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Lean-Green contributions for companies' sustainability

PhD Thesis in Industrial and Systems Engineering

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Statement of Integrity

I hereby declare having conducted this academic work with integrity. I confirm that I have not used plagiarism or any form of undue use of information or falsification of results along the process leading to its elaboration.

I further declare that I have fully acknowledged the Code of Ethical Conduct of the University of Minho.

Abstract

In our changing world, the companies must undertake hard decisions on how to position themselves for the long run. They have to innovate their processes and products to thrive against competitors and reduce their own wastes, by improving their way of designing, producing and managing the processes. Therefore, they need to compare each other by using standards and key indicators.

The aim of the thesis was to develop a model so as to assess the synergies of lean production and of eco-efficiency (lean-green). The model includes a performance indicator that jointly addresses the lean-green paradigm. This paradigm has been making a positive contribution towards the companies' sustainability.

The research study began with a critical literature review, which provided the foundation on which this research was developed. The literature enclosed the most relevant and up to date literature: knowledge in lean production, eco-efficiency and sustainability, their synergies, performance improvements and indicators.

A survey was conducted to the companies in northern Portugal. The survey was intended to understand the knowledge, the lean production implementation level and how such implementation benefited these companies. This survey included questions related to companies' sustainability knowledge and concerns. The survey results improved the understanding of the companies' awareness about lean production, green production and sustainability level.

Grounded on the survey results and on the lean-green models reviewed, it was decided to develop a new model based on widely known performance indicator, i.e. the Overall Equipment Effectiveness (OEE) and the three pillars of sustainable development: economic, social and environmental. Therefore, this model was operationalized through an indicator that aggregates and combines lean and green production strategies. It was called Business Overall Performance and Sustainability Effectiveness (BOPSE). This indicator aims to measure the operational performance and sustainability level of a lean company.

To validate the BOPSE model, three case studies from the automotive sector were used. The higher BOPSE value attained was 65% and the worst 46%. The higher BOPSE value comes from a company with a higher leanness maturity level, denoting that a lean company could be more sustainable.

Keywords: eco-efficiency, indicators, lean-green, lean production, sustainability

Resumo

No nosso mundo em constante mudança, as empresas devem tomar decisões estratégicas sobre como se posicionar a longo prazo. Para isso, precisam de inovar os processos e produtos para prosperar relativamente aos concorrentes e reduzir os seus próprios desperdícios, melhorando a maneira de conceber, produzir e gerir os processos. Desta forma, são necessárias normas e indicadores-chave para conhecerem o seu posicionamento e se compararem.

A objetivo desta tese consistiu em desenvolver um modelo que avaliasse as sinergias da produção *lean* e da eco-eficiência (lean-green). O modelo inclui um indicador de desempenho que integra o paradigma *lean-green*, que tem contribuído para uma melhoria da sustentabilidade das empresas.

Esta investigação iniciou-se com uma revisão crítica da literatura, que forneceu a base teórica sobre a qual foi desenvolvida. A revisão incluiu a literatura relevante e atual sobre: conhecimento em produção *lean*, ecoeficiência e sustentabilidade, suas sinergias, melhorias de desempenho e indicadores.

Foi realizado um inquérito às empresas do norte de Portugal. Pretendeu-se entender o nível de conhecimento e implementação da produção *lean* e os benefícios desta. Este inquérito incluía perguntas relacionadas com o conhecimento das empresas sobre a sustentabilidade. Os resultados permitiram melhorar o entendimento das empresas inquiridas sobre produção *lean* e *green* e nível de sustentabilidade.

Com base nos resultados do inquérito e na revisão dos modelos *lean-green*, desenvolveu-se um modelo baseado num indicador de desempenho, amplamente conhecido nas empresas, i.e. o "*Overall Equipment Effectiveness*" (OEE) e os três pilares do desenvolvimento sustentável: económico, social e ambiental. O modelo foi operacionalizado por meio de um indicador que agrega e combina estratégias de produção *lean* e *green*. Este modelo foi designado de "*Business Overall Performance and Sustainability Effectiveness*" (BOPSE). Este indicador visa medir o desempenho operacional e o nível de sustentabilidade de uma empresa *lean*.

Para validar o modelo, foram utilizados três estudos de caso provenientes do setor automóvel. O maior valor do BOPSE obtido foi 65% e o pior 46%. O maior valor do BOPSE vem de uma empresa com um maior nível de maturidade de *lean*, denotando que uma empresa *lean* pode ser mais sustentável.

Palavras-chave: eco-eficiência, indicadores, *lean-green, lean production,* sustentabilidade

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List of Abbreviations and Acronyms

3BL	Triple Bottom Line
3P	Planet, People, Profit
Ab	Absenteeism
Ac	Accidents rate
AFIA	Portuguese Manufacturers Association for the Automotive Industry
ANP	Analytical Network Process
APA	Portuguese Environment Agency
ASTM	American Society for Testing and Materials
BCSD	Business Council for Sustainable Development
Bi	Biodiversity investment
BOP	Bottom Of the Pyramid
Btd	Budget in training and development
CEO	Chief Executive Officer
CF	Carbon Footprint
CMMI	Capability Maturity Model Integration
CP	Cleaner Production
CSD	Commission on Sustainable Development
CSR	Corporate Social Responsibility
DEEDS	DEsign EDucation & Sustainability
DfS	Design for Sustainability
Do	Donations
Ec	Environmental compliance
EC	European Commission
Ece	Effective contracted employees
Ee	Employees' engagement
Eeiv	Employees engaged in volunteering
EFQM	European Foundation for Quality Management
EMS	Environmental Management System
EPA	Environmental Protection Agency
ESLP	Eco-Socio-Lean Production
Et	Employee turnover
EU	European Union
Fa	Fatalities
Fe	Female employees
GDP	Gross Domestic Product
GFN	Global Footprint Network
GHGei	GHG emissions intensity
GHGer	GHG emissions reduction
GLPI	Green Logistics Performance Index
GRI	Global Reporting Initiative
Hir	Hazardous industrial residues
IMVP	International Motor Vehicle Program
INE	National Institute of Statistics (in Portuguese "Instituto Nacional de Estatística")
IPCC	Intergovernmental Panel on Climate Change
ISO	International Standard Organization
IT	Information Technology
JIT	Just-in-Time
KPIs	Key Performance Indicators
KEPIs	Key Environmental Performance Indicators
LCA	Life Cycle Analysis
LCPB	Lean Cleaner Production Benchmarking
LE	Lean Enterprise
Lsm	Local senior management
MCDM	Multi Criteria Decision-Making
MDGs	Millennium Development Goals

MIT	Massachusetts Institute of Technology
Mu	Materials used
NEPA	National Environmental Policy Act
NGO	Non-Governmental Organization
Npm	Net profit margin
Nwnr	Net water needs reduction
ODS	Ozone Depleting Substance
OECD	Organization for Economic Cooperation and Development
OEE	Overall Equipment Effectiveness
PCA	Principal Component Analysis
PESO	People, Ergonomics, Sustainability and Operational performance
R&D	Research and Development
RDI	Research, Development and Innovation
Re	Renewable energy
RECP	Resource Efficient and Cleaner Production
Rim	Recycled input materials used
Rr	Recycled residues
Rrw	Recycled and reused water
Sec	Socioeconomic compliance
Sp	Spills
SCP	Sustainable Consumption and Production
SCORE	Sustainable Consumption Research Exchanges
SDC	Sustainable Development Commission
SDGs	Sustainable Development Goals
Selw	Standard entry level wage
SLCA	Social Life Cycle Analysis
SEM	Structural Equation Modelling
Sls	Spending on local suppliers
SME	Small and Medium-sized Enterprises
SMED	Single-Minute Exchange of Die
SCP	Sustainable Consumption and Production
Sus-VSM	Sustainable-VSM
Tdh	Training and development hours
TOC	Theory of Constraints
TPS	Toyota Production System
TPM	Total Productive Maintenance
TQM	Total Quality Management
Ue	Useful energy
UK	United Kingdom
UN	United Nations
UNCC	United Nations Climate Change
UNIDO	United Nations Industrial Development Organization
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNEP/IE	United Nations Environment Programme Industry and Environment Centre
UNIDO	United Nations Industrial Development Organization
VOC	Volatile Organic Compounds
VSM	Value Stream Mapping
WBCSD	World Business Council for Sustainable Development
WCED	World Commission on Environment and Development
WCM	World Class Manufacturing
WID	Waste Identification Diagram
Wim	Women in management
WIP	Work-in-Progress
Wu	Water used

1 Introduction

This chapter presents the background and motivation undertaken in this research. After, the main and specific objectives are presented, followed by the research methodology framework. Lastly, is presented this thesis organization and structure.

1.1 Background and motivation

Humankind is encountering serious sustainability challenges. Global warming and resource scarcity on the environmental perspective and increasing inequity on the social one. Simultaneously, society relies on growth, innovation and technological solutions to solve the situation, hampering these challenges achievement. Societies and economies burden the biosphere and biodiversity, beyond the impacts on human themselves (Fuchs & Lorek, 2011).

The question is not only about consumers consumption decisions, and their lifestyles, which delivers a weak sustainable consumption perspective as it relies entirely on the consumers active role in market to buy green and sustainable products. But much more about sustainable resource consumption, and considering the whole product life cycle, which delivers a strong sustainable consumption. Thus, consumption patterns of industries, governments, households and individuals have to be held within the limits of depletable natural resources (Fuchs & Lorek, 2011).

At the present time, companies face challenges ever more demanding in a globalized world, imposing higher competition levels, greater clients' demands, but also increased demands from end users, governments and society. Consequently, companies have to respond rapidly and effectively, through high quality standards, reduced costs and, simultaneously, be socially and environmentally responsible (IPCC, 2019; UNCC, 2019). This is a challenge as goods and/or services production strains planet resources.

As stated by OECD in their report on "*Global Material Resources Outlook to 2060*", the global materials use is projected to more than double from 79 Gt in 2011 to 167 Gt in 2060. This represents a materials' use per capita per day from 33 Kg in 2011 to an impressing value of 45Kg in 2060. The GHG emissions associated to materials management will increase to approximately 50 Gt CO_2 equivalents by 2060, and per the total emissions they are projected to reach 75 Gt CO_2 equivalents (OECD, 2018).

To fulfil the needs of a growing consumer society, production has assumed a prime relevance since it provides the products demanded by the marketplace, thus pressuring the environment because requires natural resources exploitation and releases pollutants. Many had been the decades of intensive industrial activity that had not only exploited the planets' resources, e.g. with massive operations around the globe for raw materials and fuels extraction, but also resulted in undesirable emissions that polluted the air, soil, and water.

On the long run, this general behaviour of consumers, which seems to exhibit no limits, will severely impact ecosystems and will threaten species survival capability. The planets' natural self-regulating mechanisms might change accordingly, to manage with the scale of the impact. This is envisioned to happen in shorter time frames than ever, which, per se, might jeopardise human life, as a species. One might seriously consider such mega threat as the climate change phenomenon. The governments, societies and companies have to work together to mitigate these pressures so as balance this activity with desired environment boundaries (IPCC, 2019; UNCC, 2019).

Even this year of 2019, according to Global Footprint Network (GFN), the "*Earth Overshoot Day*" was in July 29th, the earliest day ever. This day signs the date when humanity's annual demand on nature exceeds Earth's ecosystems regeneration in that year. This indicates that humanity is at this time using nature 1.75 times faster than the planet's ecosystems can regenerate (GFN, 2019a).

A genuine and honest approach to mitigate such challenges is that of considering environment and social responsibility, on all relevant aspects of activity, not only economic ones. This should be attained by people, when buying, using and disposing all stuff. Furthermore, should be attained by companies, when designing the products, sourcing the raw materials, and on carrying out the production activities that aggregate value to the product.

Some companies are trying to achieve that, by developing proactive attitudes and strategies towards more sustainable operations, i.e. through cleaner production and compensation mechanisms. Such behaviours offer a more balanced way to the use of nature, where eventual losses are, at least partially, counterweighted with positive environmental rewards. Such strategies may go through the adoption of organizational methodologies that promote ideas of "doing more with less", as endorsed by Lean Production (Womack et al., 1990), and of "creating more with less", as encouraged in the concept of eco-efficiency (BCSD, 1993). The synergies among those strategies are plenty and unequivocal, which has resulted in an approach known as lean-green. These link associates value with efficiency in operational and environmental terms (eco-efficiency) (Florida, 1996; Maxwell et al., 1993).

Lean production, as an organizational methodology, has been expanding through all economic activity sectors. It has roots on a new production approach conceived by the Toyota Motor Company, after the Second World War, called Toyota Production System (Monden, 1983; Ohno, 1988). This new production system arose because it was a time of financial restrain and resource scarcity in Japan, and Toyota was looking for a solution that accomplished what mass production did best, that was, to do things spending the minimum resources, while retaining its ability to adapt to changing circumstances. This new paradigm was coined by the MIT researchers (Krafcik, 1988) as "Lean Production" and became internationally known after the publication of the book "The Machine that changed the world" from Womack et al. (1990).

Toyota developed a solution where it spent less of everything, i.e. less resources, less human effort, less space and fewer inventories by the elimination of all wastes. Wastes are all the activities that do not add value to the products. Ohno (1988) classified them in seven categories: 1) overproduction; 2) over processing; 3) transports; 4) defects; 5) motion; 6) inventory and 7) waiting. Later, untapped human potential was considered the eighth waste (Liker, 2004).

In 1996, and in order to systematically eliminate these wastes, Womack and Jones developed the five Lean thinking principles: value; value stream; flow; pull production and pursuit of perfection (Womack & Jones, 1996). Pursuit of perfection implies searching for continuous improvement (*Kaizen*) and people play an important role in this aim, because a real Lean culture environment promotes people involvement and creativity (Alves et al., 2012). A Lean company is always, and continuously, concerned about waste reduction (including untapped human potential). It is a never-ending process.

However, this process needs to be measured in order to give indications about if the process is improving or not. This concern was always in scientist and engineers' minds, see for example what Lord Kelvin said at long time ago: "If you cannot measure it, you cannot improve it". To do this, in particular, to measure productivity of individual equipment in a factory, companies have been using a quantitative metric called Overall Equipment Effectiveness (OEE) developed by Nakajima (1988) in the context of Total Productive Maintenance (TPM) (Muchiri & Pintelon, 2008). According to its founder, with this indicator, equipment maintenance, equipment breakdowns and autonomous operator maintenance through day-to-day activities could be effectively improved. Indexes or indicators such as OEE are important references for others to compare and improve among their peers.

In this continuous improvement journey, inevitably a search for deliver truly green products/services is implicit. This also means that in their production, the processes must be waste free and environmentally friendly. It is on this journey pursue that the eco-efficiency concept, above mentioned, is meaningful. This concept emerged in the early years of 1990s, by Stephan Schmidheiny and the Business Council for Sustainable Development (BCSD), now the World BCSD (WBCSD). The concept was envisioned to sum-up the intent of fostering sustainable development and contributing to human well-being (BCSD, 1993).

