to companies' operations performance: Azapagic and Perdan (2000), Veleva and Ellenbecker (2001), Keeble et al. (2003), Labuschagne et al. (2005); Folan and Browne (2005), Hutchins e Sutherland (2008), van Bommel (2011), Golini et al. (2014), and Schrettle et al. (2014).

However, according to Parisi (2013) studies about how companies adopt sustainability performance measurement systems, including for those used for social and environmental goals are not explicitly addressed, and research needs to investigate the strategic and operational levels.

In this sense, the main question arises: How to select and integrate a set of sustainability indicators that perform an integrated performance measurement system? According Grabot and Schlegel (2014), ICT (Information and Communication Technologies) "[…] may positively influence enterprise competitiveness but also social and environmental issues". In this matter, processes were developed in order to support a software prototype for sustainability indicators selection.

Thus, this paper shows the results of a two-year research cooperation project between XX University ISE Department and YY Software Company for developing the software prototype called P3G®. The project started on January 2012, and in its first year developed the conceptual model and technical requirements for software design and programming. In the second year, the software prototype was developed and tested.

The purpose of the research describe in this paper is to present a framework for selecting an integrated set of sustainability indicators, and results of prototype test in Company ZZ. This paper contributes to the research related to sustainability indicators selection and management, providing a systemized framework for indicators selection that considers its content correlations, and application in different levels (product/service/process), dimensions (economic/environmental/social/

corporative governance), value-chain activities, and current and desired organization´s goals.

## 2. The research project design

Some relevant project activities were developed during the research, and will be detailed in the next sections. The first phase of the research project was developed in the first year of the project and covered:

1. literature review related to sustainable operations management and maturity based models;
2. exploratory case studies in companies that are recognized by their competences in integrating sustainability in their business model for identifying the trajectory they adopted and lessons learned;
3. sustainability indicators generation process prototype based on process-based modeling platform. Fast sustainability diagnostic procedure based on checklist development;
4. technical requirements and specifications elaboration for software development.

The second phase, that takes place in the second year, was oriented to software development and test:

1. indicators information structure (metadata) definition (described in section 2.5);
2. development and test of sustainability indicators correlation algorithm (described in section 2.5);
3. process prototype tests based on sustainability experts and cases;
4. software development and test;
5. training program for process application and sustainability indicators management.

This paper focuses on items 3 and 4 of the first phase, and 1 and 3 in the second phase. Some insights originated from the literature review and case studies insights are presented in section 3. Machado et al. (2012) and Machado et al. (2014) provide more details about research design and results.

The research design is based on action research for developing a process rationality that animates sustainability indicators design. In fact, research is approached by action research and process view.

*2.1 Action Research*

Action research can be considered a case study variation, but different from the case study in the perspective of researcher interference. An action research uses participatory observation, thus in this approach the researcher interferes cooperatively to solve a problem (Mello et al., 2012, Westbrook, 2002).

In this sense, action research works through a cyclical process organized into five steps, illustrated in Figure 1: planning, collecting data, analyzing data and planning actions, implementing actions, assessing results and generating (Mello et al., 2012).

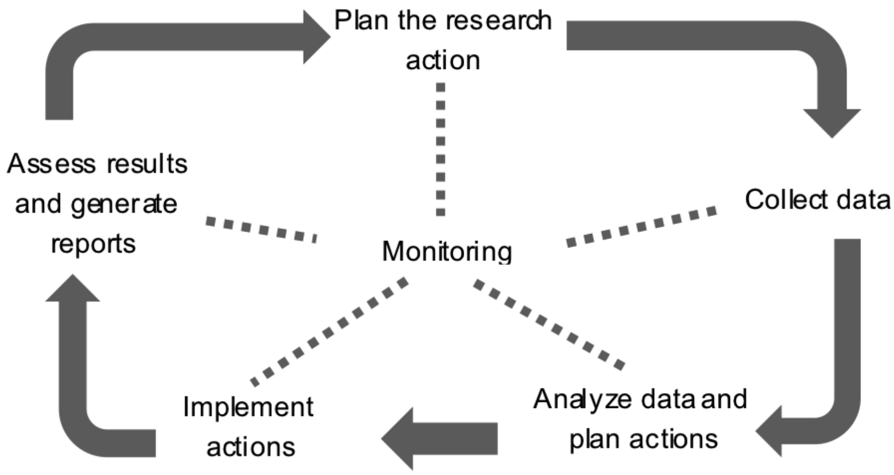



**Fig. 1** - Structuring for action research
Source: Mello et al. (2012)

Figure 1 shows the learning cycle or metaphase that instances the five steps. According to Coughlan and Coughlan (2002), this rationality is responsible for follow-up documentation and learning.

*2.2 Process approach*

The present research adopts the ‘Cambridge Process Approach’ for systematizing sustainability indicators design process. The ‘process approach’ aims to operationalize a conceptual framework, through a structured process based on action research, and by specifying procedures, data collection tools, and participation and project management activities. It shows 'how-to' achieve a desired outcome (Platts, 1994, Platts, 1993, Platts and Gregory, 1990).

Systematization is a key point in 'process approach', being preserved by a set of guidelines presented in Table 2, and by quality criteria defined in terms of feasibility - Can the process be followed?; usability - How easy is it to follow the process?; and utility - Does the process provide useful results? (Platts et al., 1996, Platts, 1993, Platts and Gregory, 1990).

**Table 2** - Process or engineering approach guidelines

| Procedure | Participation | Project Management | Point of Entry |
|---|---|---|---|
| The process is properly defined in terms of organization and operational procedures. | Individual and team based activities interrelates all the involved actors. | It is important to check if all the required resources are addressed and available. | It is important clearly define the scope, content and pretended results of the project. |
| Phases: information searching and scanning; information analysis; change and/or improvement opportunities identification. | The participative characteristics increases: the enthusiasm; the comprehension; and the involvement. | It is important to define: a coordinator group; a support group; and the operational or executive group. | The start and development of the project should have the acknowledgement and concordance of the coordinator group. |
| The applied techniques and tools should be simple enough to attend the requirements of the operational processes. Their use must be easily understood. | The participation 'spaces' could be run through workshop to: achieve the concordance around the objectives of the project; identify and to formally declare the main problems; propose and develop improvement actions; and create a locus for involvement and participation. | The project planning and chronogram should be produced by a participative and consensual process. | It is a necessary condition for the project starting activities that the groups are fully involved and identified with their roles. The coordinator group, especially their leader must receive all the required support from the involved actors. |
| The results of each phase of the project should be documented and reported. | The participative process creates a decision-making forum that guides the actions. | | |

Source: Platts (1993)

*2.3 Business Process Management cycle and Project Management*

The Business Process Management (BPM) cycle is the strategy for creating multiple and successive cycles for improving and refining the process associated to sustainability indicators generation. Baldam et al. (2007) define BPM cycle steps as:

1. Planning: it is related to action plan definition for processes implementation.
2. Modeling and processes optimization: activities that enable them generate information about the current process (‘As Is’) and/or on the proposal for a future process (‘To Be’).
3. Running Processes: activities that ensure processes implementation and execution.
4. Control and data analysis: activities related to the process general control, through various features, such as indicators use, generating information that subsequently will feedback optimization and (re)planning activities.

The BPM cycle is represented in Figure 2.

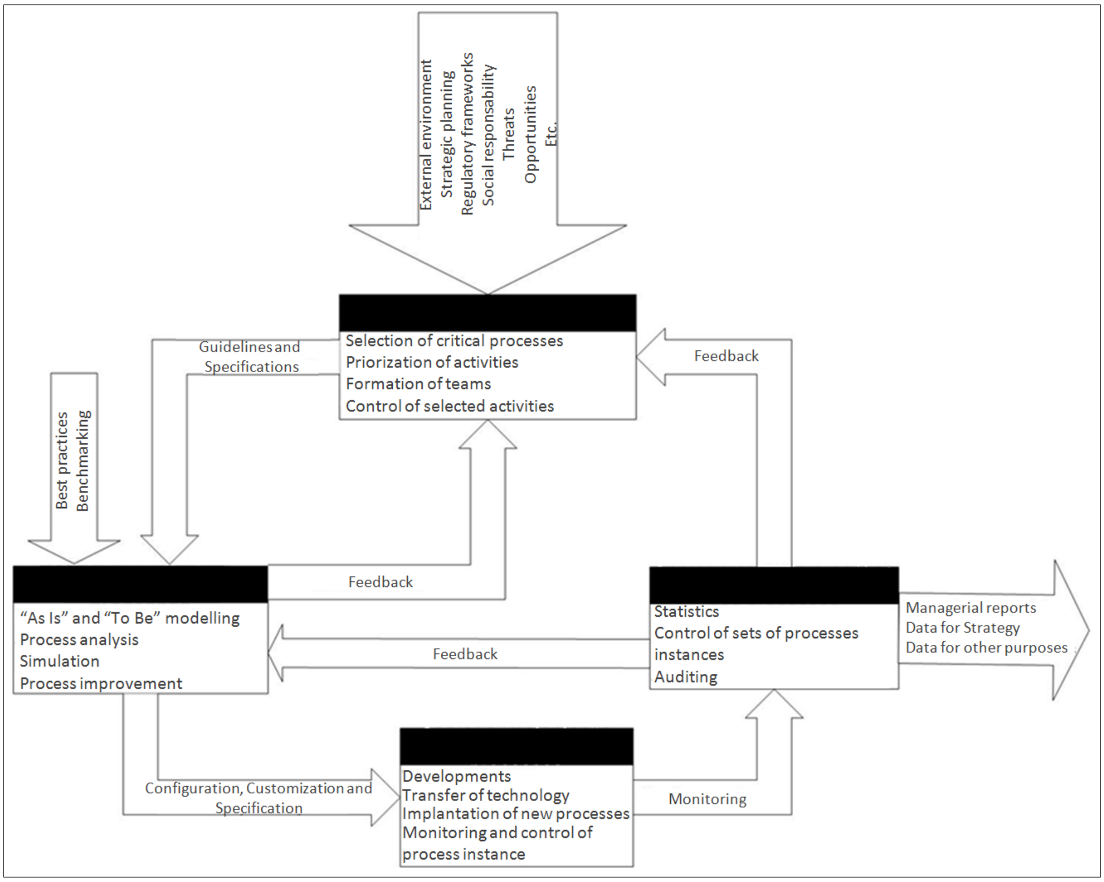



**Fig. 2** - BPM Cycle
Source: Baldam et al. (2007)

Project management is the application of knowledge, skills, tools and techniques to project activities in order to meet its requirements. The information given in PMI guide (PMBoK PMI, 2009) establishes that: "A project is a temporary endeavor undertaken to create a product, service or exclusive result".

The project has a development cycle well defined: opening, development and conclusion. For this reason, it is attributed to the project a temporary nature that does not mean a specific timeframe, but at some point will present a result that defines its conclusion (PMBoK PMI, 2009).

*2.4. A framework for the research approaches*

Based on the presented concepts and models, an initial framework is proposed for organizing hierarchically the disposal of used concepts/applications, as could be seen in Figure 3.

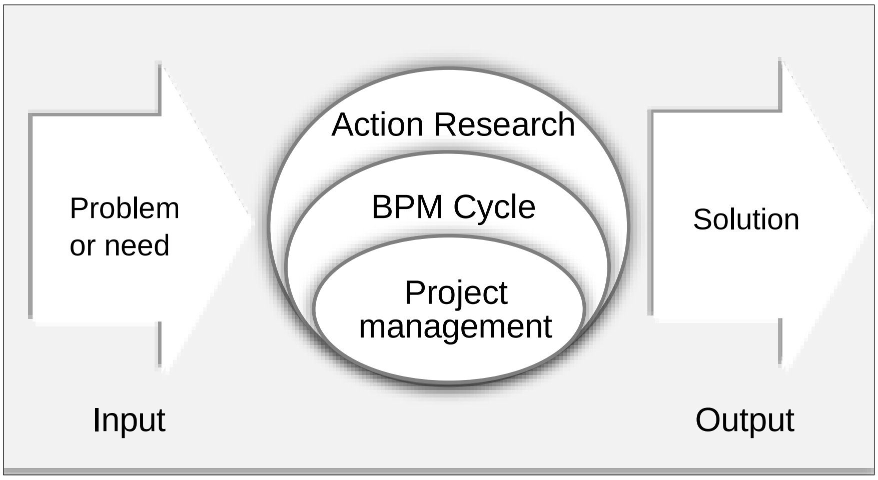



**Fig. 3** - Research design organization
Source: Kluska et al. (2013)

As shown in Figure 3, there are four application layers, one for each element previously presented. A process approach defines connections between ‘input’, through problem requirements, and ‘output’ as solution proposed. Figure 4 is an instance of Figure 3 customized for the presented research, that is, the elements are defined for generating sustainability indicators generation and test.

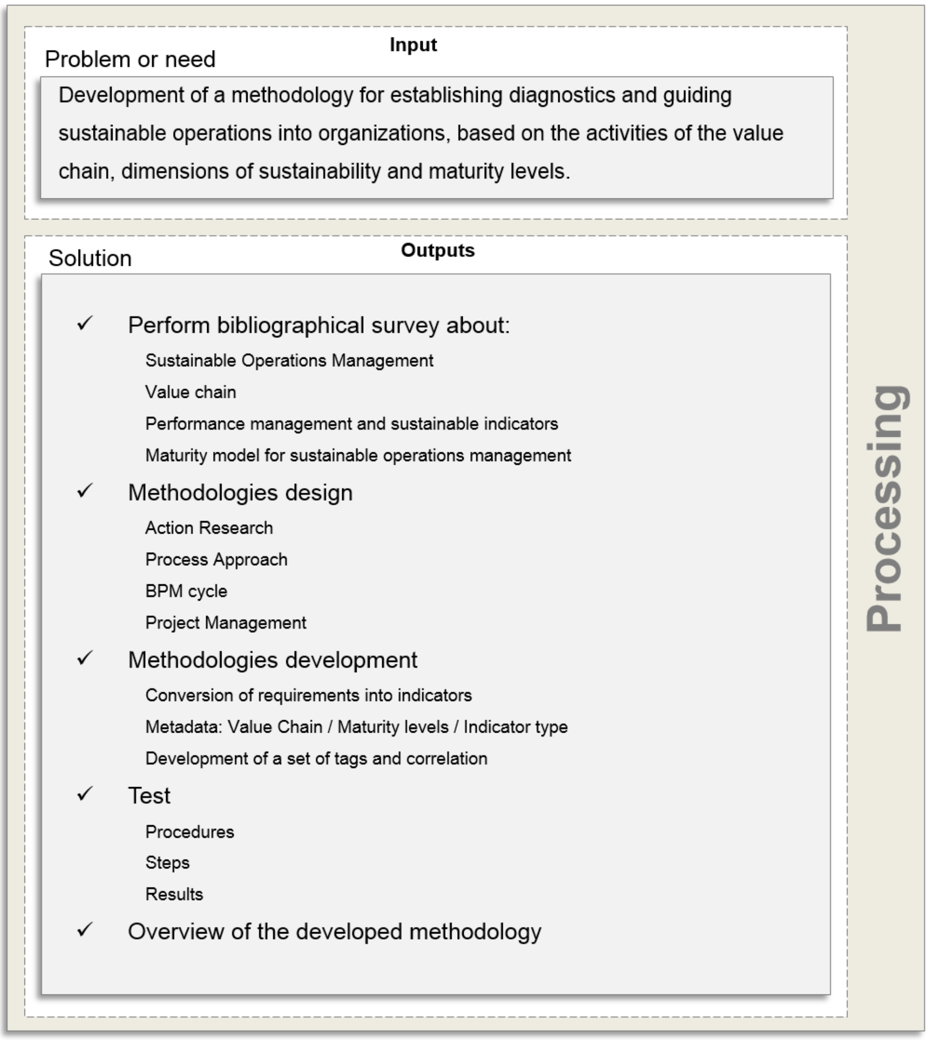



**Fig. 4** - Research design customized activities

It is possible to identify the three basic elements related to 'input', 'processing', and 'output':

- Input: developing a process rationality to support sustainability indicators based on integrated sustainable operations (based on the Triple Bottom Line approach by Elkington (2004)), value chain activities, maturity levels, and performance indicator metadata.
- Processing: action research, BPM cycle and project management are mobilized for generating through multiple tests, improvements and refinements final solutions for each component that is integrated to the final process.
- Output: there are some results that could be characterized by conceptual framework, sustainability 'tag' dictionary, correlation algorithms, software

graphical interfaces and reports, and sustainability indicators generation process.

The next subsections present details about the development of the processes of the conversion of requirements into indicators and correlation.

*2.5 Conversion of requirements into indicators and correlation process*

Organizations find themselves in an ambient of growing competition and exigency. In this context, certifications and standardizations represent a validation, given by external institutions, that the operations associated with the company are in agreement with widely accepted criteria from its clients and suppliers about quality, reliability, environmental and social responsibility (Danvers, 2012, Rosing and Schell, 2013).

However, the management of requirements for certain standards and guidelines needs to be structured, due to the fact that those does not represent formalized indicators, which establish metrics capable of being measured, monitored and managed. There are two critical features of sustainability indicators process/software prototype that must be described. The first challenge is to transform sustainability normative framework requisites into indicators.

The methodology to transform requisites into indicators is fully described by Hundzinski et al. (2013). The authors have concluded that standards and guidelines can be used as triggers for optimization of performance measurement on companies, as long as it supports the business strategies. This is due to the fact that standards and guidelines are able to: assess the organization’s value chain; reflect business and strategic objectives of organizations; relate to an ever-changing environment, with new internal and external demands. The process was developed to transform requisites into indicators based on:

- to attend requisites demands and to allow its management;
- to establish a standard procedure for converting requisites into indicators;
- to have traceability in terms process information flux;
- to enhance liability and consistency through sustainability indicators database.

The process that represents sustainability normative documents requisites conversion into indicators is presented in Figure 5.

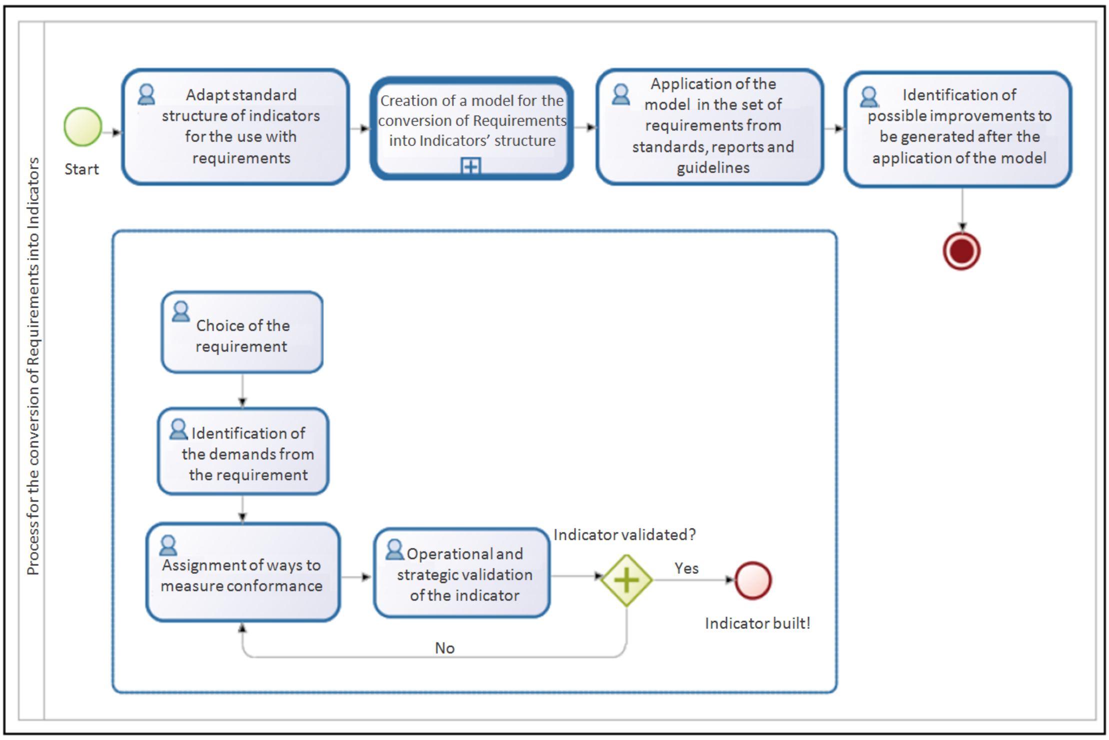



**Fig. 5** – steps to transform requisites conversion into indicators
Source: Hundzinski et al. (2013)

A requisite will be only converted into an indicator if it pass test of being validate in operational and strategic perspectives. Test criteria could be stated as (Kennerley and Neely, 2003):

- Consistency: to be based on actions that requisite looks for developing.
- Accuracy: to guarantee requisite compliance through measurement and assessment.
- Updateness: to create a capability of being continuously updated.
- Traceability: to trace data origin and to connect it to organization target and goals.

The process end when the activity 'identification of possible improvements to be generated after model application' reach an acceptable quality level, that is, the process is repeated through multiple refinements and improvements until indicator validation. The multiple and successive refinements are related to:

- indicators assessment to assure coherence among them and the requisites that they are related to;
- value chain and maturity levels categorization improvement process;
- indicators application classification.

Hundzinski et al. (2013) have provided an example of the methodology using the requisite 4.2.2 from ISO 14001, which was outspread into one indicator of management performance and other related to operations performance. Described on Table 3.

**Table 3** - Example of the methodology results

| ISO 14001 | Objectives | Responsible staff Check / develop measure | Indicator | Indicator category |
|---|---|---|---|---|
| Clause 4.4.2 | Identify and meet training needs | HR employee | Sum of investments on trainings about environmental aspects of operation offered per collaborators per year | Indicator of management performance |
| | Increase competence by training | Quality assurance area | Number of events related to significant environmental impact operations per year | Indicator of operational performance |

Sustainability indicators follow an information structure inspired by Neely et al. (2002), in which several fields that form integrated information set define a performance measure. Figure 6 presents the sustainability indicator record sheet.

| Indicator record | Existing indicator |
|---|---|
| Standard | |
| Requirement | |
| Indicator | |
| Description | |
| Category | |
| Theme | |
| Sub-theme | |
| Dimension | |
| Value Chain | |
| Maturity Level | |
| Type | |
| Correlation | |
| | |
| Propose | |
| Refers to | |
| Target | |
| Formula / Metrics | |
| Frequency of measurement | |
| Frequency of reviews | |
| Who measures? | |
| Data source | |
| Who is responsible for the measurement? | |
| What do they do? | |
| Who act on the data? | |
| What do they do? | |
| Notes and commentary | |

**Fig. 6** - Sustainability indicator record sheet
Source: Neely et al. (2002)

According to Hundzinski et al (2013), this methodology facilitates "the creation of significant KPIs by organization, in relation to its strategic orientation."

### *2.5.1 Development of a set of tags and correlation*

The second challenge for designing and implementing the sustainability indicators generation process is to correlate indicators. Sustainability normative documents have several points in common and the proposed process intends to identify them, and obtain a lean set of sustainability indicators.

For this task, content analysis techniques were applied to the sustainability normative framework in order to identify similar requisites. Coding procedures were used for producing 'comparative' tags, and they are the key element for correlating sustainability indicators. Figure 7 shows the process of tags creation.

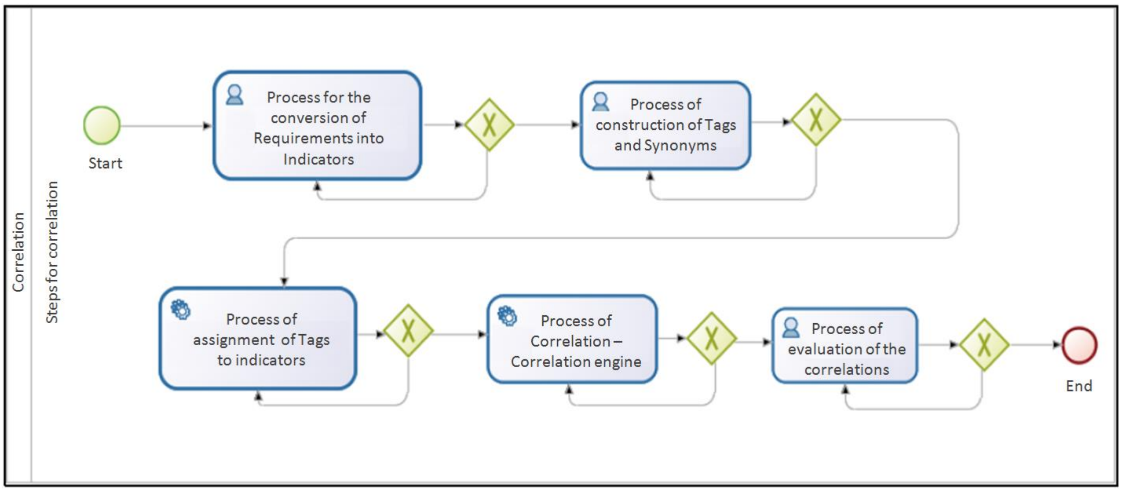



**Fig. 7** - Tag creation process and procedures
Source: Kluska et al. (2013)

Each activity described in Figure 7 is iterative process that follows improvement and refinement cycles. Quality criteria established by sustainability experts define tag creation process end.

Table 4 shows the sustainability normative documents that are integrated by the process/software prototype. The presented documents were analyzed for transforming requisites into indicators, and after that, a correlation algorithm was applied among sustainability indicators database.

Standards glossary and content helped in constructing a tag database that is related to indicators database, being the element that defines indicators similarity. Tags allow the development of a correlation algorithm. Sustainability indicators content correlation is based on correlation and application degrees.

Table 4 - Studied sustainability normative documents

| Document | Characteristics |
|---|---|
| NBR ISO 9001 | Quality Management System |
| NBR ISO 14001 | Enviromental Management System |
| NBR ISO 16001 | Social Responsability Management System |
| NBR ISO 26000 | Guidelines about Social Responsability |
| NBR ISO 50001 | Energy Management System |
| OHSAS 18001 | Health and Occupacional Safety System |
| SA 8000 | Social Responsability |
| Brazilian Agenda 21 | Sustainable Responsability |
| Global Compact | Human Rights, Work Relationships, Environment and Measures against Corruption |
| AA 1000 Accountability | Social Responsability Management |
| Ethos indicators | Corporative Social Responsability |
| GRI (Global Reporting Initiative) | Sustainability Reports |
| ISE – BM&FBOVESPA | Corporate Sustainability, based in Economic Efficiency, Ambiental Balance, Social Justice and Corporate Governance |
| Critérios Rumo à Excelência - FNQ | Organizational Management, aiming to obtain excellence in performance |

Correlation degree measure is applied when two texts are compared in order to know how much they are similar. The values range from 0 to 100% depending on the correlation degree between the texts. Stating:

- Text A= Text that is being compared to the other texts group.
- Text Bn = Group text where similarity comparison is being carried out.

And considering:

- NtA = Number of Tags assigned to text A.
- NtB = Number of Tags assigned to text B.
- NtE = Number of equivalents Tags between the texts.
- NtT = total Tags number of the texts.

$$NtT = NtA + NtB \qquad (1)$$

Being PtE as the percentage of the equivalent Tags number, by the total Tags assigned number to the two indicators.

$$"PtE = " \ "NtE \ x \ 2" \ /"NtT" \ "x100 \ \%" \qquad (2)$$

PtE represents the equivalent tags intercession between the texts, Text A ∩ Text B.