The Eco-efficiency concept encapsulates a simple but persuasive understanding that is only possible to provide more value with lower environmental impact. At the same time, such trend is imperative and a burning requirement of contemporary societies. The justification rests on a simple cradle-to-cradle premise. This premise can be progressively or more radically pursued, taking into account full lifecycles, i.e. from extraction to disposal, without unintended armful relocations among lifecycle stages (WBCSD, 1996).

To achieve this premise, authors have been talking about lean-green link (Florida, 1996; Maxwell et al., 1993). This link was investigated from the 1990 onwards (Maxwell et al., 1993; Maxwell et al., 1998; Larson & Greenwood 2004; Pojasek 2008). The two concepts in this link have different focus: reducing waste (lean) and environmental impact (green). It seems that lean was not mainly designed to address sustainability issues (Moreira et al., 2010; U.S.-EPA, 2003). Nevertheless, some authors have revealed that their principles and practices brought several benefits that could be placed under the umbrella of green (Klassen, 2000; Rothenberg et al., 2001; Found, 2009). Therefore, the lean-green approach might offer a framework for delivering cleaner and valuable products.

This is also recognized by the U.S. Environmental Protection Agency (EPA) that has been relating lean with the environment. One of its designed toolkits is "*The Lean and Environment To*olkit" (U.S.-EPA, 2007). In this toolkit, environmental waste concept was defined as "any unnecessary use of resources or a substance released into the air, water, or land that could harm human health or the environment.". This agency demonstrated that lean tools can be applied to reduce environmental wastes. These can happen when companies use resources to deliver products or services to customers, and/or when customers use and dispose products (Maia et al., 2013).

Several authors have been developing models and addressing different aspects and characteristics of lean, green and the lean-green synergy, for example, Kleindorfer et al.(2005); Corbett and Klassen (2006); Vachon and Klassen (2006); Mollenkopf et al. (2010); Paju et al. (2010); Otsuki (2011); Azevedo et al. (2012); Aguado et al. (2013); Hallam and Contreras (2016); Belhadi et al. (2018); and Carvalho et al. (2019).

Such models concern is the global sustainable development based on a waste free, clean and ecofriendly production promoted by lean-green. Others initiatives, models and case studies of how lean conduces to global development are presented in Alves et al. (2019). These have a direct impact on the Goal 12: Responsible Consumption and Production, one of the 17 Sustainable Development Goals (SDG) (United Nations, 2018).

Additionally, lean production have been inducing the economic development across the world through the inventories reduction (Sanidas & Shin, 2017). Effects of lean production could be enabled by the Industry 4.0 (Bittencourt et al., 2019a; Bittencourt et al., 2019b). Lean production also stimulated a society evolution resulting in a Society 5.0 (Keidanren, 2018; Nakanishi, 2019; Pereira et al., 2020). Such evolution is promoted by communications systems that interconnect all human activities, supported by technological paradigm called Industry 4.0 (Kagermann et al., 2013).

The purpose of Industry 4.0 is to reduce human impact in production using auspicious technologies that are emerging. These technological developments hold the possibility of impact society in countless directions. Either positively by bringing improvements at living standards and higher comfort, either negatively, impacting on employment, as well as, the growing discrepancy and unequal distribution of wealth and information (Nakanishi, 2019).

Nevertheless, society could be empowered to use digital technologies to better distribute wealth and information, benefiting the people and the planet. Therefore, people would need imagination and creativity to materialize their ideas, to be problem-solvers and value-creators and transform all existing data into useful information. Such information will improve decision making, which supported by effective indicators will lead society and, in particular, companies, to be aware of their status and compare themselves to their peers.

Considering all the above mentioned and the increasingly vital importance of environmental and social concerns, as well as, the economic and performance outcomes, this should be connected and appear as a one single indicator. This will allow position the companies related to their peers and to a standard. A lean-green approach seems to convey the right framework for companies to cope with the challenges in operation, management, markets and society. Notwithstanding, the recognizance of lean-green production synergy, there is a need for performance indicators to assess simultaneously lean and green practices in the companies. Accordingly, the motivation to choose this thesis theme within the scope of the Doctoral Program in Industrial and Systems Engineering.

1.2 Objectives

This thesis main objective is the development of a conceptual model to support the lean-green link assessment. This model is based on a performance indicator grounded on lean tools and the pillars of sustainable development. Its purpose is to be simple, straightforward and feasible for companies to use and apply, concerning the operational, economic, environmental and social performance. To achieve this objective, the following specific objectives were required:

- Identify and characterize models and indicators of lean-green;
- Identify and characterize companies that implement lean;
- Analyze companies' knowledge about the lean-green link;
- Develop a model that exploits the synergies of lean-green link;
- Implement and validate the model developed in case studies;
- Identify future research directions.

Three companies from the Northern Portugal were selected to validate the developed model. The adoption and deployment of the model hold the potential to trigger a lean-green endeavour, towards urgently needed companies that are both efficient and cleaner.

1.3 Research methodology framework

This research work was guided by the analysis, investigation and answer to the following research question: Is a lean company more sustainable? The research aim is to develop a model that assess the synergies of lean-green production by using key indicators. In order to answer this question, a research methodology was required.

The methodology began with a literature review on various topics related to the thesis' subject, which provided the foundation on which the research was developed. After the literature review, the development of a survey through a questionnaire was carried out, in order to understand the companies' awareness on the lean-green link. A deductive approach was used, that is, a theory or conceptual framework was developed, which through a research strategy was later tested with data from case studies. Based on these results, the model was developed, by means of an indicator, and three case studies were planned for its validation.

During this research, steps were planned and various research tools were undertaken, namely a survey and case studies. The chosen methodologies were those to be the most appropriate, aiming to answer the research question. In order to make a summary, this research study was developed in four phases (Figure 1). The applied methodology and research instruments are presented and detailed in chapter 3.

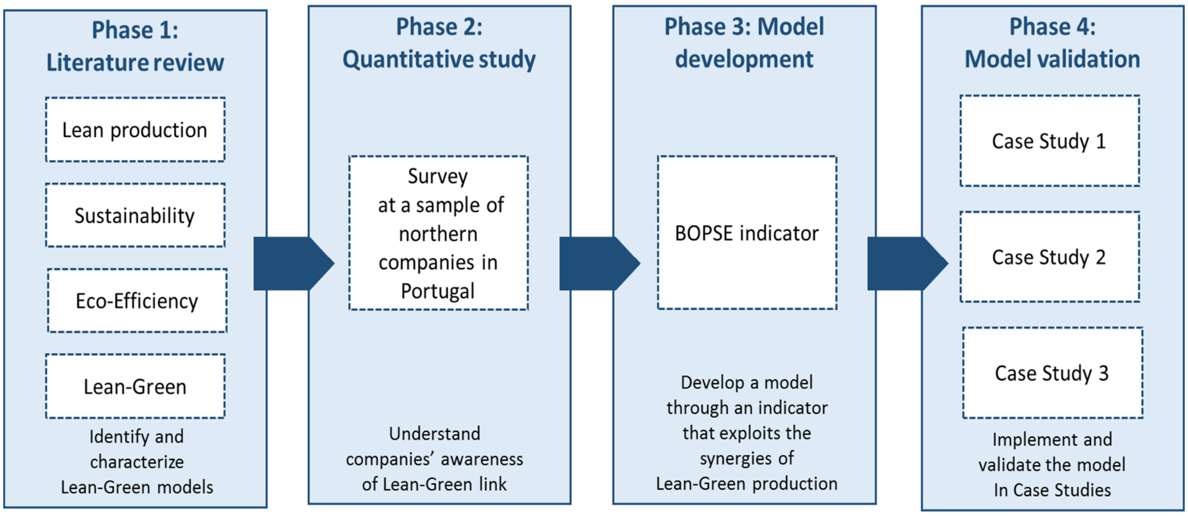

Figure 1 - Research Framework

1.4 Thesis structure

The thesis is organized in seven chapters. Chapter 1 presents the introduction and motivation, describes the research background, defines objectives and, presents the research methodology and the thesis structure.

A general review of relevant literature is depicted in Chapter 2. The chapter introduces the main concepts and terms within the research domain. First, it is presented the lean production, next, the sustainability and sustainable development. After that, the eco-efficiency and the lean-green paradigm are presented. This chapter ends with a critical analysis of this literature review.

Chapter 3 presents the overall research methodological approach, namely the survey and case study methods. The survey was applied to understand the current awareness on the lean-green link and the case study was used to validate the model.

Chapter 4 presents the results attained in the survey grounded on a questionnaire, that was applied to industrial companies, located in the north of Portugal. Discussion and conclusions are drawn grounded on the survey findings.

In Chapter 5, the model is presented and thoroughly described. The model proposed is operationalized through an indicator that aggregates and combines lean production and green production features.

In Chapter 6, the process and stages employed to validate the model are described. Then, discussion and final considerations are drawn.

The last chapter, Chapter 7, ends the thesis by presenting its conclusions, implications in terms of companies' management, and limitations, and discussion of future research contributions.

2 Literature review

This chapter intends to present the literature review on the thesis topic, in order to provide an overview of the main concepts. First, it begins by reviewing each concept involved, namely lean production, sustainability and sustainable development, eco-efficiency and lean-green. Finally, a critical review will conclude this chapter.

2.1 Lean production

This section begins presenting the lean definition viewpoints, followed by the lean designation genesis. Then, the lean thinking principles and the waste concept are described. Finally, leanness and performance indicators are presented.

2.1.1 Definition viewpoints

The lean production concept has evolved into a much broader strategy of action, since it was first used up to today (Womack et al., 1990). Lean production is usually defined from different viewpoints: a philosophical perspective; a practical perspective; a customer-focused methodology perspective; and a science perspective.

From a philosophical perspective, lean is based on lean thinking principles (Womack & Jones, 1996) that guided a company in value creation through systematic wastes elimination. This could demand an organizational culture change which needs a different fundamental mind-set (Yamamoto & Bellgran, 2010).

In this perspective, lean considers the interrelationship and synergistic effect of the practices to increase global productivity levels and product quality, waste reduction, to improve integration and collaboration across departments, and employee's autonomy, as stated by Liker (2004). He asserts: "*To be a lean manufacturer requires a way of thinking that focuses on making the product flow through value-adding processes without interruption (one-piece flow), a "pull" system that cascades back from customer demand by replenishing only what the next operation takes away at short intervals, and a culture in which everyone is striving continuously to improve.*" (Liker, 2004, p. 11).

About the genealogy of lean, Holweg (2007) pointed out the holistic and logical management system that characterized lean thinking. This justified the interest in this system since 1990 (Womack et al., 1990). In fact, lean thinking is considered more than a methodology, is a way of life. According to Flumerfelt et al. (2015) and Alves et al. (2017) educating lean to future professionals will provide content and competencies related with system-thinking, ethics and sustainability. Such competencies are essentially to develop the Society 5.0 concept, as referred by Keidanren (2018).

Considering the practical perspective, lean is seen as a management practice set of tools or techniques. Shah and Ward (2003) defined lean production as a multi-dimensional approach that encompasses a wide variety of management practices (including just-in-time (JIT), quality systems, work teams, cell production, supplier management, etc.). According to these authors these practices can work in synergy to create a simplified system that produces high quality finished products to the pace of customer demand with little or no waste (Shah & Ward, 2003). This is supported by others authors, namely, Bevilacqua et al. (2017).

Thus, the implementation of lean production practices is expected to result in improved operational outcomes, such as lower inventories, higher quality, and shorter throughput times, which, in turn, should improve financial performance. This description of lean production clearly indicates a number of mediating factors between lean production and financial performance (Hofer et al., 2012).

The National institute of Standards and Technology (NIST, 2010) presented an even more technical lean production definition as "*... a series of tools and techniques for managing your organization's processes. Specifically, Lean focuses on eliminating all non-value-added activities and waste from processes. Although Lean tools differ from application to application, the goal is always incremental and breakthrough improvement. Lean projects might focus on eliminating or reducing anything a final customer would not want to pay for: scrap, rework, inspection, inventory, queuing or wait time, transportation of materials or products, redundant motion and other non-value-added process steps*". The NIST purpose is that organizations which are lean-focused should extend out of their boundaries the concepts of waste elimination and value-added processes.

Lean production is, also, seen as a customer-focused methodology that seeks to eliminate waste and increase value to deliver timely quality products, at competitive prices and, at the same time, respecting people. The important main goals of lean production are to achieve high productivity while simultaneously synchronizing production with demand for a products variety, improve quality and reduce the production cost and delivery time, with intense operators' involvement (Lewis, 2000).

From a science perspective, Soliman and Saurin (2017) associates lean and science complexity in a synergetic way, that is, each has influence on the other. Lean impacts on the complex socio-technical systems attributes (Soliman et al., 2018). These authors think that lean production appears to balance complexity attributes, because reduces the process variety, and increases, as well, the controller variety to some extent.

Beyond the perspectives, many authors agree that Lean is extended from production boundaries. For instance, Jasti and Kodali (2015) emphasized that due to global competitiveness, companies struggle with pressures from customers and competitors. These conditions had led the way to integrate lean production concept with the whole production process (beginning in suppliers and ending with delivery to customers). This integration had given rise to "*Lean Enterprise (LE)*", concept early presented by Womack and Jones (1994). This is reaffirmed by Schonberger (2005). LE is a concept that surpasses organization boundaries and extends beyond their limits.

Interestingly, the literature review, from Sinha and Matharu (2019) also highlighted the many themes related to lean, classifying the papers in nine themes, which were: lean adoption, lean performance, leanness, lean supply chain, lean and other value creation tools, lean epistemology, organizational theory and lean, lean and sustainability and, to conclude industry 4.0 and lean.

It is also important to refer the synergy of lean with others areas such as supply chain and sustainability (Martínez-Jurado & Moyano-Fuentes, 2014; Garza-Reyes, 2015), lean and ergonomics (Arezes et al., 2015), lean and product development (Welo & Ringen, 2016). These examples displayed the lean multidisciplinary, emphasizing its role as an important paradigm and holistic approach and its transversal nature (Alves et al., 2017; Alves et al., 2014). Moreover, other papers focused in lean applied in healthcare (Mazzocato et al., 2010), education (Alves et al., 2017; Fliedner & Mathieson, 2009; Flumerfelt et al., 2016) and construction (Alves et al, 2012), and lean six-sigma (Tenera & Pinto, 2014).

Lastly, as a contemporary theme, the lean production relationship with Industry 4.0 is also outlined in literature. Mrugalska and Wyrwicka (2017) depicted a literature review about lean production and Industry 4.0 to demonstrate the possibility of linking these two approaches. The examples were for smart product, machine and augmented operator in reference to lean production principles and enabled to specify that the two approaches can support each other. Wagner et al. (2017) presented Industry 4.0 in an environment of connectability in the Internet of Things and Services with the vision of a smart factory. This paper displayed that Industry 4.0 can stabilize and support lean principles, as the Industry 4.0 impact matrix on lean production systems presented gave the framework to initiate design and develop Industry 4.0 integrated applications. This is corroborated by others authors (Bittencourt et al., 2019a; Bittencourt et al., 2019b).

2.1.2 Designation genesis

John Krafcik first used lean production system concept in 1988 to name the approach used by Toyota company in their production system (Krafcik, 1988). Subsequently, Womack et al. (1990) popularized this designation referring that it is Toyota Production System (TPS) (Holweg, 2007).