Application degree is used to verify the text application to another text. This correlation analysis model assigns values ranging from 0 to 100% depending on the text application degree. Stating:

- Text A= Text that is being compared to the other group texts.
- Text Bn = Group text where similarity comparison is being undergoing, and the application degree is calculated.

And considering:

- NtA = Number of Tags assigned to text A.
- NtE = Number of equivalents Tags between the texts.
- PAt = Percentage of text application before another text.

$$PAt = \ (NtAx\ 2)/(NtA + NtE)\ \ x\ 100\% \qquad (3)$$

The PAt value represents the text A equivalent tags intercession with the equivalent tags between the texts, Text A ∩ (Text A ∩ Text B).

Figure 8 shows the correlation process based on content analysis. Some elements that are used for operating correlation algorithm are shown, including database use. This feature is critical, since all correlation scripts and assignment work with simultaneous playback loops. The storage architecture offers this possibility.

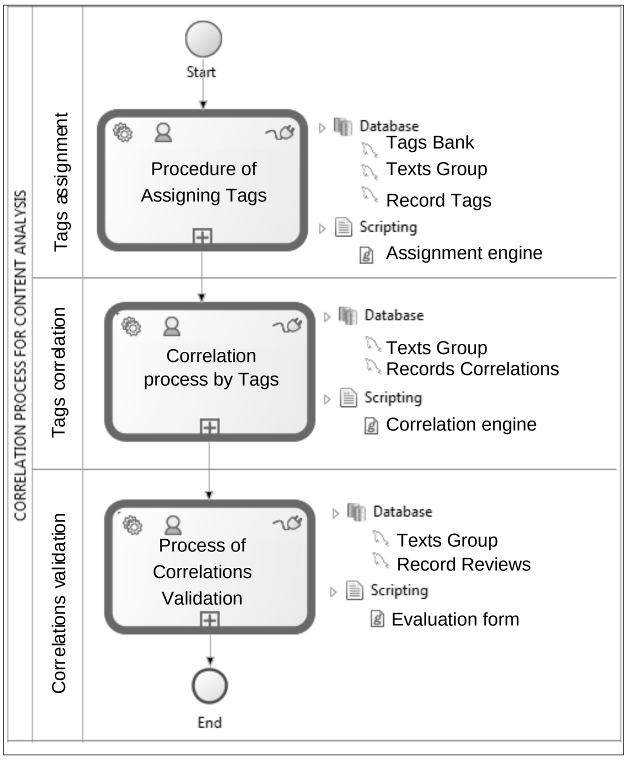



**Fig. 8** - Indicators correlation process
Source: Kluska et al. (2013)

Tables 5 and 6 shows an example of an indicator sheet and correlations generated.

**Table 5** – Indicator record sheet (example)

| **INDICATOR RECORD SHEET** | |
|---|---|
| Standard | ISO 26000 |
| Requisite | 6.3.2.2 |
| Indicator | Respect human rights and contribute to the fulfilment of human rights. |
| Description | This responsibility involves taking positive actions to avoid passive acceptance or active participation in the violation of human rights. To accomplish their responsibility in respecting human rights requires diligence. When Government fails in its duty of human rights protection, organizations may have to take additional responsibilities and actions to ensure human rights to their entire operations network. |
| Category | Social Responsibility |
| Theme | Human Rights |
| Subtheme | Responsibility |
| Dimension | Social |
| Value chain | Firm Infrastructure |
| Maturity Level | Level 3 |
| Type | Tendency |

**Table 6** – Correlations results (example)

| Standards or guidelines | Clause | Indicator | Description | Correlation (%) |
|---|---|---|---|---|
| Global Compact | 1 | Support and respect the protection of internationally proclaimed human rights. | The business community has a responsibility to respect human rights, that is, not to infringe human rights, in the context of their own activities and their business relationships. | 88 |
| Global Compact | 2 | Not complicity in human rights abuse | Avoiding complicity, which is another way, beyond their own direct business activities, that businesses risk interfering with the enjoyment of human rights. | 88 |
| NBR ISO 26000 | 4.8 | Respect for human rights | An organization should respect human rights and recognize both their importance and their universality | 88 |
| NBR ISO 26000 | 6.3.2.1 | Principles of the commitment to human rights | Human rights are inherent, inalienable, universal, indivisible and interdependent: | 85 |
| NBR ISO 26000 | 6.3.5.1 | Avoidance of complicity | An organization may be considered complicit when it assists in the commission of wrongful acts of others that are inconsistent with, or disrespectful of, international norms of behavior that the organization, through exercising due diligence, knew or should have known, could lead to substantial negative impacts on the environment or society. | 77.33 |
| GRI | HR1 | Human Rights | Percentage and total number of significant investment agreements that include human rights clauses or that have undergone human rights screening. | 77.33 |

After presenting the main characteristic of the process/software prototype, it is possible to discuss its application and report the test in a case.

## 3. Theoretical background for framework development

Operations management research on sustainability is strongly influenced by a context defined by sustainable development. The Brundtland report written on 1987 by the World Commission on Environment and Development (WCED), defined sustainable development as “development that meets the needs of the present without compromising the ability of future generations to meet their own needs” (WCED, 1987).

Isaksson and Steimle (2009) highlight that sustainable development is not only a concern for nations but also for companies. They point out importance of big corporation’s in driving sustainable development. The challenge that is presented for companies is not only defined by reducing pollution, but corporate social responsibility (CSR) represents enterprises’ commitment to behave socially and environmentally responsible while achieving their economic goals.

Hasna (2010) comment that sustainability should be approached by companies considering its multiple aspects and dimensions in a coordinated and integrated way, he also observed that the economic system is defined by sustainable development in terms of value creation.

Some international surveys are revealing that companies are integrating sustainability to their strategy and some of them are being called ‘harvesters’ because their approached to sustainability are resulting performance. Governance and leadership constructed based on sustainability principles are changing the way companies are producing value for their stakeholders (Parisi, 2013, Kiron et al., 2012).

Mori and Christodoulou (2012) show that the ‘Triple Bottom Line’ (TBL) framework is important for creating a balanced and integrated vision regarding sustainability. Van Bommel (2011), Ueda et al. (2009), Hutchins and Sutherland (2008), Porter and Kramer (2006) and Wilkinson et al. (2001) integrated sustainability to companies’ strategy, value chain and organizational design using TBL framework and also point out the necessity of coordination.

Labuschagne et al. (2005) show how difficult is to express the concept of sustainability in concrete terms and the synergy proposed by the systems of available indicators still do not adequately meet the needs of decision makers for operations analysis and assessment in terms of internal and external requirements.

Transforming sustainability strategies into actions requires new performance indicators for measuring company performance, and the management model itself also need to be redesigned. It is essential that the strategy, structure and management system be aligned to coordinate actions and motivate the teams in the process of implementing sustainability (McCartney, 2009, Epstein and Roy, 2001).

According to Veleva et al. (2001), sustainability indicators have an important role in assessing companies’ contribution for sustainable development, which is founded in their facilities and operations.

Epstein and Roy (2001) framework shows that each individual company is subject to different contexts and demands from their multiple stakeholders, and that an appropriate set of indicators should be developed for managing theses multiples interests and relationships. According to Keeble et al. (2003), sustainability indicators should be continuously revised in order to keep supplying relevant information to decision makers. Complementing this, Krajnc and Glavic (2005) suggest that sustainability performance indicators be grouped in a single platform to support the decision making process.

To generate sustainability performance indicators some criteria should be observed (Veleva and Ellenbecker, 2001): (i) the indicators should be aligned with sustainable production strategy; (ii) be based on available and liable information; (iii) should be verifiable; (iv) should be composed of key and complementary indicators; (v) contain a significant number of indicators; (vi) be easily applied; (vii) be made up of qualitative and quantitative indicators; (viii) should allow for comparisons; (ix) be close to the main global issues; (x) be aligned with national and local sustainability indicators; (xi) be developed and evaluated with the participation of stakeholders.
For this, the indicators could be based on validated and recognized sources as standards and other normative documents as: Global Reporting Initiative (GRI), ISO 9001, ISO 14001, OHSAS 18001, ISO 26000, ISO 14040, Agenda 21, Global Compact etc. (Louette, 2008).

Thus, to assess sustainable operations performance, sustainability indicators must be logical and traceable in order to be replicated and comparable. Furthermore, data collecting instruments should be certified to guarantee robustness and reliability, in addition to this, sources of information and margins of error in measurement should be clearly expressed (Kleindorfer et al., 2005, Kennerley and Neely, 2003). For this, it is essential that sustainability indicators be integrated horizontally throughout company value chain, and also represent strategy deployment as a reflection of strategic positioning and objectives (Hart and Milstein, 2003, Krajnc and Glavič, 2005).

Value chain, system of value chains, supply chain and production network are organizational structures that represent material and informational flow. Sustainability should be constructed through value creation and must be embedded in products and production processes. Sustainability indicators should be correlated to activities developed in companies' value chain (Leppelt et al., 2013, Ueda et al., 2009, Nidumolu et al., 2009, Porter and Kramer, 2006).

*3.2 Maturity levels for sustainable operations management*

According to Veleva et al. (2001) sustainable systems follow a continuous and evolutionary "[...] starting at different places in the evolutionary process". This means that a company can adapt its strategies and operations model to an evolving path towards high levels of sustainability. The companies should face the challenge of developing assessment and auditing systems that make it possible to identify the point of departure and evaluate progress through maturity levels (Software Engineering Institute, 1995).

Deloitte use maturity based models for creating competitive advantage "[...] the goal should be to embed sustainability considerations into a company’s strategy and operations in such a way as to enhance business value and derive a competitive advantage" (Mani et al., 2010).

In 1995, the Software Engineering Institute (SEI) at Carnegie Mellon University published the book 'The Capability Maturity Model (CMM): guidelines for improving the software process' focusing on the contribution of improving processes in an organization based on the evolutionary path from immature to mature and disciplined processes. Since then, various CMM's have evolved and have been developed for various fields and applications that inspired in CMM structure and processes (Software Engineering Institute, 1995, Veleva and Ellenbecker, 2001, Veleva et al., 2001, Cagnin et al., 2005, Pinheiro de Lima et al., 2012).

According to Pinheiro de Lima et al. (2012) and Machado et al. (2013), the Sustainable Operations Maturity Model (SOMM) could be defined by five maturity levels: Compliance; Internal Neutrality; Process Management; Operations Network Management; and, Strategic Integration, as presented in Figure 9.

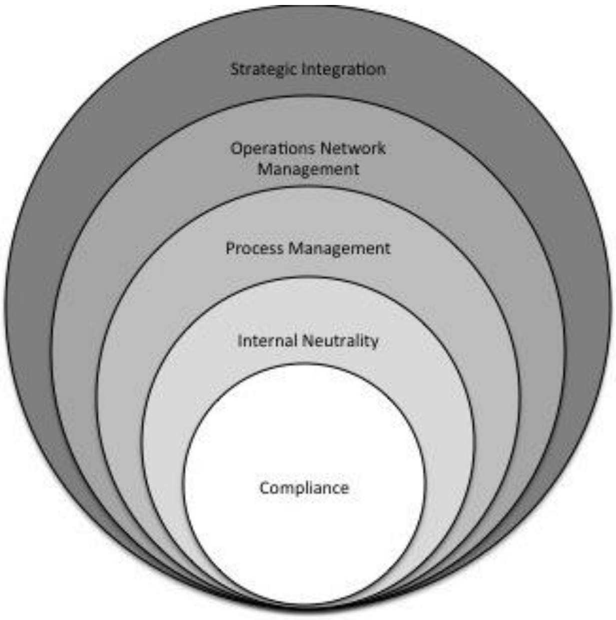



**Fig. 9** - Sustainable operations maturity model
Source: Machado et al. (2013)

SOMM 5 maturity levels could be described as follow:

- Level 1 - Compliance: The central focus is on compliance with legislation and other normative demands related to the functioning of the business. Reacting to regulatory pressure, for businesses operating at level1 there is no leadership or formal support from senior management on the issue of sustainability and the operational processes and business strategies are not carried out in an integrated manner.
- Level 2 - Internal Neutrality: In addition to the pressure of legal compliance, here there is a need to monitor the efficiency and productivity of internal operations. Topics and opportunities for sustainability are on the radar, but no effective action is taken, except for a few isolated environmental demands.
- Level 3 - Process Management: Operations are seen as an integrated unit and start to be conducted through management systems. New processes aimed at environmental and social issues are adapted based on compliance and cost, but they are not aligned with other processes and the decisions for sustainability are focused on balancing risk/reward. There is a change of posture from reactive to responsive where there is an intention to seek coherence in company activities.

- Level 4 - Operations Network Management: The company starts to include sustainability as part of its DNA (strategy) and implement corporate governance practices, both in its structure and its performance within the value chain. Integrated organizational alignment to deal with themes and the articulating of systems and processes. Sustainability is integrated with the needs of clients and the company’s target is to improve its socio-environmental sustainability, including positive aspects and impacts.
- Level 5 - Strategic Integration: senior management designs Sustainability initiatives and become business models focused on the continuous improvement of practices and processes. Strategies and activities are aligned and integrated throughout the network and sustainability is widely communicated within the supply chain and among stakeholders. Economic value is added through initiatives that benefit interested parties and the vision of sustainability goes beyond the level of costs and risks to perceive investments and opportunities (revenue, innovation and productivity).

*3.3 Conceptual framework for sustainability indicators generation*

The conceptual model presented in this paper that support sustainability indicators generation is based on extended view of TBL that includes Governance, correlated to value chain activities and organized according to a maturity based model. The process for producing sustainability indicators result in a ‘meta data’ set defined by Neely et al. (1997) framework.

Figure 10 summarizes the conceptual framework that theoretically supports the presented research.

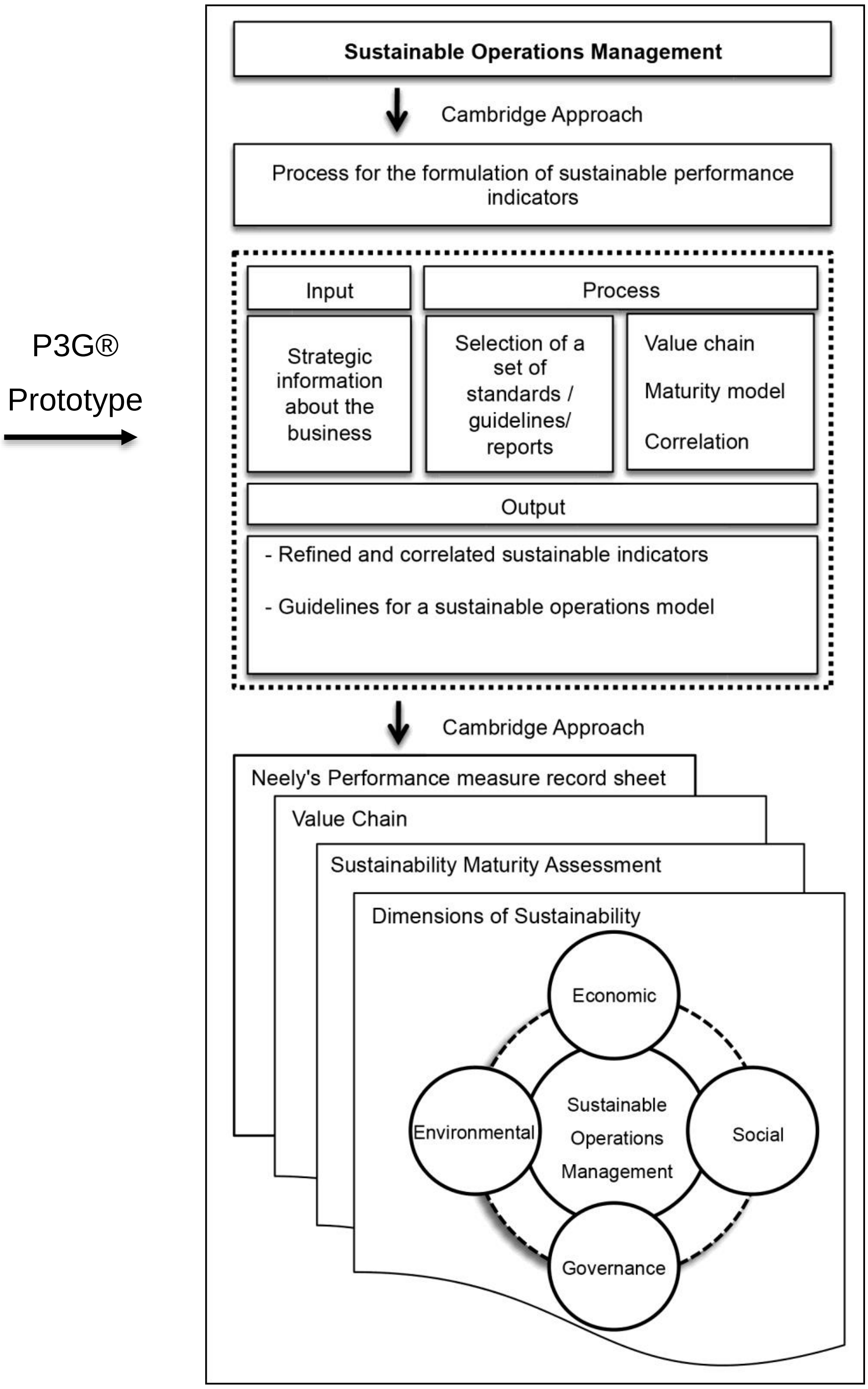



**Fig. 10** - Conceptual framework for sustainability indicators generation

The conceptual framework follows a simple input/process/output structure, defining as:

- input: business strategy definitions, sustainability scope (economic, environmental, social, and governance), value chain scope, and normative documents and standards scope.

- process: defines how the inputs could be synthesized in coherent set of measures, that is, transforming normative documents and standards requisites in measure specifications.
- output: organizes information for publishing sustainability measures, as well some graphics to represent relationships among the designed measures and TBL dimensions, value chain activities and maturity levels.

**4. Prototype application and discussion of the results**

The test conducted in Company ZZ was planned according the following activities:

1. Sustainability diagnostic survey application.
2. Inputs formalization to orient the process of generating sustainability indicators.
3. Assessment of sustainability indicators generated list in terms of present and desired situations.
4. Sustainability indicators assessment report workshop.
5. Workshop for completing sustainability indicators record information sheet.

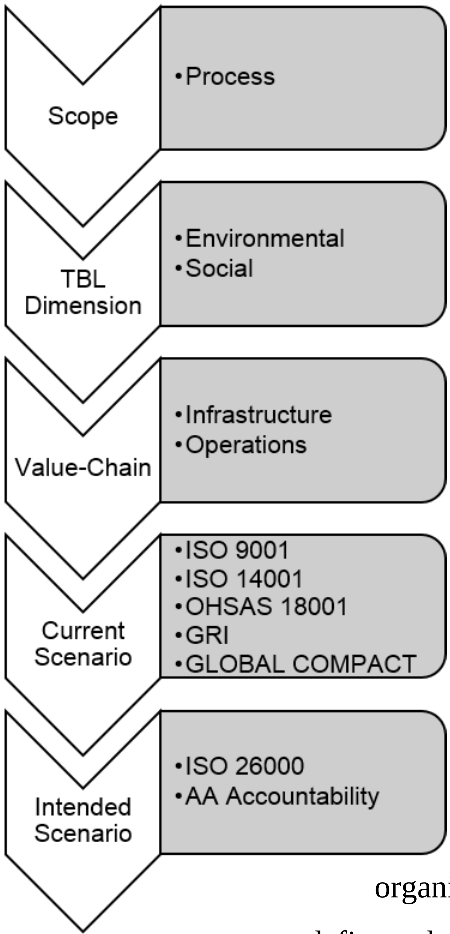
Company ZZ is a global leader in sustainable forest products development. The company has been operating in this business for the last five decades, and its mission is founded in creating forests product value in a sustainable way, integrating high standards in forestry production with efficiency in industrial transformation, for its global distribution in accordance with its customer's needs.

An online questionnaire with twenty questions was applied. The questions encompass topics about compliance, policies and commitments, certifications and management systems. The Company obtained 95 points in a 100 points scale in sustainability diagnostic survey that is one of the first activities in prototype test.

According a pre-defined scale, the results pointed that Company ZZ has a strong direction for sustainability. The only question in which the company has no score was a question related to social responsibility policy. Although it does not have yet formal Corporate Social Responsibility (CSR) policies, it attends a complete set of requirements related to TBL and Governance best practices. Based on this result, Company ZZ established its inputs.

*4.1 Inputs formalization to orient the process of generating sustainability indicators*

After completing sustainability diagnosis survey, it was possible for the company to define inputs for prototype test. This phase was conducted in a logic "As Is" - "To Be". The inputs are illustrated in Figure 11 and described by:




- Scope: Company is required to select product, process or a service perspective. This information helps researchers in the coaching process. Company ZZ selected a <u>process perspective</u>.
- Extended TBL dimensions: depending on company strategy and maturity level, it could choose to work with the entire set of social, environmental, economic and governance dimensions, or a subset. Company ZZ exercise was <u>focused on social and environmental dimensions</u>
- Value chain activities: Inbound logistics, operations, outbound logistics, marketing and sales, after sales, infrastructure (technology and organizational), human resources management, and procurement, define value chain activities and the company could select the ones to be studied. Company ZZ selected <u>infrastructure and operations</u> to be studied.
- Present situation (As Is): Company present situation in terms of implementing sustainability normative framework. <u>ISO 9001, ISO 14001, OHSAS 18001, GRI, and Global Compact</u> define its present normative model.
- Future situation (To Be): Company desired situation in terms of implementing sustainability normative framework. Company <u>selected ISO 26000 and AA 1000 AccountAbility</u> to be included in its sustainability normative model.

*4.2 Results and scenario analysis for sustainability indicators generation*

Some general results could be summarized from case application:

- Sustainability diagnostic survey identified opportunities for integrating new sustainability indicators in the social perspective.
- The entire set of proposed sustainability indicators is formed by a list of 176 elements The indicators record sheet were presented in a workshop, and the firm identified 76 sustainability indicators that are already implemented and managed, forming the 'As Is' group (see Appendix A). According to the data presented in the indicators record sheet, the 'As Is' group is formed by 40 indicators related to social aspects and 36 to environmental ones. Thus, the set of indicators is balanced.
- It is intended to adopt more 100 indicators that form the group 'To Be' (see Appendix B). In 'To Be' group, 88 indicators are related to social aspects and 12 to environmental issues. The company has developed over years, competences for managing the environmental aspects, but it does not have the same maturity in social dimension. Social dimension is related to internal and external issues.
- Performing a maturity analysis in pretended scenario 'To Be', it could be seen that company will be positioned between levels 4 and 5, indicating that its business model and strategy are defined by sustainability concepts.
- Situation 'As Is' reveal that company already attended 22% of ISO 26000 requirements. For compiling a GRI report, 51% of required information is available and integrated to the sustainability management system. For UN Global Compact company attends 57% of its requisites.
- Analyzing 'As Is' situation it could be observed that sustainability indicators are oriented to operations, infrastructure and human resources value chain activities. 'To Be' scenario includes inbound logistics (suppliers), sales and marketing, and intensify internal social aspects of human resources management and operations value chain activities.

Two scenarios could be organized using information obtained through test application. They are projections based on the selected regulatory framework, that is: GRI - Global Reporting Initiative, NBR ISO 14001, Global Compact, OHSAS 18001, NBR ISO 26000, NBR ISO 9001 and AA 1000 AccountAbility.

Scenario 1 is based on the 7 selected documents and not using any restriction in terms of TBL aspects or value chain activities. It could be taken as the complete sustainability performance measurement system. There complete input forms a set of 304 indicators. Table 7 shows some numbers analyzing correlation among the indicators.

It could be seen that 154 indicators is the set that ‘points to’ at least one indicators in the sustainability regulatory database, that is, in the worst situation it could be possible to have 77 indicators to manage all requisites that are contained in these indicators. 117 represent the set of indicators that are not pointed by any other indicators in the sustainability regulatory database. If it is summed 117 as minimum set of individual indicators and 77 as the lean set of correlated indicators, the worst situation forms a set of 194 indicators for managing the sustainability integrated system.

Scenario 2 is formed by Company ZZ choices in terms of TBL aspects and value chain activities. The total number of possible indicators decreased to 176, and Table 8 shows the improvements that could be obtained through correlation algorithm application.

Table 7 – Scenario 1: sustainability performance measurement system

| | |
|---|---|
| **Correlation algorithm output** | |
| 92416 | Total* |
| **Complete scenario considering all extended TBL dimensions and value chain activities** | |
| 304 | Total number of possible indicators |
| 154 | Indicators that are correlated to another indicator in the selected regulatory framework |
| 150 | Indicators that are **not** correlated to another indicator in the selected regulatory framework |
| 187 | Indicators that are correlated by another indicator in the selected regulatory framework |
| 117 | Indicators that are **not** correlated by another indicator in the selected regulatory framework |
| 194 | Minimum set of indicators that covers the selected regulatory framework |
| **Indicators improvement analysis** | |
| 36,20% | Improvement rate |
| 51% | Number of indicators that have any correlation |
| 61,50% | Number of indicators represented in regulatory framework |

* Correlation calculations provided by current scenario plus the desired one – pairs of possible indicators.

Table 8 – Scenario 2: sustainability performance measurement system

| | |
|---|---|
| **Correlation algorithm output** | |
| 30976 | Total * |
| **Reduced scenario considering a selected number of extended TBL dimensions and value chain activities** | |
| 176 | Total number of possible indicators |
| 85 | Indicators that are correlated to another indicator in the selected regulatory framework |
| 91 | Indicators that are **not** correlated to another indicator in the selected regulatory framework |
| 99 | Indicators that are correlated by another indicator in the selected regulatory framework |
| 77 | Indicators that are **not** correlated by another indicator in the selected regulatory framework |
| 120 | Minimum set of indicators that covers the selected regulatory framework** |
| 56 | difference between indicators that meet and that are serviced |
| **Indicators improvement analysis** | |
| 48% | Number of indicators that have any correlation |
| 56,3% | Number of indicators represented in regulatory framework |
| 68% | Number of indicators required to be managed |
| 32% | The reduction of indicators |

* Correlation calculations provided by current scenario plus the desired one – pairs of possible indicators.
** Number of indicators required to meet current and desired scenarios, the other 56 indicators can be fulfill "automatically".

Scenarios 1 and 2 show improvement potential in terms of indicators number by running a correlation algorithm. It is clear for these two case an improvement rate of 30%, but if an individual indicator analysis is performed the improvement rate tends to be better.

## 5. Conclusion

The research question proposed for this research was answered through P3G® prototype test, which results showed that an integrated set of sustainability indicators could originated and updated from the regulatory framework that encompass an extend view of sustainability dimensions.

The sustainability indicators selection and integration was optimized through a correlation process and detailed by a record sheet that could be understood as a metadata indicator.

The test shows that the developed process could generate an integrated and 'lean' set of sustainability indicators. Improvements opportunities are identified, specially those ones related to the sustainability diagnostic survey and the indicators correlation model. The process could allow company ZZ to simulate different conditions in terms of scope to develop its sustainability indicators, creating conditions for learning and improvement.

In terms of methodology, procedures developed follow systemic requirements for action research conduction, and the multiple and successive refinement and learning loops or cycles assured results quality. It is important to observe that BPM cycle model with its intrinsic improvement characteristic is a key characteristic for indicators design, and its presence is verified in different levels from requisites, tags and indicators generation.

Reaching sustainability maturity levels 4 and/or 5 should be a strategic goal for companies that intends to integrate sustainability to their business models. Companies in levels 4 and 5 developed their sustainability management system and are able to define their business based on sustainability values, but could also establish sustainability as factor for differentiate them in competition.