Toyota's Production System (TPS) roots are based, among others sources, on Henry Ford's mass-production system, which was the inspiration for Eiji and Kiichiro Toyoda and Taiichi Ohno to develop their production system, in the late 1940s (Holweg, 2007). TPS is grounded on two main technical pillars: the Just-in-Time (JIT), which aim was making only what was needed, in the amount that was needed and when was needed, and the *Jidoka* or autonomation that meant automation with a human touch (Liker, 2004; Monden, 1998).

Therefore, TPS was based on a strong commitment with employees, lean supply chain, JIT principles and techniques, waste elimination, quality assurance, the continuous improvement and a customer's closer relationship, together with a strong market research (Shingo, 1989; Womack et al., 1990). This system resulted from an adaptation to a smaller market and a different culture, and in few years turned out Toyota in a successful company. The reason for the interest in the Japanese automobile industry accrues from the excellent results achieved by Toyota's factories since the oil crisis of 1973, in the design and manufacture of cars in less time, with fewer people and less stocks (Moreira et al., 2010).

This oil crisis has renewed interest in researching the future of the automobile industry, starting with the International Motor Vehicle Program (IMVP) of the Massachusetts Institute of Technology (MIT) (Holweg, 2007). Although there have been many publications on TPS (Monden, 1998; Ohno, 1988; Shingo, 1989), on its foundations and tools, namely, JIT, *Kanban*, Total Quality, among others, it aroused little attention in the industrial environment (Holweg, 2007). This author stated that the key feature of the book "*The Machine that changed the world*" was not only discuss production operations, but also product development, supply chain and distribution issues.

The lean methodology became a successful approach, and even a reference, for shop floor improvement and has been spreading worldwide and across many economic activity sectors afterwards (Amaro et al., 2019). The TPS tried to perform well in what mass production excelled i.e. the resources smallest use to make things, while enabling for greater production flexibility, quality assurance and timely deliveries (Womack et al., 1990). TPS success and features were studied and described in a number of MIT researched work, that disseminated the concept and became the basis for many other publications (Samuel et al., 2015).

Toyota engineers designed the TPS so that fewer and fewer resources would be required for delivering the right products at the right time at the shortest timeframes possible, by eliminating all types of wastes, therefore requiring less human effort, fewer inventories and facilities space. According to Ohno, wastes are all activities that do not add value to products and classified them in seven categories (Ohno, 1988). These wastes will be detailed in section 2.1.4.

2.1.3 Lean thinking principles

Waste elimination is the lean production focus and the continuous idea leading to this elimination, is called lean thinking (Womack & Jones, 1996). Lean production aims to achieve a high products diversity, high productivity and, simultaneously, the synchronization of production and demand (Moreira et al., 2010). To achieve these goals, Womack and Jones (1996, p. 10) summarized five lean thinking principles described as: "precisely specify value by specific product, identify the value stream for each product, make value flow without interruptions, let the customer pull value from the producer, *and pursue perfection.*".

Lean Thinking provides a way for specifying value, lining up value-creating activities in the best sequence, conducting these activities without any interruption when someone demands for them, and performing them more and more effectively and efficiently (Womack & Jones, 1996), while providing customers with what they want. Next, these principles are described.

1. **Specify Value**: means create value for the customer. Value is the features set intended by the customer. Anything that does not generate value for customer should be eliminated. Value is assumed as an essential starting point for lean, and is significant only when expressed in terms of a specific product (a good, a service or both of them), that the customer wants (i.e. customized), suitable for a clear purpose, with an appropriate price and with minimum time between customer's order and its delivery. Therefore, this means a changing way in companies' thinking. They have to rethink value from the customers' perspective, ignoring existing assets and technologies, and rethinking their companies in terms of a product-line basis. This is achieved through committed product teams on a constant dialogue with customers. Moreover, companies must avoid the waste of providing the wrong product or service in the right way (Womack & Jones, 1996).

2. **Identify the Value Stream**: value stream is defined as all the specific activities required for designing, order, and providing a specific product, from concept to launch, order to delivery, and raw materials into the hands of the customer. This principle means analyse, throughout the entire production system, which processes add value. Any activity that does not add value is a waste, and therefore must

be eliminated (Wu et al., 2013). The aim is to identify the set of production steps or activities required to provide a specific product (good, a service or a combination of both) to the customer, and which, individually, generate value for the customer, eliminating all waste sources. Identifying each activity required in a value stream map has the aim of sorting these activities into three types: (1) activities that create value for the customer; (2) activities which do not create value but are required (waste Type One) and cannot be eliminated for now by current technologies and production assets; and (3) activities that do not create value for the customer (waste Type Two) and can be immediately eliminated. After these third activities elimination, the companies have to work on the remaining activities that do not add value using the flow, pull and perfection techniques (Womack & Jones, 1996).

3. **Flow**: means the progressive tasks achievement along the value stream so that a product goes from design to launch, order to delivery, and raw materials into the customer hands with no stoppages, scrap, or backflows. Create a continuous flow of materials, throughout the entire process, without waiting, without stock gatherings and without unnecessary movements. Once the wasteful activities are eliminated, the remaining value-creating activities have to be organised in a flowing way. This means move from the functional and departmental companies towards customer-focused companies, arranged along value streamlines. Usually, cellular manufacturing is adopted, where each cell encompasses all resources needed to produce a specific product, or a cells group is arranged to produce a specific product. Obviously, for enabling products to flow smoothly through company to the customer, companies will favour single-piece or continuous flow use, rejecting batch and queue production. The emphasis is on the entire value stream effectiveness. The production speed will increase if flow between steps is favourable, providing a more efficient delivery to customer. This requires continuous alignment between workflows and value creation (Womack & Jones, 1996).

4. **Pull Production**: is defined as a cascading production system and delivery instructions from downstream to upstream activities, in which the upstream supplier produces nothing until downstream customer signals a need. This means that nobody upstream should produce a product or service until the customer downstream requests for it. When the value-creating activities are organised to flow, customer can pull value through the system. Pull production means producing only what is pulled by customer, which signifies that production is carried out as customer places his orders. Thus, a process starts only when the previous one requests it, eliminating unnecessary stocks and synchronizing production with customer's orders. Contrasting the traditional production systems that produce in the hope of selling (pushing) the products (or services), the lean challenge translates into operations regulated by demand, avoiding excess production that will be transformed into inventories and unnecessary costs.

In pull production, no work is carried out upstream until customer downstream requests for it. Furthermore, in pull production the customers' demands become more stable, because then customers know that they can get what they need when they need (Womack & Jones, 1996).

5. Pursuit **Perfection**: means the complete waste elimination in order to all activities along a value stream create value. Pursuit perfection, through a process of continuous improvement, also known as *Kaizen* (Imai, 1986), means constantly improve upon the four principles above. It seeks to create a constantly revised environment in which the employees' suggestions are considered and where problems are solved at detection moment, in order to not repeat the same mistakes and avoiding waste. For companies adopting lean, it becomes clear that this improvement process is a never-ending process, because getting value to flow faster always revels hidden waste in the value stream, there is always the possibility to find more ways to remove waste through the elimination of effort, time, space, and errors. Alternatively, companies may encompass a radical path to perfection, involving all the companies from start to finish, with a global value stream *Kaikaku* (radical improvement). Perfection is not an end in itself, is a path to embrace along the way, and trying to get there offers inspiration and direction to progress along the way (Womack & Jones, 1996).

The sequential realization of these five principles leads the company to lean production implementation. These principles imply dedication of all, being the last one – pursuit perfection -, the one that implies the strongest and continuous commitment of people, in order to improve all companies' activities and processes, through waste elimination. One might say, that the later principle gives the mote for a new continuous improvement cycle, also known as *Kaizen*. This happens because people are totally committed with lean and always unsatisfied with the *status-quo*. They become thinkers (Alves et al., 2012).

2.1.4 Type of wastes

Waste or *muda* (Japanese term) was considered by Ohno (1988) as all the activities that does not add value to products, according to the customers' point of view and that he/she is not willing to pay. As Taiichi Ohno said: *"All we are doing is looking at the time line from the moment the customer gives us an order to the point when we collect the cash. And we are reducing that time line by removing the non-value-added wastes"* (Ohno, 1988, p. ix). In companies, not all operations performed create value as referred in the value stream principle (section 2.1.3), and therefore must be eliminated. Ohno (1988) classified wastes in seven categories of fundamental waste: 1) overproduction; 2) over-processing (or unnecessary processing); 3) transportation; 4) defects; 5) motion; 6) inventory or stock and 7) waiting, detailed next.

Overproduction means producing more than demand. It means larger raw materials consumption and more labour use, resulting in the need for more storage space, more tied capital, more handling and movement of materials, besides increasing the production control problems. Overproduction is considered the worst waste by TPS due to its implications (consequences): resource overload and excessive inventory.

If companies overproduce, this means that they will purchase more raw materials for producing more goods. This implies to consume more energy, water and other inputs, as well as, to allocate more human resources. Simultaneously, more wastes will be produced and more inventories will have to be managed. Therefore, overproduction will impact earth natural resources by exploring it more than necessary.

Over-processing or incorrect processing is due to unnecessary or incorrect processing operations, due to wrong methods, equipment in bad operating conditions or inadequate tools. The main consequences are defects occurrence, time and material waste.

Transportation is associated with materials transport. All products had to be transported throughout all production processes, being a significant effort in energy and labour without any value added for products. The distances travelled by materials are closely linked with the factory layout. The greater the distances travelled by materials, the greater is the tendency of transporting larger quantities to reduce the travels number, thus having an impact on inventory.

Products with defects is a waste because on these products was used labour time, equipment time, raw material, tools, and so one, without this resulting in products that can be sent to customers. In addition to the direct waste of defects, there is also an indirect impact on other types of waste such as waiting, inventory and overproduction.

Motions are related to all workers movements, which do not add any value to products. These movements result, for example, from inadequate layouts, lack of attention to ergonomic aspects, poor organization of workstations, and lack of cleaning and inconsistent working methods.

Inventory (stocks) means any raw material, work-in-process, or finished product spread through production or warehouses, hiding production balancing problems, suppliers failing to meet delivery dates, high setup times, defects, and machine failures. This causes long lead times, risk of obsolete and/or products deterioration, transportation and storage costs, and delays.

Waiting happens when workers are standing waiting for parts, machines or other co-workers (colleagues), which means the loss of resources (equipment or people) because they are waiting for something or someone. These waits can be of four types: people waiting for machines, people waiting for people, machines waiting for people and machines waiting for machines. This waste, like the inventory, is a symptom of the production system inefficiencies.

Liker (2004), beyond these wastes, and additionally, adds an eighth waste, the lack of use of human creativity, by not listening to peoples' ideas and suggestions and also by not exploring and developing their skills. When properly stimulated, workers can improve the process where they are working, since they know it better than anyone else does. For this, it is essential to strengthen their involvement and more active participation in the process. This creative thinking is considered one of the TPS pillars (Monden, 1983).

2.1.5 Leanness and performance indicators

This section presents the concept of leanness and key performance indicators (KPI). In this, it will be highlighted the OEE indicator.

2.1.5.1 Leanness

According to Cocca et al. (2019) *leanness* concept serves to quantify the overall progress and impact of lean production initiatives introduced in a company. According to the same authors, there are two approaches for leanness definition according to the focus given: 1) practices adoption and 2) performance outcomes. The first measures the degree of implementation of lean practices and the second is related with the extent of performance improvement achieved by lean implementation.

An example of the first approach is the one from Duque & Cadavid (2007). These authors integrated a set of metrics that had been proposed by different authors and that were consistent with the different stages and elements of lean manufacturing implementations. Five main dimensions can be measured to assess the evolution degree in a lean transformation and four or five metrics were defined for each of them. The dimensions were waste elimination, continuous improvement, continuous flow and pull driven systems, multifunctional teams and information systems. Then, they presented the impact that lean activities were expected to have on the different performance measures defined and they concluded that empowerment was a rather important aspect of a transformation process. The appearance of 5S was also interesting, because it was perceived by some people as a rather mundane cleaning drive when in reality it was the practical foundation for improvement of the workplace, discipline, TPM and even self-respect.

Some years later, as well, Wahab et al. (2013) developed a conceptual model to measure leanness in manufacturing industry. The emphasis was on the indicator's identification, practices, tools or techniques for lean implementation, in manufacturing. The research had shown seven main dimensions: manufacturing process and equipment, manufacturing planning and scheduling, visual information system, supplier relationship, customer relationship, workforce and product development & technology. These dimensions contributed to leanness measurement in manufacturing.

Second approach is reflected, for instance, in the work of Mourtzis et al. (2017) that proposed a methodology for improving the leanness of Product-Service System design, via the combination of real-time KPIs monitoring with lean principles and practices. The lean methodology establishes over time the lean philosophy in the factory, causing the progressively avoidance of wasteful activities and, therefore, increasing efficiency. The aim was the industry's functions transformation towards the production of leaner Product-Service System contributions through gradual improvements at process and factory levels.

Additionally, Abreu-Ledón et al. (2018) studied the impact of lean production on business performance. They considered two different performance outcomes (financial and market) and six lean production practices. The three individual lean practices considered related with business performance were process control and improvements, workforce development and customer focus.

Cocca et al. (2019) presented a literature review grounded on methods to measure leanness in manufacturing organizations. Through a systematic literature review 31 leanness measurement methods were identified and analysed considering the following set of dimensions: assessment methodology, leanness definition, inputs, outputs, and application. Considering the papers distribution over time, the authors highlighted the recent interest in this research area, since that the majority of papers were available between 2008 and 2015, and specifically more than half of the papers between 2012 and 2014.

Therefore, leanness gives some indication about the difficulties for a company to become lean. A company is not lean just because implemented one or two tools or implement the tool partially (for instance, if audits are not part of 5S implementation, a company do not have 5S implemented). Lean implementation is not an easy process and many companies fail to achieve that due to many factors such as: organizational culture; plant size and age; lack of knowhow; unionization status, fear, leadership, among others (Cowger, 2016; Frontiers, 2017; Liker & Rother, 2010; Matt & Rauch, 2013; Melton, 2005; Schonberger, 2019; R. Shah & Ward, 2003; Shah & Ward, 2007; Silva et al., 2019).

Other aspects that could be raised in this implementation are: how many tools a company has to implement to become lean? Are the tools the only thing that matters? Of course, the answer is negative. This is the reason why leanness could not be just measured having in account the tools implemented. As Stewart and Raman (2007) through interviews to a Toyota senior executives reported, more important than tools is the mind-set. How to measure the mind-set?

Probably to difficulties in obtaining the answer to this question, and even with a defined leanness concept, it is not straightforward to state when a company is a lean company and more studies are needed (Fukuzawa, 2019). Additionally, a report from Lean Frontiers (2017) highlighted that becoming lean is much more than practices and tools employment and companies need to be aware of it. According to this report, in fact, becoming lean should be an internal social movement of transformation.