Companies that are qualified to apply the process could reach: (i) Competence for identifying indicators for new certification implementation processes; (ii) Shorten time required for implementing new elements in sustainability regulatory framework (standards, reference documents and report guidelines); (iii) Low cost for implementing a new process and/or certification; (iv) Simplification in maintaining and actualizing the sustainability regulatory framework; (v) Integrated management for sustainable operations.

The process and software prototype require more cases for testing and stressing 'extreme' situations in terms of scope complexity. The system should be viewed as a supporting tool for creating and testing indicators specification or content. Future works are being planning for improving correlation algorithm and automating indicators record sheet fulfillment. These clear benefits contribute for a lean process in managing sustainability, and the management is essentially defined through measurement.

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Appendix A

**SET OF CURRENT INDICATORS**

| | |
|---|---|
| 1 | NBR ISO 26000\|6.6.1.1 |
| 2 | NBR ISO 26000\|6.6.1.2 |
| 3 | NBR ISO 26000\|6.4.5.2 |
| 4 | NBR ISO 26000\|7.8 |
| 5 | NBR ISO 26000\|7.7.2 |
| 6 | NBR ISO 26000\|7.7.1 |
| 7 | NBR ISO 26000\|7.6.2 |
| 8 | NBR ISO 26000\|7.6.1 |
| 9 | NBR ISO 26000\|7.4.3 |
| 10 | NBR ISO 26000\|7.4.2 |
| 11 | NBR ISO 26000\|7.4.1 |
| 12 | NBR ISO 26000\|7.3.3 |
| 13 | GRI\|SO5 |
| 14 | GRI\|EN21 |
| 15 | GRI\|EN22 |
| 16 | GRI\|EN24 |
| 17 | GRI\|EN25 |
| 18 | GRI\|EN23 |
| 19 | GRI\|EN19 |
| 20 | GRI\|EN20 |
| 21 | GRI\|EN18 |
| 22 | GRI\|EN17 |
| 23 | GRI\|EN16 |
| 24 | GRI\|EN10 |
| 25 | GRI\|EN9 |
| 26 | GRI\|EN8 |
| 27 | GRI\|EN7 |
| 28 | GRI\|EN3 |
| 29 | NBR ISO 26000\|6.5.3.2 |
| 30 | NBR ISO 26000\|6.5.3.1 |
| 31 | NBR ISO 26000\|6.5.2.1 |
| 32 | NBR ISO 26000\|4.2 |
| 33 | Pacto Global\|8 |
| 34 | GRI\|EN30 |
| 35 | Pacto Global\|9 |
| 36 | NBR ISO 26000\|4.3 |
| 37 | Pacto Global\|7 |
| 38 | OHSAS 18001\|4.1 |
| 39 | OHSAS 18001\|4.2 |
| 40 | OHSAS 18001\|4.3.1 |
| 41 | OHSAS 18001\|4.3.2 |
| 42 | OHSAS 18001\|4.3.3 |
| 43 | OHSAS 18001\|4.4.1 |
| 44 | OHSAS 18001\|4.4.4 |

| | |
|---|---|
| 45 | OHSAS 18001\|4.4.5 |
| 46 | OHSAS 18001\|4.4.6 |
| 47 | OHSAS 18001\|4.4.7 |
| 48 | OHSAS 18001\|4.5.1 |
| 49 | OHSAS 18001\|4.5.2 |
| 50 | OHSAS 18001\|4.5.3.1 |
| 51 | OHSAS 18001\|4.5.3.2 |
| 52 | OHSAS 18001\|4.5.4 |
| 53 | OHSAS 18001\|4.5.5 |
| 54 | NBR ISO 14001\|4.1 |
| 55 | NBR ISO 14001\|4.2 |
| 56 | NBR ISO 14001\|4.3.1 |
| 57 | NBR ISO 14001\|4.3.2 |
| 58 | NBR ISO 14001\|4.3.3 |
| 59 | NBR ISO 14001\|4.4.1 |
| 60 | NBR ISO 14001\|4.4.4 |
| 61 | GRI\|SO1 |
| 62 | NBR ISO 14001\|4.4.5 |
| 63 | NBR ISO 14001\|4.4.6 |
| 64 | NBR ISO 14001\|4.4.7 |
| 65 | NBR ISO 14001\|4.5.1 |
| 66 | NBR ISO 14001\|4.5.2/4.5.2.1/4.5.2.2 |
| 67 | NBR ISO 14001\|4.5.3 |
| 68 | NBR ISO 14001\|4.5.4 |
| 69 | NBR ISO 14001\|4.5.5 |
| 70 | NBR ISO 14001\|4.6 |
| 71 | NBR ISO 26000\|7.7.3 |
| 72 | NBR ISO 26000\|7.6.3 |
| 73 | NBR ISO 26000\|6.5.2.2 |
| 74 | NBR ISO 26000\|6.5.6.2 |
| 75 | GRI\|EN28 |
| 76 | NBR ISO 26000\|6.3.6.2 |

Appendix B

**SET OF INTENDED INDICATORS**

| | |
|---|---|
| 1 | OHSAS 18001\|4.6 |
| 2 | Pacto Global\|1 |
| 3 | Pacto Global\|2 |
| 4 | Pacto Global\|4 |
| 5 | Pacto Global\|5 |
| 6 | NBR ISO 26000\|4.1 |
| 7 | NBR ISO 26000\|4.4 |
| 8 | NBR ISO 26000\|4.5 |
| 9 | NBR ISO 26000\|4.6 |
| 10 | NBR ISO 26000\|4.7 |
| 11 | NBR ISO 26000\|4.8 |
| 12 | NBR ISO 26000\|5.1 |
| 13 | NBR ISO 26000\|5.2.1 |
| 14 | NBR ISO 26000\|5.2.2 |
| 15 | NBR ISO 26000\|5.2.3 |
| 16 | NBR ISO 26000\|5.3.1 |
| 17 | NBR ISO 26000\|5.3.2 |
| 18 | NBR ISO 26000\|5.3.3 |
| 19 | NBR ISO 26000\|6.1 |
| 20 | NBR ISO 26000\|6.2.1.1 |
| 21 | NBR ISO 26000\|6.2.1.2 |
| 22 | NBR ISO 26000\|6.2.2 |
| 23 | NBR ISO 26000\|6.2.3.1 |
| 24 | NBR ISO 26000\|6.2.3.2 |
| 25 | NBR ISO 26000\|6.3.1.1 |
| 26 | NBR ISO 26000\|6.3.1.2 |
| 27 | NBR ISO 26000\|6.3.2.1 |
| 28 | NBR ISO 26000\|6.3.2.2 |
| 29 | NBR ISO 26000\|6.3.3.1 |
| 30 | NBR ISO 26000\|6.3.3.2 |
| 31 | NBR ISO 26000\|6.3.4.2 |
| 32 | NBR ISO 26000\|6.3.5.1 |
| 33 | NBR ISO 26000\|6.3.5.2 |
| 34 | NBR ISO 26000\|6.3.6.1 |
| 35 | NBR ISO 26000\|6.3.7.1 |
| 36 | NBR ISO 26000\|6.3.7.2 |
| 37 | NBR ISO 26000\|6.3.8.2 |
| 38 | NBR ISO 26000\|6.3.9.2 |
| 39 | NBR ISO 26000\|6.3.10.2 |
| 40 | NBR ISO 26000\|6.4.6.2 |
| 41 | NBR ISO 26000\|6.5.1.1 |
| 42 | NBR ISO 26000\|6.5.1.2 |
| 43 | NBR ISO 26000\|6.5.4.1 |
| 44 | NBR ISO 26000\|6.5.4.2 |
| 45 | NBR ISO 26000\|6.5.5.2.1 |

| | |
|---|---|
| 46 | NBR ISO 26000\|6.5.5.2.2 |
| 47 | NBR ISO 26000\|6.5.6.1 |
| 48 | NBR ISO 26000\|6.6.2 |
| 49 | NBR ISO 26000\|6.6.3.2 |
| 50 | NBR ISO 26000\|6.6.4.1 |
| 51 | NBR ISO 26000\|6.6.4.2 |
| 52 | NBR ISO 26000\|6.6.5.1 |
| 53 | NBR ISO 26000\|6.6.5.2 |
| 54 | NBR ISO 26000\|6.6.6.1 |
| 55 | NBR ISO 26000\|6.6.6.2 |
| 56 | NBR ISO 26000\|6.6.7.1 |
| 57 | NBR ISO 26000\|6.6.7.2 |
| 58 | NBR ISO 26000\|6.7.7.1 |
| 59 | NBR ISO 26000\|6.7.7.2 |
| 60 | NBR ISO 26000\|6.7.8.1 |
| 61 | NBR ISO 26000\|6.7.8.2 |
| 62 | NBR ISO 26000\|6.8.1 |
| 63 | NBR ISO 26000\|6.8.2.1 |
| 64 | NBR ISO 26000\|6.8.2.2 |
| 65 | NBR ISO 26000\|6.8.3.1 |
| 66 | NBR ISO 26000\|6.8.3.2 |
| 67 | NBR ISO 26000\|6.8.4.2 |
| 68 | NBR ISO 26000\|6.8.5.2 |
| 69 | NBR ISO 26000\|6.8.6.2 |
| 70 | NBR ISO 26000\|6.8.7.1 |
| 71 | NBR ISO 26000\|6.8.7.2 |
| 72 | NBR ISO 26000\|6.8.8.1 |
| 73 | NBR ISO 26000\|6.8.8.2 |
| 74 | NBR ISO 26000\|6.8.9.1 |
| 75 | NBR ISO 26000\|6.8.9.2 |
| 76 | NBR ISO 26000\|7.2 |
| 77 | NBR ISO 26000\|7.3.1.1 |
| 78 | NBR ISO 26000\|7.3.1.2 |
| 79 | NBR ISO 26000\|7.3.2.1 |
| 80 | NBR ISO 26000\|7.3.2.2 |
| 81 | NBR ISO 26000\|7.7.4 |
| 82 | NBR ISO 26000\|7.7.5 |
| 83 | GRI\|EN1 |
| 84 | GRI\|EN2 |
| 85 | GRI\|EN4 |
| 86 | GRI\|EN5 |
| 87 | GRI\|EN6 |
| 88 | GRI\|EN11 |
| 89 | GRI\|EN12 |
| 90 | GRI\|EN13 |
| 91 | GRI\|EN14 |
| 92 | GRI\|EN15 |
| 93 | GRI\|EN26 |

| | |
|---|---|
| 94 | GRI\|EN29 |
| 95 | GRI\|LA5 |
| 96 | GRI\|SO2 |
| 97 | GRI\|SO4 |
| 98 | GRI\|SO6 |
| 99 | GRI\|SO7 |
| 100 | GRI\|SO8 |

# APPENDIX 2

RESEARCH PROTOCOL CASE STUDIES – INTERVIEW

Company name:

Area of activity:

Address:

Web site:

Number of employees (direct and indirect):

Revenue (last year):

Main markets (internal and external):

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Name of respondent:

Function/Position:

Involvement in sustainable initiatives:

Number of years in function/position:

Year entered the company:

Email:

Telephone:

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1. Is the issue of sustainability embedded in the company's business strategy? If so, when did the company begin to take this stance?
2. In your opinion, what were the company's reasons for adopting sustainable policies?
3. Besides voluntary certifications, is the company a signatory to any international commitments? If so, what were the motives for doing so, and how were the guidelines of these certifications/commitments incorporated into the business strategy?
4. Is there is a sustainability committee or an area responsible for the strategic issue of sustainability? If so, to whom do they report?
5. Is there an area responsible for certification, where the management of the indicators is centered? If not, how is this accomplished?
6. How were the certification processes conducted (individually or simultaneously)?
7. Would the company recommend a path toward obtaining certifications aimed at management with a focus on sustainability?
8. Which areas are responsible for managing the company's indicators? Is there a distinction between the management of operational indicators and sustainability indicators?
9. In your opinion, what are the barriers to implementing sustainable management practices in the company?
10. In your opinion, what are the economic impacts of adoptinggreen policies in the company?
11. Does the company have some recognition of the corporate governance system?

12. What prompted the company to disclose its sustainability report? Why did the company choose GRI as the model for promoting its sustainable management results?
13. Are the GRI indicators used in the organization's routine, or are the indicators used in routine operations translated/adapted to create the GRI report?
14. Does the company measure the economic impacts of adopting sustainable practices? If so, how is this done, and what are the significant impacts?
15. Does the company use the principles of *Life Cycle Assessment (LCA)* to measure the impact of products and processes throughout the entire life cycle?
16. Does the company have plans to pursue a new certification or seal?

# RESEARCH PROTOCOL CASE STUDIES – TECHNICAL VISIT

## Evidence to be collected during the technical visit

| Question | Researcher's notes |
|---|---|
| 1. In what markets does the company compete, and what is its position in relation to the competition? | *Confirm the deciding factors that impact the company's competitiveness (ex. Price differentiation).* |
| 2. How is the plant divided operationally? | *Evaluate how the plant is structured or divided in order to meet different types of demands related to products/applications/clients.* |
| 3. Is there evidence that the strategy is being communicated on the factory floor? | *Verify existence of banners, charts, newsletters, or other forms of communicating the strategic objectives of the operation.* |
| 4. What are the priorities in the plant's operations? | *Cost? Flexibility? Quality? Speed? Cutting waste?* |
| 5. Are the shop floor employees in line with the operational priorities? | *Verify evidence of practices and ask the operators (for example, verify the existence of mechanisms to reduce defects and waste, etc.).* |
| 6. Do the operations meet the company's stated objectives? | *Verify evidence of practices that support the company's mission/strategic goals.* |

Structural alignment

| Question | Researcher's notes |
|---|---|
| 1. Are the plant's equipment/systems adequate to implement the operational objectives and priorities? | *Verify how well the physical structure is suited to the strategy; analyze the speech of the person conducting the tour.* |
| 2. What were the most recent investments in equipment/systems? | *Look for evidence that the investments that were made are aligned with the strategic objectives of the operations.* |
| 3. Is there any feature of the equipment/systems that increases or decreases the plant's expected performance? | *Verify evidence and analyze the speech of the person conducting the tour (do not only focus on whether things work well, but look for evidence of major investments in "big" and equipment/complex systems that when implemented are expected to solve the plant's problems).* |
| 4. Are plant operations interconnected with the information system used by the company? | *Verify evidence at the supervisory level, control level, and automation level. It is important to know what types of systems (operational and management) are used.* |
| 5. How well is the plant managed? | *Check for evidence of good management (e.g. excessive losses and high variability in processes may be signs of poor/problematic process management).* |

Trajectory of improvements

| Question | Researcher's notes |
|---|---|
| 1. Is there clear guidance for improvements in the process? | *Try to identify the goals for improvement and verify which area(s) is considered the primary focus for improvement.* |
| 2. What demands for improvement have been imposed by the company's competitive environment? | *Try to identify external factors that may affect the operation (equipment/systems/quality criteria/environmental management and socioeconomic/legislation etc.)* |
| 3. What techniques and tools are being used to implement and manage the improvement process? | *Look for evidence that tools and techniques are being used, such as statistical process control etc. The discourse of continuous improvement must be accompanied by actions showing that this is the company's commitment to results.* |

IT support

| **General Objective** | **Specific/Strategic Objectives** | **Questions** |
|---|---|---|
| Collect data pertaining to technological structure used in production planning and control | Information system | Is some type of integrated management system used? If so, what? |
| | | Which areas of the industry are connected to this system? |
| | Production control systems | What tools are used in production control? |
| | | Which system is used to handle and monitor indicators aimed at measuring performance? |
| | Managing customer and supplier relationships | Has the company implemented a CRM platform? If so, which one? |
| | | Is there any system to control and monitor suppliers? How is this procedure done? |
| | Production processes | What are the main production processes? |
| | | How is supervision, control, and acquisition of data done in these processes? |
| | Control and automation | Is some supervisory system that covers the entire production process used? |
| | | Where are the acquired data stored? |
| | Data center and network infrastructure | Is there a data center?<br>"IT Center/Server"<br><br>It was not possible to identify, as the technical visit focused on the factory floor. |
| | | What resources (software and hardware) are used to store and process data? |
| | | Is there a network/telecommunications infrastructure? What does it encompass? |
| | Integrated management of the performance management system | On what platform are the various generated indicators integrated/monitored to comply with the company's certification requirements? |
| | | If there is no integration platform, how is this controlled? |

# APPENDIX 3

## APPENDIX 3A - EXPERTS' QUALIFICATION

Exhibit 20 - Experts' qualification - CMMI panel

| **PANEL CMMI** | |
|---|---|
| Experts | Qualifications |
| 1 | Doctoral candidate in industrial and systems engineering. Master's in computer science. Has been working for years in the area of software engineering, including project management and deployment of maturity models (such as CMMI and MPS.BR). Areas of expertise: CMMI, MPS.BR, ISO 9001, software engineering, project management, development management, process improvement, implementing maturity models. |
| 2 | Doctoral candidate in industrial and systems engineering. Master's in software engineering, CMMI certified instructor, with more than 70 classes taught. Conducted improvement programs (CMMI, DMAIC, Lean, etc.). Participation in several CMM/CMMI/eSCM official and preparation appraisals. Participation in national and international congresses related to quality, processes and performance improvement. |
| 3 | Master of Business Administration (MBA), business management and coaching. Specialization, quality management of product & process (production engineering). Experience in modeling and defining processes using BPMN. Experience in software engineering, worked throughout the project life cycle (analysis, design, development, testing, management, quality of process). Good knowledge of unified process (RUP), agile methodologies (SCRUM, XP, Crystal Clear), design patterns, BPMN, PMBOK, ITIL, green IT, cloud computing, MPS.BR, CMMI, project management, process management, portfolio management, service management and more. |
| 4 | Master's in controllership and accounting, and Ph.D. in industrial engineering. Professor in the graduate course in industrial engineering in the department of industrial engineering, at the Engineering College of Universidade Estadual Paulista-UNESP, Bauru Campus, and ad hoc evaluator for INEP, the National Institute of Educational Research and Studies. Worked as a consultant for many years. Experience in the area of administration, with emphasis on production administration and financial administration, working mainly on the following topics: cost management, budgets, competitiveness, manufacturing strategy, sustainable manufacturing, reverse manufacturing, business performance and balanced scorecard, sustainability. |
| 5 | Specialist in administration, master's and Ph.D. in industrial engineering, professor and researcher in the graduate program in industrial and systems engineering at the Universidade do Vale do Rio dos Sinos (UNISINOS). Works in the areas of industrial management and strategy and organizations, mainly in: logistics and supply chain management, green supply chain management, organizational sustainability, production strategy, complexity, performance measurement, and management of industrial maintenance and technical assistance. |
| 6 | Master's in industrial engineering with a concentration in strategic management of operations and systems, and Ph.D. in industrial engineering with a concentration in performance measurement systems (2012). Has more than 10 years of professional experience, and has worked in large-scale multinational companies in industry and services in the area of logistics and supply chain management. As a researcher, works with research in supply chain management, with an interest in the issues of performance measurement, maturity, and practice in supply chain management. |

Exhibit 21 - Experts' qualifications - SOM capabilities evaluation

| Expert | Qualifications |
|---|---|
| 1 | Ph.D. candidate at the University of Padova, Italy, Departament of management and engineering. Skills and expertise: logistics, OM, SCM, lean manufacturing, total quality management, sustainable supply chain management |
| 2 | Ph.D. in industrial and systems engineering, master's in industrial and systems engineering, specialist in business logistics. Skills and expertise: Supply logistics, production planning and control, industrial logistics, production management (supply chain management, lean and green supply chain, lean production, operations strategy, inventory control, and production planning and control) |
| 3 | Specialist in product engineering and design, master's in industrial and systems engineering. Associated with the PMI Project Management Institute. Skills and expertise: Product engineering, production and operations management (Computer Aided Design [CAD], creativity and aesthetics in product development, production systems design, and management of sustainable operations). |
| 4 | Specialist in accounting and finance, master's in industrial and systems engineering, doctoral candidate in industrial and systems engineering. Skills and expertise: Controllership. Administration and accounting, especially in the areas of finance and cost management. |
| 5 | Naval Engineer. MBA in Business Management. Business manager with focus on business development. Skills and expertise: general management, commercial, marketing, sustainability, shared value). |
| 6 | Master's in chemical engineering and doctoral candidate in industrial engineering. Skills and expertise: Food science and technology and supervision of processes, quality management, operations management, energy management. |
| 7 | Master's and Ph.D. in industrial engineering, assistant professor in the department of industrial and systems engineering (EPS) at UFSC. Skills and expertise: environmental management, environmental management systems, green supply chain management, operations management, and performance evaluation. |
| 8 | Production Engineer. Quality manager, environment, occupational health and safety. Skills and expertise: EMS, forest certification, QMS, OH&S, audit. |
| 9 | Ph.D. and master's in industrial engineering. Professor at Université de Sherbrooke, Faculté d Administration, Canada, in the area of operations management. Skills and expertise: operations management, green supply chain management, project management, business strategy, strategic planning. |
| 10 | Master’s in science and mechanical engineering. Major in production systems. Associate professor at Chalmers University of Technology, Sweden. Skills and expertise: technology management and economics, operations strategy manufacturing strategy, sustainable operations management. |
| 11 | Master's and doctorate in industrial engineering. Tenured professor at the Universidade do Vale do Rio dos Sinos. Skills and expertise: Industrial engineering, with emphasis on planning, design and control of production systems, working mainly in the following areas: quality systems, services operations, and organizational sustainability. |
| 12 | Doctoral student at the Division of Operations Management. MSc in quality & operation management. Working as a consultant at Volvo Trucks Global Manufacturing, mainly as project quality and assurance manager in Sweden. Skills and expertise: sustainable operations management, supply chain management, quality management. |
| 13 | Lecturer in the area of industrial engineering, doctorate and post-doctorate in civil engineering, master's degree in business administration. Professor in the department of production at the College of Engineering at UNESP, Guaratinguetá campus. Skills and expertise: Administration and industrial engineering, with an emphasis on production administration, working mainly in the study of industrial clusters and certifiable management systems: quality management, environmental management, workplace safety and health. |
| 14 | Master's in industrial and systems engineering. Strategy manager. Skills and expertise: lean manufacturing, sustainable operations management, strategic planning, organizational sustainability, performance management, and quality management. |

Exhibit 22 - Experts' qualifications - SOM capabilities evaluation (cont.)

| Expert | Qualifications |
|---|---|
| 15 | Specialist in environmental management. Master’s in environmental management. Has been working as a consultant since 2003 in environmental projects, coordinating projects for private and government institutions throughout Brazil addressing the forest sector/industry, especially in the areas of renewable energy, conservation, sustainability and climate change. Assistant professor in the area of environmental management and sustainability for courses in environmental engineering and administration. Skills and expertise: sustainability environmental management, climate change. |
| 16 | Master's degree in industrial and systems engineering. Currently, Ph.D. candidate in industry and systems. Assistant professor of industrial engineering. Skills and expertise: sustainable product design, probability and statistics, with emphasis in quality and productivity management, mainly: management and quality tools; statistical process control, and database quality information |
| 17 | Doctorate in industrial engineering and management. Doctoral student in production engineering. Master's in industrial engineering. Skills and expertise: economics, engineering, and environmental sustainability |
| 18 | Master's in administration and doctorate in industrial engineering. Professor in the master's and doctoral program in business administration at PUCPR and professor at the Faculdades da Indústria. Skills and expertise: sustainability and sustainable supply chains. |

## APPENDIX 3B - INVITATION LETTER – SPECIALIST PANEL - CAPABILITIES

Dear Colleagues,

This panel represents an important phase in my PhD research, which focuses on developing a maturity model for sustainable operations implementation and management.

I am developing a survey questionnaire and the purpose of this panel is to ensure that the aspects being considered are appropriate for understanding the process of integrating sustainability into companies.

The first goal is to relate sustainable operations management practices to the sustainability context, thus classifying them according to their order of importance to cover each aspect. The second goal is to check the topics that should be investigated to understand how companies are integrating sustainability into their businesses.

Questions 1 and 2 are on the following sheets and we ask that you please return them by September 21st.

Thank you for your support.

Best regards,

Carla G. Machado
PhD researcher
PUCPR/PPGEPS/Brazil
KTH/Sweden
Capes PDSE - 7323-13-1

# APPENDIX 3C - QUESTIONNAIRE – SPECIALIST PANEL - CAPABILITIES

Respondent Data

1. Name:

2. Institution/Company:

3. Which of the following best describes your current position? (multiple answers allowed).

( ) Academic/Researcher
( ) Consultant
( ) Director
( ) Senior manager
( ) Middle manager
( ) Front-line employee
( ) Other:

4. Which of the following best describes your organization's sector? (multiple answers allowed).

( ) Education or research
( ) Technology and Telecommunications
( ) Financial services
( ) Consumer products
( ) Healthcare
( ) Energy and utilities
( ) Industrial Goods and Machinery Retail
( ) Conglomerate/Multi-industry
( ) Media and Entertainment
( ) Chemicals
( ) Construction
( ) Automobiles
( ) Commodities
( ) Industrial Services
( ) Other:

5. Describe your current expertise area:

6. Please select which sectors you previously worked (multiple answers allowed).

( ) Education or research
( ) Technology and Telecommunications
( ) Financial services
( ) Consumer products
( ) Healthcare
( ) Energy and utilities
( ) Industrial Goods and Machinery Retail
( ) Conglomerate/Multi-industry
( ) Media and Entertainment
( ) Chemicals
( ) Construction
( ) Automobiles
( ) Commodities
( ) Industrial Services
( ) Other:

7. How long has worked in the operations management field?

( ) > 5 years
( ) 5 - 10 years
( ) 10 - 20 years
( ) 20 - 30 years

Matrix

Q. 1 - Analyzing the following sustainable operations practices, please rate how important you think they are for acheiving each aspect of the sustainable operations context. The order of importance includes six levels of importance and you must choose one (Very important - Important - Moderately important - Unimportant - Slightly important - Not at all important/Not applicable - Not sure / No opinion). Each answer cell has a degree list. Thus, it is not necessary to write your answer just click on the validation list (see the example below). Important: Each item is followed by a short explanation in comments. Please, don't leave any blank cells.

| | | SUSTAINABLE OPERATIONS CONTEXT | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Environmental regulations | Economic regulations | Social regulations | Industry regulations | Product design | Manage ecological resources | Suppliers compliance - human resources | Suppliers compliance – raw materials and manufacturing | Socio-environmental regulations compliance | Optimized processes - resources efficiency | Continuous improvement process | Automation | Process management | Stakeholders awareness and collaboration | Suppliers awareness and collaboration | Innovation management | Material sustainability issues | Business model innovation | Integrated management system | Creating shared-value |
| SUSTAINABLE OPERATIONS MANAGEMENT CAPABILITIES | Life Cycle Analysis | | | | | Extremely important | | | | | | | | | | | | | | | |
| | Design for Disassembly | | | | | | | | | | | | | | | | | | | | |
| | Design for the Environment | | | | | | | | | | | | | | | | | | | | |
| | Design for the Recycling | Slightly important | | | | | | | | | | | | | | | | | | | |
| | Reverse Logistics | | | | | | | | | | | | | | | | | | | | |
| | Closed Loop Supply Chain | | | | | | | | | | | | | | | | | | | | |
| | Lean and green process | | | | | | | | | | | | | | | | | | | | |
| | Sustainable Purchasing | | | | | | | | | | | | | | | | | | | | |
| | Eco-efficiency strategies | | | | | | | | | | | | | | | | | | | | |
| | Cleaner Production | | | | | | | | | | | | | | | | | | | | |
| | Quality Management System | | | | | | | | | | | | | | | | | | | | |
| | Environmental Management System | | | | | | | | | | | | | | | | | | | | |
| | Occupational Health and Safety Management System | | | | | | | | | | | | | | | | | | | | |
| | Social Accountability | | | | | | | | | | | | | | | | | | | | |
| | Suppliers Development Program | | | | | | | | | | | | | | | | | | | | |
| | Sustainability Business case | | | | | | | | | | | | | | | | | | | | |
| | Stakeholder engagement | | | | | | | | | | | | | | | | | | | | |
| | Information System | | | | | | | | | | | | | | | | | | | | |
| | Sustainable Marketing | | | | | | | | | | | | | | | | | | | | |

Q.2 -The integration of sustainability into business models and operations can be characterized as a 'change context'. Pettigrew et al. [19] proposed a list of topics that need to be understood in the strategic change context, listed below.

| **Dimensions** | **Context** | | **Content** | | **Process** |
|---|---|---|---|---|---|
| **Aspects** | **Internal Context** | **External context** | **Tangible Outputs** | **Intangible Benefits** | **Process** |
| **Examples** | antecedent conditions | economic | strategy | insights into the business | frameworks |
| | structure | political | business objectives | | patterns |
| | leadership | social | performance measures | | actors |
| | frames of thought | | | | tools |
| | culture | | | | practices |

Source: Pettigrew et al. [19]

Do you think that this aspect covers all the relevant aspects for understanding how companies are integrating sustainability into their business or if there is any other aspect that should be investigated?