Nevertheless, lean production implementation needs to be supported by tools and techniques and over the years, a set of tools have been developed and applied to the industrial and service work environment. These tools helped companies to improve production flow, create value and make processes more effective and profitable. Many times, these tools are referred to as sets of "bundles" of practices (Cua et al., 2001; Duque & Cadavid, 2007; Flynn et al., 1999; Matt & Rauch, 2013; Shah & Ward, 2003; Wahab et al., 2013).

These authors studied the lean practices contribution into the competitive companies' performance. Some of these practices and/or lean tools can be listed: Value stream mapping (VSM); standard work; 5S; one-piece flow production; JIT production; OEE, Kanban; Kaizen, among others. Some of these tools are, briefly, described in Appendix A, Table 61.

2.1.5.2 Key performance indicators

Lean tools are not sufficient if companies do not know their position in terms of performance. This means that companies need to have and define key performance indicators (KPIs), to evaluate their performance and to improve their value creation process. Measuring performance enables a company to quantify all its activities, through a set of parameters, which are the KPIs. As reviewed above, leanness concept is strictly related with KPIs.

In the following sections, it will be explained what are performance measures and why they are important. Furthermore, this thesis author presents deeply one of KPIs currently applied in many companies, the

OEE, because it is an indicator that aggregates other performance measures and constitutes an important piece of the BOPSE indicator developed in the thesis, as will be show in the chapter 5.

2.1.5.2.1 Performance measures

The standard ISO 22400 focuses on performance measures significant for the improvement of operational performance (ISO, 2014). These performance measures could be achieved through the combination of numerous measurements from operations and serve to establish KPIs. According to this standard, key performance indicator is a quantifiable level of achieving a critical objective.

The selection of KPIs is a concern for companies, and, sometimes, companies struggle to select their specific indicators from a large number of standalone indicators set available. The question is that companies seek to improve products, processes, quality, lead time, costs, business and operational performance, safety, satisfaction, sustainability performance among others and, for that, they need to measure.

For instance, Kibira et al. (2018) presented a procedure to select KPIs for measuring, monitoring and improving environmental aspects of manufacturing processes. This procedure was developed as a basis for a guideline and proposed for standardization within ASTM International. According to the authors, the existence of KPIs repositories for manufacturing processes will provide pre-defined KPIs, for companies select those that are suitable for their specific processes. They also stated that these repositories should be effortlessly accessible and extensible to organize KPIs, as more are incorporated.

Having KPIs defined, then a company will monitor its performance, identifying trends and comparing it to the objectives. Several operational areas, like sales, manufacturing, engineering, marketing, and other support functions will have their sets of performance indicators, which then are combined together to monitor the company goals achievement (ISO, 2014). KPIs that combine various indicators will have advantages because it interrelates various departments, giving a global picture of the company performance.

2.1.5.2.2 Overall Equipment Effectiveness

One of the indicators that is worth to highlight is the combined indicator Overall equipment Effectiveness (OEE). It considers the most important sources of manufacturing productivity losses, classifying them within three categories: 1) availability, 2) performance and 3) quality (Nakajima, 1988). It is calculated as a product of its three components, Equation 1.

$$OEE\ (\%) = Availability\ (\%)\ x\ Performance\ (\%)\ x\ Quality\ (\%)$$

Equation 1 - Overall Equipment Effectiveness formula

Availability measures the effective time available for production (the operating time), accounting the down time losses. Availability is calculated by the following:

$$Availability = \frac{Operating\ time}{Planned\ production\ time}$$

Equation 2 - Availability formula

Performance measures the net operating time for producing, considering the speed losses that cause the process to operate at less than the maximum possible speed. It is calculated as:

$$Performance = \frac{Ideal\ cycle\ time}{\frac{Operating\ time}{Total\ pieces}}$$

Equation 3 - Performance formula

Quality measures the produced pieces that meet the quality requirements (the fully productive time), accounting for all quality losses, the ones that do not meet the requirements, as well as, the ones that require rework. The goal is to maximize this fully productive time. It is calculated as:

$$Quality = \frac{Good\ pieces}{Total\ pieces}$$

Equation 4 - Quality formula

The manufacturing productivity losses are the chronic and sporadic disturbances in the process that result in different categories of losses or waste (Nakajima, 1988). Table 1 depicts them.

One might say that the OEE is an indicator that measures the performance in a three-dimensional way, because it reflects the:

1. time the equipment has to run/produce;
2. established efficiency during operation, i.e. the ability to produce at nominal rate;
3. product quality obtained by the process (Silva, 2013).

Bamber et al. (2003) stated that OEE is being used “increasingly” in industry. The OEE as a total measure of performance in modern operations is discussed. OEE was considered suitable to all operations encompassing plant and machinery. These authors referred that using cross-functional teams, heading for improving the business competitiveness, was the most effective method of applying OEE.

OEE is used as a key metric in TPM and lean manufacturing, portraying a consistent measure for assessing production effectiveness and efficiency (Vorne-Industries, 2008). OEE can support management to unleash hidden capacity and thus, reduce overtime expenses.

Table 1 - The Six big losses (Nakajima, 1988)

OEE loss category	Six big losses category	Description
Downtime losses	Breakdowns	Include the time losses when productivity is reduced, and the quantity losses caused by defective products.
	Set-up and adjustment	Result from downtime and defective products that happen when production of one item ends and the equipment is adjusted to encounter the requirements of another item.
Speed losses	Small stops	Happen when production is interrupted by a temporary malfunction or when a machine is idling.
	Reduced speed	Refer to the difference between equipment design speed and actual operating speed.
Quality losses	Start-up rejects	Include the yield losses that happen during the initial stages of production, from machine start-up to stabilisation.
	Production defects	Include the losses in quality caused by malfunctioning production equipment.

Also, by reducing changeover times and improving operator performance, it helps to reduce process variability. These benefits improve the production bottom line and increase companies' competition (Muchiri & Pintelon, 2008).

More recently, Ali and Deif (2014, p. 578) stated that: "*OEE measurement is commonly used as a key performance indicator (KPI) in conjunction with lean manufacturing efforts to provide and indicator of success*". This portrays that OEE associated with lean is a usual indicator to access company's performance.

Over the years, the OEE is being applied as a measurement to improve manufacturing performance (Jonsson & Lesshammar, 1999). In collaboration with a first-tier automotive component supplier, the OEE was determined for a semi-automated assembly cell. The OEE obtained was 62% and the future action for the company would be TPM implementation (Chand & Shirvani, 2000).

From a case study in a steel company, Almeanazel (2010) reviewed the goals and benefits of implementing TPM. This author pointed out that the company needed to know where it was to improve, so the OEE was calculated and the value was 55%. Acknowledging this, the company knew where it was and, then, identified weaknesses and opportunities to improve.

Gola and Nieoczym (2017) studied the OEE for improvement of manufacturing lines reliability. They analised the operation of a filling line for beverages. For them, in a company, OEE is one of the most significant metrics to describe equipment performance. OEE allowed the identification of "bottlenecks", and technical and organizational problems. They concluded stating that OEE can be used to assess the benefits of process improvement and eliminate individual problems. Bamber et al. (2003) agree with this last statement, corroborating that OEE could be used for setting improvement objectives, internally.

Nevertheless, they go further stating that it could also be used with an external target, as the achievement of 85% world class value.

It is possible to notice that this type of calculation makes OEE a severe test. For instance, for 72.9% in the OEE, its three components must be 90%. The OEE rate in manufacturing plants is 60%, according to worldwide studies (Vorne-Industries, 2008). However, the generally accepted world class for OEE is 85% (Jonsson & Lesshammar, 1999), as shown in Table 2. Therefore, within manufacturing plants there seems to be room for improvement, considering the OEE world class.

Table 2 - OEE rate for the world class

OEE components	World Class
Availability	90.0%
Performance	95.0%
Quality	99.9%
OEE	85%

In the context of Industry 4.0 (Kagermann et al., 2013), OEE appears as a value driver for companies capturing actual value through Industry 4.0 in a McKinsey report (2019). OEE arises, either, as data-driven OEE optimization in small-lot manufacturing, either, as in high-volume production, where fully automated production and maximized OEE are required. Data-driven OEE optimization purpose is to identify the root causes of OEE loss within the three OEE components of availability, performance, and quality, through the use of advanced analytics. Then, countermeasures to these root causes will be identified (Mckinsey, 2019).

2.2 Sustainability and sustainable development

The section begins presenting the sustainability definitions and origin, followed by the sustainability interpretations and paradoxes. Then, the sustainable development goals are described, afterwards, responsible production and consumption are presented. Lastly, some sustainability tools and sustainability indicators framework are presented and the integrated management systems discussed.

2.2.1 Definitions and origin

Sustainability is not a new concept, as the United States National Environmental Policy Act (NEPA) from 1969 shows. This document stated sustainability as a national policy and defined it. Sustainability "*means to create and maintain conditions under which humans and nature can exist in productive harmony, that permit fulfilling the social, economic, and other requirements of present and future generations*." (US-

EPA, n.d.-a). This means that sustainability is perceived as the continued protection of human health and the environment while fostering economic prosperity and social wellbeing.

Sustainability is the main concept underlying the sustainable development because it is the framework of this development mode. In 1987, the Bruntland Commission report called "*Our Common Future*" 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, p. 24). However, as pointed out by several authors this definition is too much general or macroeconomic for companies to follow (Gimenez et al., 2012; Wu & Wu, 2012; Zhang et al., 2017).

According to Costanza (1991, pp. 8-9) "*Sustainability is a relationship between dynamic human economic systems and larger dynamic, but normally slower-changing ecological systems, in which: 1) human life can continue indefinitely, 2) human individuals can flourish, and 3) human cultures can develop. But in which effects of human activities remain within bounds, so as not to destroy the diversity, complexity, and function of the ecological life support system.*".

The sustainability idea came, in part, of human awareness, provided by nature (mineral, vegetable and animal) over time that resources are scarce and finite. Therefore, originated in Biological Sciences renewable resources, especially those who may be finished by the uncontrolled exploitation, then, can be assumed as the quality of what is sustainable, meaning *ab aeterno* natural resources maintenance and conservation. What means, using natural resources without destroying them, without exceeding its resilience, and without excluding their possible use by future generations.

In business and industrial field is given special attention to the so-called "triple bottom line" (3BL), namely the economic, environmental and social sustainability. Elkington developed this concept in 1998, which considers and balances simultaneously these "three pillars" of sustainability from a microeconomic point of view (Elkington, 1998).

This concept implies that all three pillars are necessary and equally important for sustainability. Economically, companies must grow without compromising their integrity. Environmentally, companies should be concerned about environment, always seeking to reduce environmental impact, from cradle to grave. Socially, it has to respect human rights, with equity promotion and social investment. The 3BL is also called as "planet, people, and profit" (3P), nevertheless their relationships with each other is a controversial subject (Elkington, 1998).

At the same time, in this sustainability debate, one cannot forget the ones in the "Bottom of the Pyramid (BOP)", as Prahalad (2005) identified as "*those 4 billion people who live on less than $2 a day*", representing two-thirds of the world's population. Prahalad (2005) argues that the focus should be on the underserved consumer (and not "the poor") and in his potential for global growth, as he becomes part of an inclusive capitalism system. He states that the process should start with respect for Bottom of Pyramid consumers as individuals and that the BOP is an opportunity to boost the process of change in the traditional relationship among the company and the consumer. He also argues that recognizing the BOP as an active market is a development activity and it is not serving an already existing market more efficiently. The challenge will be encounter new and creative approaches to convert poverty into an opportunity for all involved.

Based on the view of Sachs (1986), Colombo (2004) defined sustainability as the idea of minimizing the irreversible changes, leaving open possibilities for the present and the future, in a very wide time scale. Is the awareness that every single living being is not alone, that all are a network part, and each destroyed network node destroys a little of each other nodes, among which we are one and the life quality of all depends on that whole life.

While the perceived need to stay within bounds of natures' recovery capacity is rather essential, it is necessary to expand the spectrum of what needs to be done and preserved, e.g. cultural diversity. Then sustainability is not limited to nature, it also encompasses other dimensions. Several sustainability dimensions can be found in distinct authors (Colombo, 2004; Diegues, 1992; Munasinghe, 1993; Pappas, 2012; Pelizzoli, 1999; Sachs, 1993; Ultramari, 2001) such as: economic or financial; ecological or environmental; individual; cultural; etc. Some authors presented combined dimensions, such as socio-cultural (Munasinghe, 1993) or spatial-political and political-temporal (Sachs, 1998).

In 2012, Pappas extended WCED definition, and defined sustainable society as "*a society possessing the ability to continue to survive and prosper, not just with respect to environmental resources and economic development, but also with respect to quality of life as it pertains to conditions that promote sustainable human activity and growth (...). A sustainable society meets these needs simultaneously, and in the context of human respect and the ability to negotiate differences without violence.*" (Pappas, 2012, p. 2).

This author considered that sustainability goes far beyond than the treatment of environmental resources and waste. He considered five sustainability dimensions: social-cultural, economic-financial, environmental or ecological, technical or technological, and individual (Pappas, 2012; Pappas et al., 2015). Other authors added three more dimensions: Relational or Convivial, Territorial or Geographical and Epistemological (Alves & Colombo, 2017).

2.2.2 Sustainability interpretations and paradoxes

The sustainability debate started in the 90´s and continues till today (Ayres et al., 1998; Wilkinson et al., 2001; Edwards, 2009), (Ang & Passel, 2012; Hahn et al., 2018; Verboven & Vanherck, 2016). For instance, Ayres at al. (1998) argued that the focus is on "weak" versus "strong" sustainability, where discussion is on the sustainability ability to allow, or not, for substitution among natural and human made capital. As an illustration, the question may be: can a high level of economic development be substituted for a low level of environmental quality? Weak sustainability allows mutual substitutability among three dimensions, while strong sustainability does not (Ayres et al., 1998; Bergh & Gowdy, 2000; Kuhlman & Farrington, 2010; Wu & Wu, 2012).

Weak sustainability emphasis is on achieving a non-declining level of the total capital. Strong sustainability implies that the environment provides natural resources and ecosystem services needed for economic and social development. Economic development depends on both environmental and social capital, while both social and economic processes affect environmental conditions (Wu & Wu, 2012). The environmental dimension is regarded as a fundamental basis for sustainability, due to the natural resources increased scarcity and the environmental pressures imposed by the growing human population. The argument for this is that, without an acceptable level of biodiversity and without ecosystems functioning and services, no economic or social development is sustainable.

Ang and Passel (2012) continued the debate on weak versus strong sustainability and on the substitutability of human-made capital for natural capital.

Edwards (2009) presented seven stages of organizational sustainability as the transformations spectrum that are hypothetically available to companies. Each organizational sustainability form was related with certain internal qualities types and environmental conditions. The author meta-theorized the sustainability paradoxes: the growth, the learning and the sustainability one. He theorized that companies, as well as national and international economies had to struggle in the paradoxical status quo of the increasing pressure to generate economic growth. At the same time, it was in this same economic development and consumption that was triggered the environmental disorder and, simultaneously, causing the ultimate social displacement.

This sustainability paradox strives on this ever-standing problem of balancing sustainable change with sustainable stability. This growth-sustainability paradox was acknowledged by Stacey (2005). For Rotmans (2006, p. 37) the sustainability paradox is "*the unsustainability problems humankind is faced* *cannot be solved with current tools and methods that were applied - or seemed to work - in the past. Obviously, the paradox is that we cannot wait for the next generation of tools and methods (and minds)*".

More recently, Verboven and Vanherck (2016) stressed out the unintended negative side-effects of new 'sustainable' business models as the sustainability paradox. Already, Hahn et al. (2018, p. 237) discussed a paradox perspective on corporate sustainability. They defined it as: "*A paradox perspective on corporate sustainability accommodates interrelated yet conflicting economic, environmental, and social concerns with the objective of achieving superior business contributions to sustainable development*".

Over time, sustainability has been studied in many perspectives and viewpoints, for instance, reporting its practical application (Qu et al., 2015; Sengupta et al., 2015; Wagner, 2015; Luqmani et al., 2017; Weissbrod & Bocken, 2017) and presenting indexes and frameworks (Harik et al., 2015; Helleno et al., 2017; Kim et al., 2015; Vimal et al., 2015). Also, reports have been presented (Chen et al., 2015; Greco et al., 2015), focusing on corporate social responsibility (Lai et al., 2015) and reviews (Zaman, 2015; Cherrafi et al., 2016; Caldera et al., 2017).

2.2.3 Sustainable development goals

The sustainable development achievement encounters numerous ecological and social challenges, due to the growing populations and the increasing individual consumption. As stated by the Global Footprint Network (GFN), the global economy driven by consumption uses natural resources that are equivalent to over 1.5 planets earth (called the global ecological footprint of humanity) (Munasinghe, 2012).

Even this year of 2019, and according to Global Footprint Network the "*Earth Overshoot Day*" was in July 29th, the earliest day ever. This day signalled the date when humanity's annual demand on nature surpasses what Earth's ecosystems can regenerate in that year. This signifies that humanity is at this time using nature 1.75 times faster than the planet's ecosystems can regenerate (GFN, 2019a).

Thus, societies are under severe pressures because of the global scenario of natural resource depletion, the environmental degradation and social tensions. To face those pressures, on the 25th September 2015, a historic global political agreement was made, when 193 countries signed the United Nations Sustainable Development Goals for 2030, known as SDGs or "*Global Goals*" (Pedersen, 2018).

The 17 Sustainable Development Goals and its 169 targets demonstrate the scale and ambition of this new Agenda - "*Transforming our world: the 2030 Agenda for Sustainable Development*" (United Nations, 2015).

Figure 2 presents the three sustainable development pillars and partnerships engaged, where the three pillars are equally significant and essential for a sustainable development. Therefore, economically, companies should prosper without compromising their integrity. Socially, should respect human rights, pursuing social equity and social investment. Environmentally, companies should be concerned with reducing environment impact. Therefore, sustainable development is a concept with strong connections to companies, but likewise strongly involving government and civil society partnerships in its path.

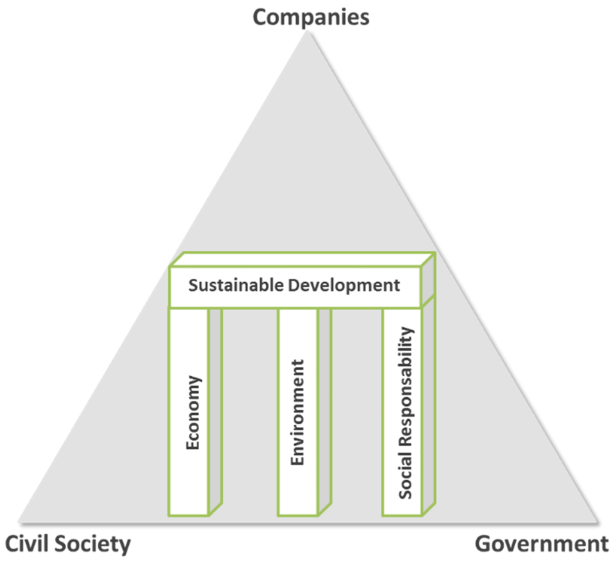

Figure 2 - Sustainable development pillars and partnerships involved
(adopted from Maia et al., 2013)

According to Holliday et al. (2002), the prices of products should reflect all costs (financial, environmental and social) involved in their production, their use and their deposition and recycling. Companies must have economic viability, respect for environment and promote social equity to have a sustainable business.

The Millennium Development Goals (MDGs) were launched, in 2000, by the United Nations (UN) member states as an agreement for global development, aiming at driving the global development agenda for the 2000-2015 period. The targeted strategic areas were poverty, education, gender equality, child mortality, maternal health, disease, the environment and global partnership. The development process of the SDGs had its kick off at the RIO+20 UN Earth Summit, in Rio de Janeiro, Brazil 2012. The intention was a new set creation of global goals to address the increasing challenges for a sustainable development, and to carry on the journey started with the MDGs (Pedersen, 2018). The 17 SDGs are (United Nations, 2015, p. 14):

- **Goal 1.**End poverty in all its forms everywhere,

- **Goal 2.**End hunger, achieve food security and improved nutrition and promote sustainable agriculture,
- **Goal 3.**Ensure healthy lives and promote well-being for all at all ages,
- **Goal 4.**Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all,
- **Goal 5.**Achieve gender equality and empower all women and girls,
- **Goal 6.**Ensure availability and sustainable management of water and sanitation for all,
- **Goal 7.**Ensure access to affordable, reliable, sustainable and modern energy for all,
- **Goal 8**. Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all,
- **Goal 9**. Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation,
- **Goal 10**. Reduce inequality within and among countries,
- **Goal 11**. Make cities and human settlements inclusive, safe, resilient and sustainable,
- **Goal 12**. Ensure sustainable consumption and production patterns,
- **Goal 13**. Take urgent action to combat climate change and its impacts,
- **Goal 14**. Conserve and sustainably use the oceans, seas and marine resources for sustainable development,
- **Goal 15**. Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss,
- **Goal 16**. Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels,
- **Goal 17**. Strengthen the means of implementation and revitalize the Global Partnership for Sustainable Development.

The SDGs and targets, as already said, are integrated and indivisible, but also global in nature and with universal applicability, considering the diverse national realities, capacities and development levels and respecting the national policies and priorities. Ambitious targets were defined globally and each country government defined its own national targets accounting for its national conditions (United Nations, 2015).

As currently, global businesses face novel and multifaceted opportunities and challenges, and in order to accomplish the Sustainable Development Goals (SDGs), the WBCSD promotes six programs to realize systems change and transformation, which are: circular economy; cities & mobility; climate & energy; food & nature; redefining value and people (WBCSD, 2019).

2.2.4 Responsible production and consumption

This section depicts the concepts of sustainable production and consumption, then sustainable production, followed by sustainable consumption. The section concludes with cleaner production.

2.2.4.1 Sustainable production and consumption

Sustainable consumption and production (SCP) can be dated to 1992, in the UN Conference on Environment and Development, held in Rio de Janeiro. It was recognized as a main and all-embracing concept to link environmental and development challenges. In the final report - Agenda 21 - it was stated that the most important cause of global environment constant deterioration were the consumption and production unsustainable patterns (UNEP, 2010).

In 1994, at the Oslo Symposium on sustainable consumption, the Norwegian government hosted a roundtable on sustainable consumption including business, NGO and government representatives, which analysed the stakeholder's role and provided a working SCP definition. This definition is the most widely accepted one and is about "*the use of goods and services and related products, which respond to basic needs and bring a better quality of life, while minimizing the use of natural resources and toxic materials as well as the emissions of waste and pollutants over the life cycle of the service or product so as not to jeopardize the needs of further generations*" (UNEP, 2012, p. 19; Norway Ministry of Environment, 1994).

In 2002, ten years after the Rio Conference, the concept of SCP was recognized in the Johannesburg Plan of Implementation, signed at the World Summit on Sustainable Development. On that year, three overarching objectives were identified as essential requirements for sustainable development, which were: SCP; poverty eradication; and natural resources management with the purpose of fostering economic and social development. Simultaneously, for achieving sustainable development world leaders recognised that it was required fundamental changes in the societies' habits of production and consumption.

The SCP interrelated objectives are to achieve well-being for people and to keep negative environmental impacts of socio-economic activities within carrying capacity. Specifically, SCP establishes the degree of sustainability for the next areas: energy production, agricultural practices, food security, industrial pollution, water quality, biodiversity loss, marine issues, wood production and mining, and gender equality and education (Akenji & Bengtsson, 2014).

To overcome the environmental deterioration surpassed and inverted by production overall increase, the environmental problems arising during products use phase, the transition to a technology-based economy, and the fact that environmental considerations were still not being incorporated into social programmes and vice versa, UNEP presented a new approach – the life cycle perspective (UNEP, 2012).

Engaging the life-cycle approach means considering the whole value chain, from the point of product design and development, to selection, procurement and raw materials supply, investigating the manufacturing, packaging and distribution phases, and assessing potential impacts through all the phases: retail, purchasing, use and service. It also studies the product impacts when it is recycled, reused or disposed of. This approach assesses too the value chain environmental and social impacts, such as: identify the impacts on local communities, cultural heritage, access to material and immaterial resources, safety and living conditions, bearing in mind the rights of indigenous people, community engagement and local employment (UNEP, 2012).

SCP implies a changing of consumption patterns from households and from governments by means of changes in lifestyles and individual consumer behaviour and choices, in addition to changing public procurement strategies. Changing to SCP patterns are reflected in targets related with 13 of the 17 SDGs. The 12th SDG focuses clearly on "ensuring" SCP patterns, while other targets "mainstream" SCP objective into several other SDGs (UNEP, 2015).

SCP implementation as an integrated approach helps to accomplish overall development plans, reduce future economic, environmental and social costs, reinforce economic competitiveness and reduce poverty (UNEP, 2010).

The SCP theme is being addressed all over the years, focussing different aspects. For instance, Lebel and Lorek (2008) presented a definition for production-consumption systems. Tukker et al. (2008) presented a framework for SCP regarding the key domains of food, mobility, and energy use/housing. Others focused on tools, as Jawahir et al. (2006) and Nidumolu et al. (2009) on the 6Rs approach (6R of reduce, reuse, recycle, recover, redesign and remanufacture) and Parent et al. (2013) on the role of life cycle analysis (LCA) and social life cycle analysis (SLCA) tools in the transition towards SCP patterns.

Some authors focused on SCP programmes implementation (Berg, 2011) and on SCP leading role in the implementation of the SDGs (Akenji & Bengtsson, 2014). Cohen and Munoz (2016) investigated SCP systems in cities, displaying a sharing cities-SCP typology. Already, Lukman et al. (2016) review was on identification of challenges and provision of solutions for SCP. They, yielded a model to attain sustainable urban development, grounded on small communities and neighbourhoods. The emphasis should be on changing lifestyles and improving political collaboration internationally, but also, locally, particularly a bottom-up and stakeholders' approach.

More recently, Govindan (2018) researched SCP in the food supply chain. This author developed a conceptual framework by means of identifying the indicators, drivers, and barriers grounded on the stakeholder theory to accomplish SCP. Moreover, the stakeholders' important role to guide customers and organizations to be more sustainable concerning their food consumption and production was referred. Additionally, he stated that "*there is no sustainable consumption without sustainable production and vice versa. These two facts go along and together they contribute to sustainable development goals.*" (Govindan, 2018, p. 31).

2.2.4.1.1 Sustainable production

All over the years, there was an evolution of sustainable production concepts and practices. First, started with the concept of pollution control, focusing on treatment after event occurrence, through non-essential technologies implementation, based on end-of-pipe solutions. Then, the cleaner production concept arose, focusing on prevention before occurrence, through products and production methods modification, based on process optimisation, lower resource input and output, substitution of materials by non-toxic and renewable ones.

Following it, the eco-efficiency concept (explained in section 2.3) appeared, focusing on managing the occurrence, through systematic environmental management, based on environmental strategies and monitoring, and on environmental management systems. Then, the lifecycle thinking concept was brought into light, focusing on expanding management, through the extension of environmental responsibility, based on green supply chain management and corporate social responsibility.

Succeeding this, the concept of close-loop production emerged, focusing on revitalising the life cycle, through production methods restructuration, based on minimising or eliminating virgin materials. Finally, the concept of industrial ecology was encountered, focusing on the synergising, through production system integration, based on environmental partnerships and on eco-industrial parks (OECD, 2009).

The National Council for Advanced Manufacturing (NACFAM, 2010) framed sustainability for manufacturing sectors. Sustainability intentions are to create manufactured products through processes and practices application that maximize profits, minimize negative environmental impacts, preserve natural resources and energy, being safe for employees, consumers, and communities.

In 2011, the United States Department of Commerce defined sustainable manufacturing as "*The creation of manufactured products that use processes that minimize negative environmental impacts, conserve energy and natural resources, are safe for employees, communities, and consumers and are economically sound.*" (US Department of Commerce, 2011). This means that, sustainable manufacturing is about minimising the various inherent business risks in any manufacturing operation whereas maximising the new opportunities that rise from processes and products improvement.

U.S. Environmental Protection Agency (EPA) presented similar definition: "*sustainable manufacturing is the creation of manufactured products through economically-sound processes that minimize negative environmental impacts while conserving energy and natural resources. Sustainable manufacturing also enhances employee, community and product safety.*" (US-EPA, n.d.-b). This was due to the interest of sustainability as a significant goal in many companies' strategy and operations to face global competitiveness.

Moreover, as pointed out by Maxwell et al. (2006), manufacturing industries have the potential to become a driving force for the construction of a sustainable society. These, have the ability to design and implement integrated sustainable practices to develop products and services that will concur to improved environmental performance. To do this, it is required a holistic approach in conducting business and a change in the industrial production insight and understanding.

According to OECD (2009), industry and government need to comprehend and define their move towards a sustainable future. Furthermore, innovation stages a main role in moving manufacturing industries in their way to sustainable production, where process modification, product design and alternative business models, as well as, the definition of new procedures and organizational arrangements need to go along to leverage economic and environmental benefits.

Nevertheless, manufacturing industries are accountable for an important share of the world's consumption of resources and generation of waste. Worldwide, the manufacturing industries' energy consumption grew by 61% between 1971 and 2004, being responsible for almost a third of the world's energy usage. Similarly, manufacturing industries were responsible for 36% of global carbon dioxide (CO_2) emissions (IEA, 2007).

Having this in mind and to operate a shift on these manufacturing pressures and impacts, for Faulkner and Badurdeen (2014), sustainability in manufacturing involves a whole view covering the product and processes required in its production, but as well the overall supply chain and the manufacturing system.

The authors developed a methodology for sustainable VSM (Sus-VSM) to assess economic, environmental and social sustainability performance in industry.

Roberts and Ball (2014, p. 161) proposed a definition for sustainable manufacturing practices as "*the techniques, policies and procedures a firm uses to create manufactured products, that use processes that minimize negative environmental impacts, conserve energy and natural resources, are safe for employees, communities and consumers and are economically sound*". that was based in the United States Department of Commerce definition. These authors developed a classification scheme to record promising sustainable manufacturing practices. This classification enabled the practices organization with the aim of associate them with good quality environment management and performance consistent with environmental sustainability goals.