## APPENDIX 3D - INVITATION LETTER - SPECIALIST PANEL - CMMI

Dear Specialist,

Thank you so much for participating in my research as a collaborator.

Experts will be consulted through a semi-structured interview; in other words, you will receive some questions that will guide the subjects that will be addressed. The goal is for the respondents to have enough time to reflect on the topic.

The interview is expected to take a maximum of 40 minutes.

Again, thank you very much for making yourself available.

Best Regards,

Carla Machado
Doutoranda PUCPR
PUCPR/PPGEPS/KTH
Capes PDSE - 7323-13-1

## APPENDIX 3E – INTRODUTORY CONTEXT AND QUESTIONS FOR INTERVIEW

One of the results I sought in my research relates to developing a normative maturity model for managing sustainable operations, which helps companies integrate sustainability into their business.

The model is being developed based on the academic literature related to the subject, academic maturity models, and consulting that adheres to the concept of operations management, through consultation with specialists and refined by the companies' experiences, through conducting case studies, and (in the next step) a research survey.

The Capability Maturity Model Integration (CMMI) has been used as a structural reference in the research, which means that the model will be comprised of elements found in CMMI and adapted to the context of operations management.

> *"The CMMs focus on process improvement in an organization. They contain the essential elements of effective processes for one or more disciplines and describe an evolutionary path to improvement from immature or ad hoc processes to mature, disciplined processes, with improved quality and efficiency" (SEI, 2010, p. 5).*

Beyond CMMI, the aspects related to Andrew Pettigrew's process of organizational change (CONTENT, CONTEXT, and PROCESS) are included, because it is understood that the integration of sustainability is complex and is based on changes to the organization's culture and structure. Another addition is the elements related to organizational performance management, including recommendations for management tools and management indicators.

These elements are presented below: (1) the structure of the model for sustainable operations management, adapted from the CMMI model; (2) the model for characterization of maturity levels, adapted from elements of the CMMI, Pettigrew, and performance management; (3) questions used to guide the interview.

**1. Adaptation of the structural model based on the CMMI maturity model**

The structure of the CMMI has been adapted according to the theory of operations management. In this context, the "Sustainable Operations Maturity Model (SOMM)" consists of:

• **5 Levels -** Application in the SOMM: compliance, internal and external neutrality, case management, operations network management, and strategic integration.

• **Processes -** a set of practices related to an area that, when implemented, satisfy a set of goals considered important to achieving significant improvements in that area.

Application in the SOMM: the processes that form Michael Porter's value chain represent the organization of a company's operations. In the SOMM, they represent the areas of the process that must be constantly improved.

• **Generic goal -** these describe the features that are necessary to institutionalize the processes that implement the area of the process in question.

Application in the SOMM: market requirements and requirements to sustainable operations are represented by traditional performance objectives (quality, speed, reliability, flexibility, innovation, cost) and by the socio-environmental performance goals (impact mitigation, pollution prevention, climate change, quality of life at work, social justice and community development, ethics and compliance).

• **Generic practices -** describe an activity considered important for meeting the associated generic goal.

Application in the SOMM: generic practices are characterized by the organization's resources, namely, the decision areas that represent the set of policies and important activities for institutionalization of a process associated with the value chain.

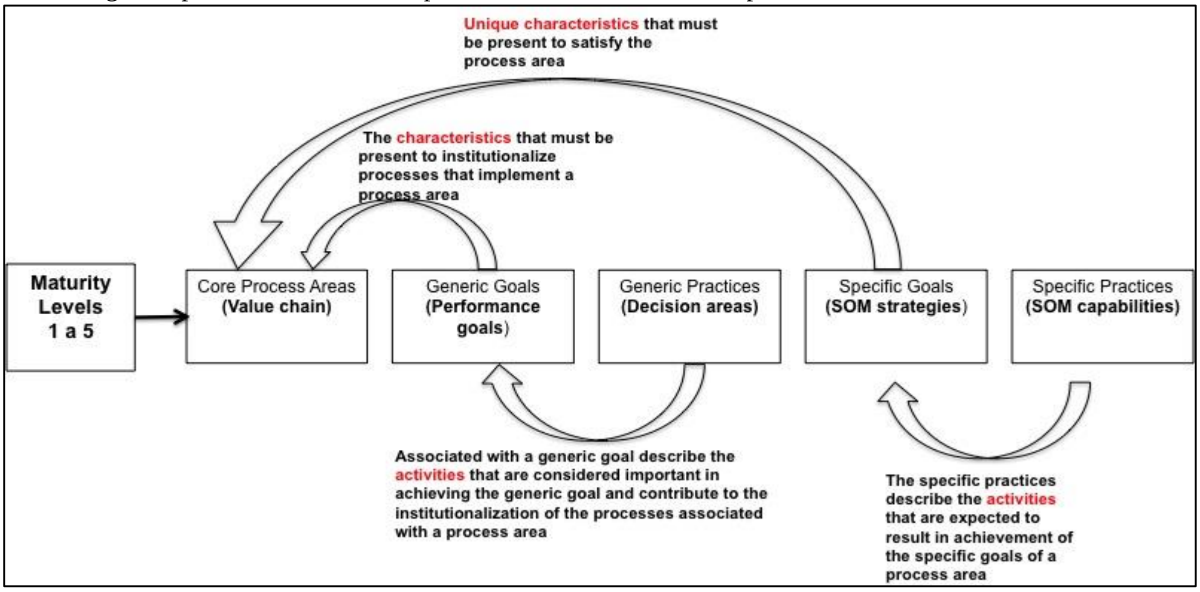
• **Specific goals:** describe the characteristics that must be present to properly implement a process area.

Application in the SOMM: requirements for sustainable operations management represent the unique features in products and processes that satisfy the value chain.

• **Specific practices:** describe an activity considered important for meeting the associated specific goal.

Application in the SOMM: represented by sustainable operations management capabilities, i.e. activities that are expected to ensure that the unique characteristics of the decision-making areas are targeted and covered.

Fig.1. Representation of the adapted model and the relationships between the structural elements




**3. Questions for discussion**

1. As presented above, one of the strategies used in this research is adaptation of the CMMI model to the context of the integrating sustainability based on operations management (value chain).
   What is your general opinion of the approach used?
   How would you rate the sustainable operations management model with regard to:
   Feasibility (can the model be followed)?
   Usability (how easy it is to follow it)?
   Utility (the framework provides a useful step towards solving the problem presented, around the integration of sustainability)?

2. Have new components been added to those proposed by the CMMI model, representing the approaches of the organizational process and performance management?
   Is the chart summarizing maturity level adequate, or do you think that any component should be added or removed?
   Do you think that the chart favors the applicability and usability of the maturity model?

3. If you already have worked directly with the CMMI model, or with some other maturity model based on CMMI, how would you rate your experience with regard to:
   Feasibility (can the model be followed)?
   Usability (how easy it is to follow it)?
   Utility (does the framework provide a useful step towards solving the problem it is meant to solve)?

## 2. Chart for maturity levels description

**Level 1 - Business and operations compliance**

**General Description**

Guided by business responsibility, company applies initial considerations about sustainable operations focused on compliance with governmental regulations and conformity with industry/association standards.

**Generic Description of the Content**

Internal – achieve internal processes and facility compliance
External – audit compliance of key suppliers
Companies must choose acting in two different approaches: only reacting to regulatory pressure or anticipating trends and future compliance requirements.

**Generic Description of the Context**

Business responsibility implies in compliance with regulation and industry standards in order to ensure license to operate, reduce reputational, compliance and operational risks.

**Generic goal (Performance goals)**

Ethics and Compliance
Cost
Quality of working life

**Specific Goal (Sustainable operations processes)**

Legal and regulatory regime

**Generic Practices (Decision areas)**

Facilities
Organisation
Work Design & HR managament
Information Systems

**Specific Practices**

Environmental management
Ocuppational health and safety management

**Core Process Areas**

Operations
Organisation and Governance
Human resources
Inbound and Outbound Logistics

**Process Design**

Processes can be conducted ad hoc fashion, but it is important establish initial links with strategy.

**Management Tools**

Monitoring system of legal and regulatory regime

**Sustainability Performance Indicators driven by TBL - Corporate level**

4.3.2 (ISO 14001; OHSAS 18001); 3.3.2 (ISO 16001); 4.1, 4.8, 6.4.1.1, (ISO 26000); 4.6.2 (ISO 50001); SO8, SO7, PR9 (GRI); 1-6 (Global Compact).

**Sustainability Performance Indicators driven by TBL - Operations level**

4.3.2 (ISO 14001; OHSAS 18001); 3.3.2 (ISO 16001); 4.1, 4.8, 6.4.1.1, (ISO 26000); 4.6.2 (ISO 50001); SO8, SO7, PR9 (GRI); 1-6 (Global Compact).

**Triggers for Level 2**

Waste minimisation
Emissions reduction strategies
Pollution prevention strategies
Alignment between strategy and internal sustainability goals
Performance management goals for sustainability compliance indicators

# APPENDIX 4

## APPENDIX 4A – INVITATION LETTER – SURVEY

The graduate program in industrial engineering systems (PPGEPS) at the Pontifical Catholic University of Paraná is conducting a series of studies directed at the processes of integrating the concepts of sustainability into manufacturing and infrastructure companies.
In this stage, as the final step in a doctoral research project, our objective is to assess the degree to which sustainability practices have been implemented into the companies' value chain.
The questionnaire is comprised of 24 issues grouped into 7 blocks. Starting in Block 2, a group of assertions about practices related to your company's operations will be presented. The objective is for you to identify the level to which these practices have been implemented in your company. The pre-test indicated that it should take an average of 40 minutes to complete the questionnaire.

To simplify the process, we suggest the following:
1. The answers are saved automatically, so you can respond to the questionnaire in steps with no loss of data. However, to avoid losing the data, please complete the entire questionnaire within a period of 7 days at the most. This also allows you to share the link with colleagues from your company, indicating specific questions for each one to answer. To access the questionnaire in progress, click on the link that appears at the end of this message.
2. Read and assess the content of the questions; if you feel that you are not able to answer them completely, please forward the link to the most appropriate person.

Important information:
- The data submitted will be treated as confidential and analyzed in aggregate form, that is, it will not be linked to the companies in any type of publication. The information in this report also will not be associated with the respondents, guaranteeing total confidentiality.
- The questionnaire will be available until **XX / XX/ 2015**
- If you identify an opportunity to forward this survey to other respondents in your company (e.g. other units or areas), or even to partner companies, please forward this email with the link to ACCESS THE QUESTIONNAIRE, or send us the information by email:

The project was undertaken in collaboration with the Swedish universities KTH-Royal Institute of Technology and Chalmers University of Technology, and received financial support from CAPES (award recipient 7323/13-1).