EPA also reported reasons why companies from all sizes, ages and sectors pursue sustainability to improve performance and reduce their resource footprint. The reasons were: increasing operational efficiency through reduction of costs and waste, responding or reaching new customers and increasing competitive advantage, protecting and strengthening brand and reputation and building public confidence, building long-standing business viability and success and responding to regulatory restrictions and opportunities (US-EPA, n.d.-b).

Therefore, at the business level, companies and organizations have to analyse and assess their actions in order to delineate their path to sustainable development. To achieve this, a comprehensive cross-section of government agencies, non-profit and non-governmental organizations developed a set of tools. These tools, presented in Appendix B, Table 62, can deliver awareness into resource use, benchmark performance against peers, generate sustainability goals and action plans, and reduce emissions and wastes throughout facility operations and supply chains (U.S.-EPA, 2013).

2.2.4.1.2 Sustainable consumption

Sustainable consumption terminology is recent. Nonetheless, and for some decades at least, the concept has been on the policy agenda. In 1972, the "*Limits to Growth*" report from Club of Rome called attention to the impact that increasing levels of wealth would have in resource scarcity and environmental degradation. The price escalations of oil in 1973/4 and in 1979/80 gave the impression that business-as-usual consumption levels would not continue, though after these rises, the oil prices decreased and resource scarcity forecasts did not happen. Nevertheless, by the initial 1990s, the consumption patterns significance for pressing environmental questions like ozone depletion, climate change and hazardous waste management turned out to be more and more clear (Jackson & Michaelis, 2003).

Sustainable consumption term appeared for the first time, at the 1992's Rio Earth Summit, as one of the sustainability main challenges, being stated at Agenda 21, on chapter 4 entitled "*Changing Consumption Patterns*" and asked for "*new concepts of wealth and prosperity which allow higher standards of living through changed lifestyles and are less dependent on the Earth's finite resources and more in harmony with the Earth's carrying capacity.*" (United Nations, 1992, section 4.11). The chapter triggered an order for the examination, question and revision of consumption patterns and, consequently, consumer behaviour, choices, expectations and lifestyles (Jackson & Michaelis, 2003).

According to the sustainable consumption definition framed at the Oslo Symposium (in section 2.2.4), sustainable consumption searches for achieving a high ratio of basic need fulfilment per resource use, that is to say, it is an effective contribution to human well-being per resource use (Fuchs & Lorek, 2011).

Over the years, several organizations have presented multiple sustainable consumption definitions (Jackson & Michaelis, 2003), however an agreement on what sustainable consumption was or should be was hard to negotiate (Manoochehri, 2002).

Some definitions focus on the fact that the sustainable consumption domain of interest is the activity of consuming and the consumers behaviour, others, appear to focus on production processes and consumer products through more efficient production of more sustainable products. Another discrepancy point relates to the extent of consumption, for some definitions, sustainable consumption asserts consuming less, others implies consuming differently, and for others firmly does not represent consuming less (Jackson, 2007).

In 1999, the UNEP stated that "*Sustainable consumption is not about consuming less, it is about consuming differently, consuming efficiently, and having an improved quality of life*" (UNEP, 1999). UNEP launched a sustainable consumption network, integrating sustainable consumption policies into the consumer protection guidelines and, in 2001 published a strategic document highlighting the opportunities via the new sustainable consumption emphasis (UNEP, 2001). In this document, UNEP stated that: "*Sustainable consumption is an umbrella term that brings together a number of key issues, such as meeting needs, enhancing quality of life, improving efficiency, minimising waste, taking a lifecycle perspective and taking into account the equity dimension; integrating these components parts in the central question of how to provide the same or better services to meet the basic requirements of life and the aspiration for improvement, for both current and future generations, while continually reducing environmental damage and the risk to human health*" (UNEP, 2001).

This definition brings attention to the degree to which essential improvements in environmental quality can be accomplished through the substitution of more efficient and less polluting products and services (patterns of consumption). However, it does not mention the reduction in the volumes of products and services consumed (levels of consumption).

Spaargaren (2003) argued that environmental sociologists have to conceptualize sustainable consumption behaviour, lifestyles, and daily routines. The model proposed combine the central role of human activity with the important role of social structure.

In the same year, Tanner and Kast (2003) investigated the personal and contextual barriers to consumers' purchases of green food, through a survey. The results encountered showed that green food purchases are enabled by consumers' positive attitudes related to environmental protection, fair trade, local products, and action-related knowledge availability. The consumers' green behaviour is negatively related with perceived time barriers and shopping frequency in supermarkets.

Others authors also investigated the green buying in the background of sustainable ways of living that integrate other environmental actions in a holistic sustainable lifestyles conceptualisation (Gilg et al., 2005). Young et al. (2010) investigated the purchasing process involved in consumer technology products by green consumers. These authors pointed out the "attitude/behaviour gap", where 30% of consumers regardless being much worried about environmental subjects, were fighting to reflect it in their purchases.

More recently, some authors researched the sustainable consumption habits of generation Y (Bernardes et al., 2018a; Bernardes et al., 2018b) in Portugal. First, they studied the gap among what the Millennials thought about sustainability and how they realized it with their real consumption habits concerning footwear, through two focus groups: marketing students and fashion students (Bernardes et al., 2018a). Then, they presented a systematic literature review related to sustainable consumption within the generation Y consumers, aiming to find out ways for marketers to appeal this consumers segment, as it is regarded as the most influential group (Bernardes et al., 2018b).

Additionally, Jackson (2005) report studied the consumer behaviour and the behavioural change of sustainable consumption on a social psychology level.

Seyfang (2005) researched how sustainable consumption could promote ecological citizenship, in other words, examined the choices and actions that individuals and households made on everyday basis, in supermarket and on the high street. The year after, this author researched the ecological citizenship and sustainable consumption influence on local organic food networks (Seyfang, 2006).

In 2011, the Sustainable Development Commission (SDC), from UK, launched a report identifying what was needed to enable all people to live sustainable lives. The need for behaviour change, as well as, the part government, business and society played in was also addressed. The report identified the important role from governments in providing leadership through an explicit strategic direction to enable people to live more sustainable lives (SDC, 2011).

Fuchs and Lorek (2004) investigated the outlooks for global sustainable consumption governance. The authors highlighted that main players and attempts focused on the efficiency of consumption, whereas fundamental aspects of sustainable consumption governance strategy had been neglected, such as: sustainability of consumption levels and essential changes in consumption patterns in industrialized countries. These same authors, researched strong sustainable consumption governance, distinguishing "weak sustainable consumption" from "strong sustainable consumption". The first focused on efficiency gains issues, though the second focused on the degrowth debate (Fuchs & Lorek, 2011).

Hobson (2013) also study the "weak" or "strong" sustainable consumption, pointed out the rapidly growing global resource use, specifically per the Asia and Pacific region and the 10YFP political move towards restricting this increasing. This author also stated that was essential the geographical extension of sustainable consumption and production work across the world in order to challenge the prevailing *status quo*.

Lorek and Spangenberg (2014) presented their research on sustainable consumption in a sustainable economy. They argued that green economy or green growth, focusing on efficiency and innovation could not promise to fulfil the Brundtland concept. Therefore, the authors engaged for a practical method to reduce the size of the economy, which for them would be accomplished through strong sustainable consumption and required a transformation of the civilisations' institutional backgrounds. These authors also emphasized the special role of NGOs.

In this ever-standing question of the sustainability paradox, referred in section 0, companies and economies have to balance the pressures to generate economic growth with the global consumption and the environmental burdens associated in a desired equilibrium.

2.2.4.2 Cleaner production

In 1993, in a joint workshop held in Paris, the United Nations Environment Programme Industry and Environment Centre (UNEP IE) and the Organization for Economic Cooperation and Development (OECD) decided to publish an information and guidance document on strategies and policies that governments could use to stimulate cleaner production (CP) in developing countries and in economies in transition (UNEP IE, 1994).

The cleaner production concept was first launched in 1989 by United Nations Environment Programme (UNEP). The UNEP, in 1998, through the International Declaration on Cleaner Production defined cleaner production as "*the continuous application of an integrated, preventive strategy applied to processes, products, and services in pursuit of economic, social, health, safety, and environmental benefits*" (WBCSD/UNEP, 1998, p. 9). This definition brought a more active view, seeking for better conditions of economic activities so as to get real benefits for human beings and the environment.

For production processes, CP includes conservation of raw materials, water and energy, the elimination of toxic and dangerous raw materials and the reduction of the quantity and toxicity of all emissions and wastes at source. For products, it focuses in the reduction of environmental, health and safety impacts through the whole life-cycle, from raw materials extraction, till conception, use, to the ultimate disposal of product. And, for services, the strategy focuses on the incorporation of environmental concerns into designing and delivering services (WBCSD/UNEP, 1998). Thus, the CP approach continually aims to reduce the generation of pollution at every stage of the life-cycle.

In summary, CP comprehends the continuous application of an integrated preventive environmental strategy to processes, products and services with the purpose of enhancing overall efficiency, while decrease risks for humans and the environment (UNEP IE, 1994).

CP definition had been evolving and expanding all over the years (Hens et al., 2018). And, as inefficiency and wastefully use of natural resources was at the core of the main environmental challenges, plus climate change, the UNEP and UNIDO expanded CP definition, in 2007/2008 to incorporate resource efficiency, which was considered an significant element towards green industry and green economy and it was presented the Resource Efficient and Cleaner Production (RECP) term (UNEP, n.d.; UNIDO, n.d.).

The benefits pointed to CP are: it leads to product and process improvements; it saves on raw materials and energy, therefore reducing production costs; it increases competitiveness by means of new and improved technologies; it reduces the requirement of more restrictions and prohibitions; it reduces risks from toxic wastes treatment, storage and disposal; it improves the health and safety of employees, consumers and community; it improves company's public image; and it reduces the cost of end-of-pipe solutions (UNEP IE, 1994).

Therefore, CP besides reducing environmental impact, it also enhances improvements in all company´s performance features, such as: improving quality and productivity, encouraging innovations, decreasing costs, increasing readiness and survivability, and achieving service excellence (UNEP, 1996). Simultaneously, industrial efficiency, profitability, competitiveness and the products and/or services quality is potentiated (UNEP, 2006).

For implementing CP, companies need to know where they are, through the realization of an inventory of waste generated. This can be done through a diagnostic procedure, developed by UNEP and United Nations Industrial Development Organization (UNIDO), the waste audit procedure used to identify CP areas in order to address first the most important sources for potential preventive actions (UNEP, 1996).

Many are the CP tools that could be used, though as assessment and audits are fundamental to decision-making (UNEP, 1996). Some important procedures to assist CP initiatives are presented in Appendix C, Table 63.

Gavrilescu (2004) work considered CP as a tool for sustainable development of production, environment and society. The author argued that CP drives to cleaner and sustainable products and services, achieving significant reductions in environmental impact, as it reduces waste and emissions generation, preserves materials, energy and water, whereas concurrently reduces operating costs. CP integrates and implements an array of good environmental practices, such as: pollution prevention, waste minimization, recycling and reusing waste resources as a new product. She also states that CP entails a new "*attitude*" and "*way of thinking*" to processes, products, as well to make these in a less harmful way to humans and the environment.

Based on their study of 30 large corporation's sustainability initiatives, Nidumolu et al. (2009, p. 12) displayed that sustainability is a layer of organizational and technological innovations that provide equally bottom-line and top-line returns. Companies turning into environment-friendly companies drops costs since companies end up reducing the inputs used. They considered that leadership and talent play a key role for the development of a low-carbon economy and that this would happen when executives acknowledge that "*Sustainability = Innovation*".

In 2015, Khalili et al. (2015) presented an interconnected decision-making framework that translate sustainability into the resource efficient cleaner production guidelines formulation. This framework is responsive to macro and micro level economic development goals and organizations aims.

CSR embodies a CP thinking development and a new form of being in the market, being specified for instances as ethical labour practices, local community support, environment commitment, as well as, arts funding. As consumer mentality and market changes, an increased engagement with social causes is being demanded and communities are attending to changes in companies' driving factors and missions, that are including social aspects as a core filed of action.

These social aspects, in particular, social responsibility, are addressed in the ISO 26000:2010 standard (ISO, 2010). This standard presents the social responsibility in seven action vectors, which are: human rights, labour practices, the environment, fair operating practices, consumer issues and, community involvement and development. The revision of ISO 14001:2015 standard (ISO, 2015a) increased the connection among CSR and sustainability, emphasising the companies' role in the environmental preservation (Silva & Gouveia, 2019).

2.2.5 Sustainability main tools and indicators frameworks

This section presents some sustainability main tools besides a description of some indicators' frameworks that companies may use to evaluate their sustainability.

2.2.5.1 Sustainability tools

One might say that sustainability is on the World agenda, as proved by the several papers recently published (Boggia et al., 2018; Ciccullo et al., 2018; Ramos et al., 2018; Souza & Alves, 2018; Soytas & Atik, 2018). Some tools that contribute to sustainability are depicted in Appendix D, Table 64.

2.2.5.2 Indicators frameworks

This study's author researched for frameworks internationally, and in Portugal, that companies can use to assess their sustainability. Several frameworks for sustainability were considered:

- Business Sustainability Index (ISE), from Business Sustainability Observatory (OSE), for the Business Council for Sustainable development (BCSD) Portugal;
- Sustainable Development Indicators System (SIDS), Portugal, a national strategic document;
- MAESTRI Total Efficiency Framework, a European partnership;
- STeP Certification by OEKO-TEX – International Association for Research and Testing in the Field of Textile and Leather Ecology;
- Global Reporting Initiative (GRI), internationally.

Business Sustainability Index (ISE). The Business Sustainability Observatory (OSE) presents the Business Sustainability Index (ISE) as its main measurement and communication instrument to promote and publicly disclose the importance and the economic, social and environmental impacts of Business Council for Sustainable development (BCSD) Portugal's members in the sustainable development of the country (IST, 2013). The ISE is an integrated metric of the companies' performance in a sustainability perspective, surpassing the concept proposed by the Triple Bottom Line (TBL), already referred in section 2.2. That is, the ISE relies on already integrated indicators, each with the TBL dimensions, not distinguishing environmental, social or economic levels.

Top indicators and descriptive indicators were defined to reflect the companies' practices and performance comprise the ISE. There were defined five top indicators, which are energy and climate; biodiversity and ecosystem services; sustainable production and consumption; strategic leadership and human capital. The ISE value for each of the associated companies will result from the top five indicators arithmetic mean. The sixteen descriptive indicators are calculated based on the weighted sum of the scores obtained through the answers of a survey carried out by companies. They also intend to provide information on the members' sustainable performance (IST, 2013).

Sustainable Development Indicators System (SIDS), Portugal (DGA, 2000) was developed to assess the country's progress relatively to sustainability, allowing strategic decisions – policies, plans and programs – either at national, regional and sectorial levels. Therefore, in 2000 the first edition of the national SIDS "Proposal for Sustainable Development Indicators System" was published, as the result of the work begun in 1997 (APA, 2007). Hence, alongside the main international initiatives in the field, Portugal presented a platform of environmental, social, economic and institutional indicators, based on the Pressure-State-Response model. In 2005, was initiated a SIDS review, focused fundamentally on the methodology analysis and consolidation and on the indicators assessment that integrate the system. SIDS Portugal main aim is to evaluate and report the evolution of the country's sustainability levels. It also seeks to improve the environmental, economic and social management as well as the institutional performance. It aims to make the systematization and exchange of information processes on environment and sustainable development more efficient.

Among the SIDS specific objectives listed, it is important to enumerate the followings: developing a broad base of sustainable development indicators, promoting SIDS as a decision support tool and assessing environmental integration in various economic activity sectors. The SIDS comprises four indicators groups: 1) Base indicators; 2) Key indicators; 3) Regional indicators; and 4) Sectorial indicators (APA, 2007).

MAESTRI Total Efficiency Framework (MAESTRI, 2015), European partnership, is a project that aims to advance the sustainability of European manufacturing and process industries. MAESTRI is a total resource and energy efficiency management system for process industries. This project will provide a management system in the form of a flexible and scalable platform, through the implementation of the Total Efficiency Framework. The Framework general aim is to encourage an improvement culture within process industries by supporting the decision-making process, supporting improvement strategies deployment and assisting in the definition of priorities to improve the company's environmental and economic performance. Its validation will be made in four real industrial companies from different activity sectors.

The Total Efficiency Framework is based on four key pillars, which are: a) an effective management system targeted at process and continuous improvement; b) efficiency assessment tools to define improvement and optimization strategies and support decision-making processes; c) integration with a toolkit for Industrial Symbiosis with a focus on material and energy exchange; d) a software Platform, founded in the Internet of Thing (IoT), to simplify the implementation and guarantee an integrated improvement process control. In practical terms, the goal of MAESTRI is to build concepts and tools in order to achieve energy adoption and prosecution, as well as, resource efficiency in production system of any company, regardless it is a large, medium or small one (Baptista at al., 2018; MAESTRI, 2015).

STeP Certification by OEKO-TEX® – International Association for Research and Testing in the Field of Textile and Leather Ecology. STeP by OEKO-TEX® standard can be applied for the certification of production facilities throughout the entire textile and leather production chain. It is a normative document that also establishes the technical conditions for the licensing of the STeP by OEKO-TEX® trademark (OEKO - TEX®, 2019). OEKO-TEX® is the International Association for Research and Testing in the Field of Textile and Leather Ecology, being represented in Portugal by CITEVE "Centro Tecnológico das Indústrias Têxtil e do Vestuário de Portugal" translated by Technological Center of the Textile and Clothing Industries of Portugal.

Sustainable Textile Production (STeP) by OEKO-TEX® is an independent certification system for brands, retail companies and manufacturers from the textile and leather chain that want to communicate their achievements regarding sustainable production to the public in transparent, credible and clear way. The goal of STeP certification is the permanent implementation of environmentally friendly production processes, optimal health and safety protection and socially responsible working conditions. STeP certification offers a comprehensive analysis and assessment regarding sustainable production conditions. To qualify for certification in accordance with STeP by OEKO-TEX®, production facilities must meet the necessary criteria in the following modules: chemical management, environmental performance, environmental management, social responsibility, quality management and health and safety. STeP certification allows a comprehensive and reliable analysis of the degree of sustainable management of a production facility (OEKO - TEX®, 2019).

Global Reporting Initiative (GRI) is an independent international organization that initiated sustainability reporting since 1997 (GRI, 1997). GRI is a wide-ranging system that comprises 91 indicators (the specific standard disclosures), structured in three main categories (the three sustainability dimensions): the economic, environmental and social aspects. The last one being subdivided in four social subcategories: Labour practices and decent work, human rights, society and product responsibility. GRI Sustainability Reporting Standards are the most widely adopted global standards for sustainability reporting (GRI, 1997). They feature a modular, interrelated structure for reporting on a range of economic, environmental and social impacts and, at the same time, any company or organization that wants to report about its impacts, and display its contribution towards sustainable development can use them as a set. Sustainability reporting enables companies or organizations to reflect their impacts of wide range of sustainability issues, allowing them to be more transparent about the risks and opportunities they face. A sustainability report is a published report where a company or organization states the economic, environmental and social impacts triggered by its daily activities. It also describes the company's or organization's values and governance model, as well as, the link between the strategy and the commitment to a sustainable global economy (GRI, 1997).

2.2.6 Integrated Management Systems

Currently, it is assumed that to implement and improve lean and cleaner production within companies, a strategic way is through the combination of an effective environmental management, integrated with other management areas, such as, quality and occupational health and safety (Rebelo et al. , 2016). The integrated management systems and their benefits support companies, in their way, towards the sustainable development of a cleaner production (described in section 2.2.4.2 above), by opposition to an individual implementation of management systems standards. For Sebhatu and Enquist (2007), sustainable value creation required a change in the mind-set to do a radical jump towards sustainable value, being much more than adhere to external standards.

As stated by Jørgensen (2008), the integration of management systems was not, by itself, a guarantee of more sustainable management systems, being conditioned by the level of integration. He reported that, a company required a focus on the integration of different management systems standards to evolve towards a sustainable integrated management system. According to Khanna et al. (2010), the reasons for implementing an integrated management system were: synergies promotion among management systems; shared objectives for the current management systems; redundant procedures avoidance; corporate image improvement; and, finally, third-party audits requested by each management system were reduced.

The systematic integration leads to a holistic, result-driven approach, towards the identification of priority working areas. Consequently, it produce numerous benefits in the goal of quality, environment, occupational health and safety, and social responsibility (Zeng et al., 2007). Others benefits reported were: elimination of the conflicts among independent management systems; promotion of synergies and costs saving; optimization of resources; elimination of numerous organizational waste types; empowerment of collaborators; reduction of the audits number; integration of management of sustainability components; and reduction of the time spent when managing systems individually (Bernardo et al., 2015; BSI, 2012; Majstorovic & Marinkovic, 2011; Rebelo et al., 2014a, 2014b; Simon et al., 2011; Suditu, 2007; Tarí & Molina-Azorín, 2010). By opposition, Zeng et al. (2007) stated that companies which operate several parallel management systems have a lower management efficiency.

This supports the need to have a proactive approach and commitment to cleaner production, reinforced by an integrated management system, as stated by Rebelo et al. (2016). Furthermore, it brings about important savings for companies, as described above, besides providing value to the interested stakeholders. These authors presented a sustainable development and integrated management systems contextualization model, as well as, a method and related model to support integrated management systems development, and the guidelines for integration.

Additionally, Souza and Alves (2018) developed a model for corporate sustainability improvement. Their model uses the synergies generated from the integration of management systems of quality, environment, social responsibility, and occupational health and safety with the lean manufacturing system. Their model was grounded on the rational use of resources and energy whereas, simultaneously, engaged and empowered people. The model was applied in a company for the refinement and critical analysis of it and, the findings suggested the model had potential to improve corporate sustainability and thus yield more sustainable and competitive companies.

Companies should have the goal to implement Environmental or Sustainability Management System (WBCSD, 2000a). An Environmental Management System (EMS) is a tool for ensuring that all risks and opportunities relating to sustainability are appropriately identified and efficiently managed. It should be integrated with their current business management systems to drive the eco-efficiency approach, defined in the following section.

2.3 Eco-efficiency

The section begins presenting the eco-efficiency definitions, followed by the eco-efficiency origin and applications examples. Then, the seven elements to promote eco-efficiency are described, and afterwards, some eco-efficiency practices/tools are presented, as the most used ones.

2.3.1 Definition and key ideas

In 1993, the Business Council for Sustainable Development (BCSD), now the World BCSD (WBCSD), defined eco-efficiency as: "*The delivery of competitively priced goods and services that satisfy human needs and bring quality of life, while progressively reducing ecological impact and resource intensity throughout the life cycle, to a level at least in line with the Earth's estimated carrying capacity.*" (BCSD, 1993). This concept was introduced by Stephan Schmidheiny and the BCSD in the 1990s and it intended to foster a new kind of development, the sustainable development, which wants to contribute truly to a better world, including to human and nature well-being.

The Eco-efficiency concept, along with other similar and dissimilar ones, represent a dynamic set of assets that can be used to deal with the most fierce consequences of a number of pressing challenges of contemporary societies, namely the ecosystems and atmosphere depravation, and the depravation of the respective provision of fundamental services (e.g. freshwater, fertile soil, adequate climate for human settings, etc.). This definition brings together four critical elements: an emphasis on services, a focus on needs, a life cycle view and the eco-capacity imperative (BCSD, 1993).

OECD (in 1998) named eco-efficiency as the efficiency with which environmental resources are employed to meet human needs, defining it as a ratio of an output divided by an input. Being the output, the products and services value produced by a company, sector or economy, and the input, the environmental pressures amount produced by the company, sector or economy (WBCSD, 2000a).

European Environment Agency (EEA) describes eco-efficiency as more wellbeing from less nature. Declaring that eco-efficiency arises from decoupling resource use and pollutant release from economic development. EEA aims to measure progress toward sustainability on the macro-level by means of eco-efficiency indicators (WBCSD, 2000a).

WBCSD in their guide "*Measuring Eco-efficiency*" proposes a framework to report company performance (WBCSD, 2000b). This framework comprises three levels of organization for eco-efficiency information: categories, aspects and indicators. The framework is consistent with ISO 14000 series and Global Reporting Initiative (GRI) terminology. Categories are wide areas of environmental influence or business value (e.g. environmental influence in product creation). Aspects are the general information related to a specific category and describe what is to be measured (e.g. material consumption). Indicators are specific measures of an individual aspect that can be used to track and demonstrate performance (e.g. tonnes CO_2 emitted).

Eco-efficiency concept takes together the two eco-dimensions of economy and ecology to relate product or service value to environmental influence (WBCSD, 2000b), being represented by Equation 5:

$$Eco - efficiency = \frac{Product\ or\ service\ value}{Environmental\ influence}$$

Equation 5 - Eco-efficiency ratio

The progress in eco-efficiency can be accomplished by yielding more value per unit of environmental influence or unit of resource consumed. There are many ways to calculate eco-efficiency using this basic equation. Companies will have to choose the best eco-efficiency ratios for their process communication and decision making. Depending on each individual company needs, particular calculations will be chosen (WBCSD, 2000b).

Frequently eco-efficiency is stated as "*creating more value with less impact*" or "*doing more with less*" by business leaders, from indoors WBCSD and outdoors. Already, practitioners and academic experts entitled eco-efficiency as the synthesis of environmental and economic efficiency in parallel, where the prefix eco stands equally for economy and ecology (WBCSD, 2000a).

2.3.2 Concept genesis and applications examples

Numerous are the concepts that stand up when Eco-efficiency concept and its efforts are discussed. Some of them are Green (Production), Cleaner Production, Industrial Ecology, Cradle-to-Grave, Cradle-to-Cradle, Design for the Environment. From these, some focused on specific features (e.g. design stage), while others embrace broader perspectives (e.g. full life cycles).

Business Council for Sustainable Development (BCSD) created Eco-efficiency concept, in 1991, to prepare the Earth Summit, held in 1992, January. Stephan Schmidheiny and BCSD published the eco-efficiency concept, in 1992, in the book entitled "*Changing Course*" (BCSD, 1993). Thus, associated to eco-efficiency is the need for companies to provide products and services that consumers value and benefit from, while the environmental impact is minimized. That is, companies need to adapt their practices and systems through continuous improvement, in order to achieve high levels of economic and environmental performance (Moreira et al., 2010).

WBCSD works have spread this concept and brought together contributions from around 200 international companies from the 20th largest industrial sectors. As a result, energy waste in its various forms and materials waste have been a concern for many companies and organizations, namely the United States Environmental Protection Agency (U.S.-EPA, 2003).

Borchardt et al. (2011) presented a longitudinal study in a footwear industry to investigate eco-design application to redesign a shoe component. The factors that influence its use, benefits, and difficulties were also analysed. It was observed an environmental impact and cost reduction.

Koskela and Vehmas (2012) investigated the eco-efficiency definition in order to produce a comprehensive definition of it. Additionally, they presented a conceptual framework of the relationship between environmental and economic performance in the companies and concluded that resource intensity, environmental intensity, average resource price, resource productivity and eco-efficiency can be identified and defined. The case companies belonged to the Finnish forest industry.

Another paper describes the traps of green technology promotion (Bréchet & Ly, 2013). The authors provide a framework to understand the effects of technological greening on firm's profit, firm's emission, global emissions, and on the indicator of eco-efficiency. They highlighted that technological greening may raise conflicting effects and that eco-efficiency cannot be reliable as an indicator for decision-making.

More recently, Wakeford et al. (2017) studied the role innovation plays in the way to green industrialization. Innovation appears as an industrialization critical driver and as a way to deliver green innovations, in order to improve resource productivity and reduce pollution. They investigated the relationship between green innovation and industrialization in Ethiopia's cement, leather and textile sectors. They concluded that interactions between firms, government and other actors encourage innovation, therefore they suggest enhancing coordination between key actors, providing financial incentives for companies, and enforcing environmental regulations.

Caiado et al. (2017) through their systematic literature review highlighted the lack of an explicit integrated framework to attain sustainable development through eco-efficiency indicators. It was used a variation of the Knowledge Development Process intervention instrument - constructivist (ProKnow-C). The authors presented an innovative conceptual framework grounded on the sustainability pillars and on four measurement levels, which were: industry, organization, project and process.

Likewise, in the same year, and with a systematic literature review, Pacheco et al. (2017) identified the determinants of eco-innovation in manufacturing SMEs and relationships between them. The goal was to understand specific elements that might impact the eco-innovation success in manufacturing SMEs.

2.3.3 Measures to promote eco-efficiency

Based on the preservation of nature, the eco-efficiency concept, by means of yielding the conservation on its resources follows seven elements, which are (Hendrickson et al., 2006; WBCSD/UNEP, 1998):

1) Reduction on materials intensity;
2) Reduction on energy intensity;
3) Reduction on the quantity and level of toxicity of substances;
4) Promotion of closed cycles and use of meaningful end-of-life strategies;
5) Promotion of renewables, abundant and local resources;
6) Improvement of the durability of the products;
7) Intensifying the use of services.

To provide more value with less impact, companies need innovation efforts, both at the product and production processes, as well as, a different perception on the assessment of products' environmental performance. To avoid unintended armful relocations among lifecycle stages, a system strategy is particularly advised, because the products worst impacts may reside on any full lifecycle stage. Simultaneously, this system strategy will allow identifying gains opportunities that would be hard to figure otherwise. A continuous improvement process may be used to achieve successive marginal gains, along with more substantial gains, normally attained by way of radical innovation, which may include as well, green logistics and alternative ownership models, among others. Eco-efficiency is concerned with three wide-ranging goals (WBCSD, 2000a):

1) Reducing the resources consumption: by minimizing the use of energy, materials, water and land, enhancing recyclability and product durability, and closing material loops;

2) Reducing the impact on nature: by minimizing air emissions, water discharges, waste disposal and the dispersion of toxic substances, as well as promoting the sustainable use of renewable resources;

3) Increasing product or service value: by yielding more benefits to customers by means of product functionality, flexibility and modularity, yielding additional services (such as maintenance, upgrading and exchange services) and focusing on selling the functional requirements that customers really want. Selling a service instead of the product itself raises the possibility of the customer receiving the same functional need with fewer materials and less resources.