# APPENDIX 4A – QUESTIONNAIRE PROTOCOL - SURVEY

1. Respondent name (Optional)

2. Which of the following best describes your current position?
   - Board member (1)
   - Chief executive (ex. CEO, CSO, CFO) (2)
   - Executive director (3)
   - Senior manager (4)
   - Mid-level manager (5)
   - Front-line employee (6)
   - Supervisor (7)
   - Analyst (8)
   - Other (9)

3. If your professional position is related to sustainability, how long have you been working in this post, or in a related function?
   - Less than 5 years (1)
   - 5 to 10 years (2)
   - 10 to 20 years (3)
   - More than 20 years (4)
   - My work is not related to sustainability (state your role) (5)

4. How would you describe your experience related to how sustainability affects business?
   - Expert/leader in this subject (1)
   - Some knowledge, but not expert (2)
   - Beginner (3)
   - No experience (4)

5. Is sustainability embedded in your business's strategic management agenda?
   - Yes (1)
   - No (2)

6. How long has sustainability been embedded in your company's strategic management agenda?
   - less than 2 years (1)
   - 2 to 5 years (2)
   - 10 to 20 years (3)
   - topic is not embedded in the strategic management agenda (4)

7. How well informed are you about your organization's sustainability strategy?
   - Not informed about anything (1)
   - Not very informed (2)
   - A bit informed (3)
   - Fully informed (4)

8. Which of the following best describes your company's area of industry?
   - Telecommunications (1)
   - Pulp & paper (2)
   - Health （3）
   - Technology and computing (4)
   - Holding company (5)
   - Chemicals and petrochemical (6)
   - Oil, gas, and fuel (7)
   - Consumer products (8)

- ☐ Mining (9)
- ☐ Food and beverage (10)
- ☐ Transport and logistics (11)
- ☐ Civil construction （12）
- ☐ Agriculture/ranching （13）
- ☐ Steelworks and metallurgy (14)
- ☐ Heavy construction and engineering (15)
- ☐ Wood (16)
- ☐ Equipment, machines and parts (17)
- ☐ Automotive and agricultural machinery (18)
- ☐ Textile, leather, and apparel (19)
- ☐ Other (20)

9. Your company is:
   - ☐ Headquarters (1)
   - ☐ Subsidiary (2)
   - ☐ Outra (3)

10. In which country is your company's headquarters located?

11. In which region does your company conduct its major operations?
    - ☐ Brazil (1)
    - ☐ Global — primary business distributed over more than 3 regions (2)
    - ☐ North America (3)
    - ☐ Europe (4)
    - ☐ Asia/Pacific (5)
    - ☐ Latin America (6)
    - ☐ Africa/Middle East (7)
    - ☐ Australia/New Zealand (8)

12. What is the total number of employees in your unit?
    - ☐ Fewer than 50 (1)
    - ☐ Between 50 and 200 employees (2)
    - ☐ Between 200 and 1000 employees (3)
    - ☐ Between 1000 and 10,000 employees (4)
    - ☐ Between 10,000 and 100,000 employees (5)
    - ☐ More than 100,000 employees (6)

13. Identify the management systems that your company has (multiple responses possible). After selecting the type of management system, describe what standards support it (e.g.: ISO 9001)
    - ☐ Quality Management
      - ○ ________________
    - ☐ Environmental Management
      - ○ ________________
    - ☐ Occupational Health and Safety
      - ○ ________________
    - ☐ Social Responsibility
      - ○ ________________
    - ☐ Energy Management
      - ○ ________________
    - ☐ Environmental Management of Product Life Cycle
      - ○ ________________
    - ☐ Business Continuity Management
      - ○ ________________
    - ☐ Information Technology Management

- ○ ________________
- □ Corporate Governance
  - ○ ________________

14. If your company publishes some kind of public sustainability report, select it from the list below.
    - □ GRI - Global Report Initiative
    - □ Ethos indicators for Sustainable and Responsible Businesses
    - □ COP - Communication for progress - Global Compact
    - □ Management Report- FNQ National Quality Foundation
    - □ DJSI - Dow Jones Sustainability Index
    - □ Other(s)
    - □ Company has not

15. If your company is a signatory to a voluntary commitment to sustainable development, select it from the list below.
    - □ Agenda 21
    - □ Global Compact
    - □ Carbon Disclosure Project
    - □ Commitment to eradicate child labor
    - □ Commitment to eradicate slave labor
    - □ Other(s)
    - □ Company has not

16. Please, describe your company's current position with regard to sustainability (ex.: strategy involving compliance, or innovation)

18. Rate your company's level of adherence with relation to the following statements. Your response should use the following scale:

**(0) Non-existent:** total lack

**(1) Initial:** only potential approaches have been identified and applied in isolated situations.

**(2) Managed or repeated:** process, area, or activity implemented by project, and repeated in similar applications.

**(3) Defined:** process, area, or activity integrated into the organization's processes.

**(4) Quantitatively managed:** systematized process, area, or activity, measured and managed based on continuous improvement.

**(5) Optimizing:** process, area, or activity considered to be at best-practice level.

18.1 The sustainability strategy is directed at fulfilling/complying with all the regulations and/or standards applied to the business.

18.2 The company directs its efforts to stay ahead of emerging regulations, especially those that can create competitive advantage.

18.3 There are formal research processes to identify and analyze sustainability trends related to the business.

18.4 The sustainability strategy is formalized and supported by the company’s upper-level management

18.5 There is a specific area for managing sustainability (ex. sustainability director or manager).

18.6 The company develops sustainability business cases that clearly demonstrate the economic results of sustainable practices or prove the proposition of value for the sustainable approach.

18.7 Operations or practices applied to the company's value chain are adjusted or changed according to the results of sustainability practices and/or strategy.

18.8 The company's business model was changed according to the results of sustainability practices and/or strategy.

18.9 There are operational KPIs related to sustainability.

18.10 There are personal KPIs related to sustainability.

18.11 The company is linked to regulatory agencies and other parties responsible for formulating policies as a reliable source of information, able to influence and perhaps compile new regulations and policies.
18.12 The company tries to identify significant sustainability issues (environmental, social, and economic) that directly impact the business (material sustainability/materiality).
18.13 The company has a strategy for managing risks related to climate change, disasters, and other risks.
18.14 The guidelines and objectives for sustainability are defined and shared by upper management.
18.15 Upper management plays a strong role in the company´s sustainability efforts.

19. Rate your company's level of adherence with relation to the following statements. Your response should use the following scale:
**(0) Non-existent:** total lack
**(1) Initial:** only potential approaches have been identified and applied in isolated situations.
**(2) Managed or repeated:** process, area, or activity implemented by project, and repeated in similar applications.
**(3) Defined:** process, area, or activity integrated into the organization's processes.
**(4) Quantitatively managed:** systematized process, area, or activity, measured and managed based on continuous improvement.
**(5) Optimizing:** process, area, or activity considered to be at best-practice level.

19.1 Implementation of environmental improvements in disposing waste or excess materials (reuse, recycling, etc.).
19.2 New product designs are supported by research into regulations and policies to guarantee compliance.
19.3 The process for designing new products includes consideration of the environmental impact of the materials, resources, or parts that are used.
19.4 The company identifies environmental impacts resulting from the design/conception of the product using data/studies about product life cycle (LCA).
19.5 Sustainability is one of the criteria considered in developing new products.
19.6 The company uses checklists or other tools to compare the sustainability of new products during the design process.
19.7 The focus of the new product development area is on eliminating risks.
19.8 Data/studies about product life cycle (LCA) are being used to evaluate the overall environmental impact of manufacturing processes.
19.9 The company relies on cooperative processes with suppliers to create more sustainable logistics systems.
19.10 There are processes co-developed with the suppliers to reduce the environmental impact of the product (e.g. tradeoff of materials and processes, packaging recycling programs, etc.)
19.11 The company’s processes and products add value to the business while at the same time reducing environmental impact and benefiting society.
19.12 The company has a specific area dedicated to LCA studies and producing inventories.
19.13 The company supports the design of products, through the implementation of new techniques/processes or other business models, to ensure reuse/recycling or project carried out together with partners to build infrastructure to guarantee reuse/recycling beyond the standard reuse/recycling streams.
19.14 Secondary data from LCA studies are used in developing all products.
19.15 The LCA studies consider the entire product life cycle, from the extraction of raw materials until the end of life (stage of use).

20. Rate your company's level of adherence with relation to the following statements. Your response should use the following scale:
**(0) Non-existent:** total lack

**(1) Initial:** only potential approaches have been identified and applied in isolated situations.
**(2) Managed or repeated:** process, area, or activity implemented by project, and repeated in similar applications.
**(3) Defined:** process, area, or activity integrated into the organization's processes.
**(4) Quantitatively managed:** systematized process, area, or activity, measured and managed based on continuous improvement.
**(5) Optimizing:** process, area, or activity considered to be at best-practice level.

20.1 The company tracks its water, energy, and emissions footprint at an internal operational level.
20.2 The company promotes tracking carbon emissions/calculating the ecological footprint in the supply chain.
20.3 In the process of selecting key suppliers, there are criteria based on social and environmental policies.
20.4 The company invests in the use of alternative energy, water reuse, and carbon-neutral technologies.
20.5 The company carries out environmental remediation projects, such as cleaning or recovery related to past practices.
20.6 The company has ongoing practices for reducing waste in the internal process to improve productivity and efficiency.
20.7 Training around quality management is offered to managers and supervisors throughout the organization.
20.8 Information about productivity and defect rates is readily available to employees.
20.9 The majority of the factory floor processes are currently under statistical quality control.
20.10 The company estimates the useful life of its equipment, so that repairs or replacements are planned.
20.11 The company uses the Kanban system for controlling production.
20.12 The company’s processes are designed to be error-proof.
20.13 Training in techniques for resolving problems is provided to employees.
20.14 The company works in conjunction with equipment manufacturers to reduce the environmental impacts of their equipment and/or develop more sustainable manufacturing processes.
20.15 Suppliers and logistics partners deliver products and materials according to need (just in time).
20.16 Suppliers are evaluated through an auditing system that considers the economic, environmental, and social aspects of their activities.
20.17 The suppliers are included in efforts to improve quality.
20.18 The company promotes changes/innovations in processes and technologies to improve the environmental and social performance of its operations.
20.19 The company has processes to develop the local network of suppliers.
20.20 The company invests in the use of clean technologies in the productive process to reduce pollution emissions and/or the use of resources.
20.21 The company exhibits efforts to replace hazardous or non-renewable materials with less dangerous or renewable ones, as well as to use more durable materials.
20.22 Work procedures, instructions for machine operators, and process records are in line with principles of greater efficiency and less generation of waste and emissions during production.
20.23 There are procedures for reusing waste materials in the same process or for another type of use within the company.

21. Rate your company's level of adherence with relation to the following statements. Your response should use the following scale:
**(0) Non-existent:** total lack
**(1) Initial:** only potential approaches have been identified and applied in isolated situations.
**(2) Managed or repeated:** process, area, or activity implemented by project, and repeated in similar applications.
**(3) Defined:** process, area, or activity integrated into the organization's processes.
**(4) Quantitatively managed:** systematized process, area, or activity, measured and managed based on continuous improvement.
**(5) Optimizing:** process, area, or activity considered to be at best-practice level.

21.1 The company monitors working conditions on the premises of key suppliers, meeting regulations and/or standards specific to the industry or operations.
21.2 The company ensures healthy and safe working conditions in its operations, meeting internal regulations and/or standards specific for the industry or operations.
21.3 Part of the work force participates in committees or formal health and safety working groups to monitor and guide workplace health and safety programs.
21.4 Suppliers are encouraged to be aligned with global sustainable development initiatives (ex. Millennium Goals, Global Pact, or Agenda 21).
21.5 The company has processes to combat gender discrimination and guarantee equal work opportunities and remuneration for men and women.
21.6 Agreements and contracts with suppliers include clauses guaranteeing respect for human rights and encouraging eradication of child and forced/slave labor.
21.7 The company has processes that guarantee the freedom of association and collective bargaining.
21.8 The company has a code of conduct and ethics that applies to its own employees, contracted parties, and suppliers, and has processes that ensure compliance.
21.9 The company’s values can be identified in the way the company conducts its activities.
21.10 The company has processes to assess impacts and local development in the area surrounding it.
21.11 The company has procedures to assess corruption-associated risks and promotes activities to combat these risks in all operations within its value chain.
21.12 The company cooperates with processes to create public policies.
21.13 The company has processes to combat unfair competition practices.
21.14 Key suppliers are audited based on criteria related to their impact on society.

22. Rate your company's level of adherence with relation to the following statements. Your response should use the following scale:
**(0) Non-existent:** total lack
**(1) Initial:** only potential approaches have been identified and applied in isolated situations.
**(2) Managed or repeated:** process, area, or activity implemented by project, and repeated in similar applications.
**(3) Defined:** process, area, or activity integrated into the organization's processes.
**(4) Quantitatively managed:** systematized process, area, or activity, measured and managed based on continuous improvement.
**(5) Optimizing:** process, area, or activity considered to be at best-practice level.

22.1 The company encourages suppliers to improve environmental performance in their processes, e.g. control and reduction of greenhouse gases (GHG).
22.2 The company builds a shared understanding of supply chain information with the suppliers, such as demand planning, transport, and production.
22.3 The company has an information system to support its relationship with customers.
22.4 The company utilizes systems such as ERP (Enterprise Resource Planning).
22.5 The company promotes customer engagement in the development of new products or services.
22.6 The company shares understanding of the implications of its supply chain activities with its

partners.

22.7 The company is engaged in activities related to developing its suppliers to improve financial and socio-environmental performance.

22.8 The company maintains an integrated database and accesses methods to facilitate information sharing with members of the supply chain.

22.9 The company uses information technology (for example, RFID or PIDT) to track and/or speed up shipments to major suppliers.

22.10 The company shares knowledge with the members of the supply chain.

22.11 Upper-level administration considers it fundamental to share information with customers.

22.12 Suppliers are involved in redesigning internal processes (for example, remanufacturing, reducing by-products).

22.13 The company has processes related to guaranteeing customer privacy.

23. Rate your company's level of adherence with relation to the following statements. Your response should use the following scale:

**(0) Non-existent:** total lack

**(1) Initial:** only potential approaches have been identified and applied in isolated situations.

**(2) Managed or repeated:** process, area, or activity implemented by project, and repeated in similar applications.

**(3) Set:** process, area, or activity integrated into the organization's processes.

**(4) Quantitative Management:** systematized process, area, or activity, measured and managed based on continuous improvement.

**(5) Optimized:** process, area, or activity considered to be at best-practice level.

23.1 Information provided by the marketing department is used in developing solutions and production plans.

23.2 Information provided by the production department is used in developing solutions and marketing plans.

23.3 The company understands and contributes to the clients' marketing strategy.

23.4 The company measures performance effectiveness on sustainability issues.

23.5 The company has processes to identify the most relevant economic, environmental, and social aspects to ensure the viability of its operations in the long term.

23.6 The company has processes to identify the economic, environmental, and social aspects that can influence evaluations by stakeholders.

23.7 The company has procedures that align internal organizational processes and resources for creating value for the stakeholders.

23.8 The company has processes to identify new opportunities related to sustainability.

23.9 The company has procedures for developing consumers with more sustainable aspirations (ex.: waste reduction and social engagement).

23.10 Sustainability is integrated into the business strategy, in products and services, and in the supply chain.

23.11 Internal and external communication processes are conducted in a transparent manner and focus on engagement and meeting stakeholder demands.

23.12 There are indicators that make the creation of value in the value chain tangible.

23.13 The company tangibly measures the creation of value from sustainability for the company's reputation and brand.

24. In the future, this survey will be replicated in other countries. Please help us improve describing your impressions related to filling out this questionnaire.