Implementing eco-efficiency in a company is about navigating for opportunities, which can be found in four areas (WBCSD, 2000a):

1) Re-engineering processes, companies can reduce resources consumption, pollution and avoid risks;
2) Finding creative ways to re-valorise by-products, through cooperation with other companies;
3) Re-designing products, companies can turn out to be more eco-efficient;
4) Re-thinking markets and re-shaping demand and supply, companies can discover new ways of meeting customer needs.

In the book "Walking the talk: the business case for sustainable development" ten steps were presented for building sustainable progress (Holliday et al., 2002). Following these steps, coupled with cooperation between companies, government and civil society, can create a market that maximizes opportunity for all. Within these ten steps, the eco-efficiency concept should be emphasized, since it links sustainable development to companies' agenda (Maia et al., 2013).

2.3.4 Some eco-efficiency tools

Organizations can use a panoply of concepts and tools, some described in in Appendix E, Table 65 to support the integration of Eco-efficiency into their decision-making process. There are no universal application tools for all companies and for all specific cases, and it is up to companies to identify which ones are best and fit the intended objectives (BCSD Portugal, 2013).

Some features distinguish the various tools to be used, such as its main focus (the organization and/or its management, product/service, operational and risk management and communication and marketing), and the levels of organization in which can be applied (product or business units). Some tools are widely known and used by industry, such as environmental management systems and others have come to evolve over time, such as environmental design and eco-labelling.

Given the large number and variety of tools available, careful evaluation of these will enable organizations to avoid wasting resources, gathering relevant information for decision making, and making it fit the company culture. To know how to properly select and apply the tool (or toolkit), decision makers need:

- Information to the scale to which it is applied;
- Analysis of the benefits and costs arising from its use;
- Temporary framework necessary for its implementation or its achievement goals.

In addition, lifecycle dimension consideration can also be useful, since it can, among other things, identify at which product/service cycle stage the tool can be applied.

2.4 Lean-green paradigm

The section begins presenting the lean-green concept and definition, genesis and evolution, followed by the environmental wastes concept and impacts. Then, the lean-green models and frameworks, as well as, the lean-green tools are presented.

2.4.1 Lean-green concept and definition

The lean focus is on reducing waste, while the green focus is on reducing the environmental impact. Therefore, the lean-green approach might offer a framework for delivering cleaner and valuable products.

Several authors like Yang et al. (2011) underlined the convergence between the lean and green concepts. They pointed out that the lean orientation may also help companies to adopt environmental management practices to reduce waste and pollutant emissions. Moreover, Hajmohammad et al. (2013), in their research, argued that the creation of an adequate operating context grounded on lean management principles will facilitate the environmental practices adoption and implementation, as well as, will improve the plant's environmental performance.

In 2014, Galeazzo et al. (2014) stated the importance of the collaboration between the different actors (environmental managers, operations managers, suppliers, etc.) in a lean-green program implementation. Furthermore, Tseng et al. (2013) considered that lean supply chain management as a key component to promote large-scale sustainable production. In their opinion, generally, researchers converge on the mutual and reciprocal benefits derived from lean and green strategies combination.

Mollenkopf et al. (2010) argued that lean and green strategies are perceived as compatible initiatives since both focus on waste reduction. Dues et al. (2013) agree, nonetheless display that the overlapping of lean and green paradigms embraces additional common features (besides waste and waste reduction techniques), like people and organization, lead time reduction, supply chain relationship and Key Performance Indicators supported around service level attributes.

Salvador et al. (2017) presented a debate of the probable two-way influence between lean and green manufacturing and its connection to related organizational areas. They pointed out that lean practices seem more probably to deploy into green effects, although the other way around may also happen. The joint adoption of both approaches may result in benefits and impacts on several areas from an organization, occurring either simultaneously or sequentially. Afterwards, Salvador et al. (2017) literature review also investigated lean and green potential two-way influence, and concluded that an unquestionable synergy exists.

The state-of-art papers from Martínez-Jurado and Moyano-Fuentes (2014) and from Garza-Reyes (2015) corroborate the interest in the lean and green strategy.

2.4.2 Lean-green genesis and evolution

The link between lean production and green (production), called the lean-green link has been investigated from the 1990 onwards (Maxwell et al. 1993; Maxwell et al. 1998; Larson & Greenwood 2004; Pojasek 2008). Although lean was not mainly designed to address sustainability issues (Moreira et al., 2010; U.S.-EPA, 2003), some authors unfolded that its principles and practices brought several benefits that could be placed under the umbrella of green (Klassen 2000; Rothenberg et al. 2001; Found 2009).

Only a year after the spread of the concept of eco-efficiency (in 1992), many organizations and authors started investigating the relationship between lean and environmental performance: eco-efficiency. Moreira et al. (2010), through a literature review, studied lean's contribution to achieve better environmental performance of production systems, named by several authors as green-lean or lean-green.

Fercoq et al. (2016) described a quantitative study on lean/green integration focused on waste reduction techniques in the manufacturing processes. First, using the design of experiments tool to measure the influence of the seven lean wastes and the 3R hierarchy – Reduction/Reuse/Recovery, which derived from the lean and green approaches, on solid waste management performance. Then, demonstrating that the integration of both methods in a lean/green matrix strengthens the performance of a solid waste progress plan.

Cherrafi et al. (2016) conducted a literature review on the integration of lean, six sigma and sustainability and identified several major gaps in the existing literature. One of this gaps was the one related to the absence of a specific integrated model, thus the authors proposed a model for the integration of these three management systems with three constructs: drivers and barriers; synergies, conflicts and compatibility; and critical success factors, that are linked to benefits of the integration and to tools and techniques.

The year after, Ruiz-Benitez et al. (2017) investigated the environmental benefits of lean, green and resilient supply chain management in a case on the aerospace sector. They used a combined methodology to identify the relationships' map among practices and performance measures. These authors concluded that Lean supply chain practices emerge as drivers for green and resilient supply chain practices and that their influence on environmental performance is greater than the one of the resilient supply chain practices.

The work of Martínez León and Calvo-Amodio (2017) is a literature review that expands previous literature reviews, through analysing lean and sustainability from a systems' thinking lens. They identified and analysed lean and sustainability interrelationships and their influence on performance form several viewpoints: the operational, the financial, the societal, and the environmental one. A building block set for developing a lean-sustainable integration framework was identified, with the promoting purpose of discussing how companies can embed sustainability into their operations. In general, the authors founded a consensus lack on lean and sustainability definitions, which in their opinion reflects how the distinct perspectives are significantly influenced by the context in which they emerged (Martínez León & Calvo-Amodio, 2017).

Caldera et al. (2017) through a systematic literature review, investigated how lean and green implementation could drive to sustainable business practice. The authors highlighted the lean thinking restricted use within corporate sustainability, and defined a "lean and green matrix" to identify opportunities to embed lean and green practices into five workflows: waste, energy, emissions, water and chemical management.

The year after, Ruben et al. (2018) presented their systematic review on lean six sigma in the manufacturing sector and designed a generic framework, which incorporates environmental focus into the lean six sigma framework.

More recently, several papers described studies on the lean-green integration (Chaplin & O'Rourke, 2018; Gandhi et al., 2018; Gupta at al., 2018). The first one argues that lean and green agenda can drive the integration of any continuous improvement activity (the example is the lean six sigma) through the organization, by placing continuous improvement and the lean six sigma within the corporate social responsibility mission (Chaplin & O'Rourke, 2018). The second one identifies the drivers for integrated lean-green manufacturing in small and medium size enterprises (Gandhi et al., 2018). The third one presents an approach for wastes assessment, using a system dynamics model and testing it in a radial tire manufacturing organization (Gupta et al., 2018).

Another systematic literature review was most recently published to assess the present state-of-the art in the topic of lean-driven sustainability (Tasdemir & Gazo, 2018). The authors concluded that attention in lean-driven sustainability has gained momentum lately, particularly by researchers from Europe, USA and Asia. This study concluded that synergies between lean and sustainability are stronger than their divergences, that lean could be used to set the basis for sustainability frameworks and that they both could provide true sustainability. They also stated that there are some internal and external obstacles related with integration of lean and 3BL philosophies. Finally, they consider that lean-driven sustainability still has a countless deal of unexploited potential that has to be discovered.

The study on lean-green integration further continues, with others papers being published (Belhadi et al., 2018; Caldera et al., 2019; Ghobakhloo et al., 2018; Marco-Ferreira et al., 2019; Siriban-Manalang et al., 2019; Tenera et al., 2019). Interestingly, all these papers reported a positive relationship between lean and green. From these, some are applications that are portrayed as case studies, namely Dieste and Panizzolo (2019), Siriban-Manalang et al. (2019) and Tenera et al. (2019) emphasised how lean implementation had foster companies' sustainability outcomes. The papers findings showed that lean implementation would considerably reduce waste generation through prevention, yielding industries sustainable, by means of enhancing resource-use efficiency and higher adoption of clean and environmentally comprehensive technologies and industrial processes. Also, they highlighted how lean implementation directly impacts responsible consumption and production, building robust infrastructure and endorsing sustainable industrialization. The work of Belhadi et al. (2018) displays a framework described in section 2.4.4.

Ghobakhloo et al. (2018) investigated the relationships among information technology (IT), lean manufacturing (LM), organizational environmental subjects and business performance. These authors pointed out that was crucial for modern manufacturers to invest both in technological and human aspects of IT resource designed to increase the lean manufacturing activities and proactive environmental practices efficiency, concluding that these would allow manufacturers to work in a contemporary social environment successfully, ensuring longstanding sustainability.

Caldera et al. (2019a), through a series of in-dept interviews with Chief Executive Officers and senior managers engaged in sustainability and lean manufacturing, investigated the lean and green thinking development and lean and green practices potential to drive effective changes to sustainable practice. This study was held in twenty manufacturing SMEs in Queensland, Australia, identifying four main enablers and six main barriers to sustainable business practice. The enablers were: integrated strategy, continuous improvement, stakeholder involvement and streamlined processes, and per barriers were: lack of financial resources, lack of time, lack of knowledge, risks related to new sustainable practice implementation, current policies and regulations, and prevailing organizational culture.

The authors highlighted that lean and green strategies grounded on less material and energy used per product manufactured will drive SMEs to capitalize their material and energy efficiency and concur to circular economy. The authors also mentioned the role that education through organization structure played to change employee behaviours and perceptions to embed lean and green practices in SMEs (Caldera et al., 2019a).

It was presented a matrix linking main lean practices to detailed environmental measures. The JIT and TQM techniques were the most used to investigate their relationship with environmental performance. The VSM and the *Kaizen* or continuous improvement are the lean practices that most positively improve the environmental measures, such as: air emissions, energy use, solid waste, materials use, toxic/hazardous chemicals use and money saved (Dieste et al., 2019).

Another study has to be reported, as lean-green integration with Industry 4.0 was investigated (Bittencourt et al., 2019a). By means of a systematic literature review, these authors encountered that both concepts integration had resulted in a synergetic relationship that improved companies.

However, some doubts persisted relatively to the environmental consequences of allowing shorter inventories, associated with the more frequent trips in JIT deliveries (Dues et al., 2013; Mollenkopf et al., 2010).

2.4.3 Environmental wastes concept and impacts

The U.S. Environmental Protection Agency (EPA) has been working to relate lean with the environment and published various toolkits, some related with lean and the environment (U.S.-EPA, 2000a, 2000b, 2003, 2004, 2007), others relating lean and six sigma (U.S.-EPA, 2008b, 2009a), even other relating lean with specific applications (U.S.-EPA, 2008a, 2009b, 2011a, 2011b, 2015). Among these toolkits, the environmental waste concept was defined in "*The Lean and Environment Toolkit*" (U.S.-EPA, 2007).

Environmental waste was defined as "*any unnecessary use of resources or a substance released into the air, water, or land that could harm human health or the environment*" (U.S.-EPA, 2007, p. 12). The lean tools can be applied to reduce environmental wastes, and these can happen when companies use resources to deliver products or services to customers, and/or when customers use and dispose products (Maia et al., 2013; U.S.-EPA, 2007).

In terms of day-by-day practice, companies will encounter environmental waste, such as:

- Energy, water, or raw materials that are consumed in excess to meet customer desires;
- Pollutants and material wastes that are released into the environment (such as, air emissions, wastewater discharges, hazardous wastes and solid wastes);
- Hazardous substances that unfavourably affect human health or environment during their production or their presence in products.

Environmental wastes do not add customer value, likewise other lean wastes, nevertheless they signify costs to companies and society (U.S.-EPA, 2007). For instances, hazardous materials released to environment are an environmental waste, which are not clearly encompassed in the TPS' seven wastes, however this does not specify that the "*deadly*" lean wastes are unrelated to environment (U.S.-EPA, 2007). Moreover, the EPA-supported case studies at the Boeing Company in 2000 exposed important environmental benefits related with Boeing's lean implementation efforts (U.S.-EPA, 2003).

The next table, Table 3, lists environmental impacts that are related with the lean wastes targeted by lean methods.

The U.S. EPA (2007) also highlighted that environmental performance metrics use in lean efforts allows managers to recognise main areas for improvement. These environmental metrics comprise: use of energy, materials and water; air emissions; water pollution and wastewater; and hazardous waste and non-hazardous solid wastes.

Table 3 - Environmental impacts of Lean Wastes (adapted from (U.S.-EPA, 2003))

Waste Type	**Examples**	**Environmental impacts**
Overproduction	Manufacturing items for which there are no orders	• More raw materials and energy consumed in making the unnecessary products • Extra products may spoil or become obsolete requiring disposal • Extra hazardous materials used result in extra emissions, waste disposal, worker exposure, etc.
Inventory	Excess raw material, WIP, or finished goods	• More packaging to store work-in-process (WIP) • Waste from deterioration or damage to stored WIP • More materials needed to replace damaged WIP • More energy used to heat, cool, and light inventory space
Transportation and Motion	Human motions that are unnecessary or straining, and WIP transporting long distances	• More energy use for transport • Emissions from transport • More space required for WIP movement, increasing lighting, heating, and cooling demand and energy consumption • More packaging required to protect components during movement • Damage and spills during transport • Transportation of hazardous materials requires special shipping and packaging to prevent risk during accidents
Defects	Scrap, rework, replacement production, inspection	• Raw materials and energy consumed in making defective products • Defective components require recycling or disposal • More space required for rework and repair, increasing energy use for heating, cooling, and lighting
Over processing	More parts, process steps, or time than necessary to meet customer needs	• More parts and raw materials consumed per unit of production • Unnecessary processing increases wastes, energy use, and emissions
Waiting	Stock-outs, lot processing delays, capacity bottlenecks, equipment downtime	• Potential material spoilage or component damage causing waste • Waste energy from heating, cooling, and lighting during production downtime
Unused creativity	Long time, ideas, skills, improvements, and suggestions from employees	• Fewer suggestions of pollution prevention and waste minimization opportunities

Following this idea, Moreira et al. (2010) sought to illustrate, through a cause-and-effect diagram (Figure 3), how lean's main waste is reflected in terms of environmental performance, and consequently its elimination will lead to a reducing environmental impact culture.

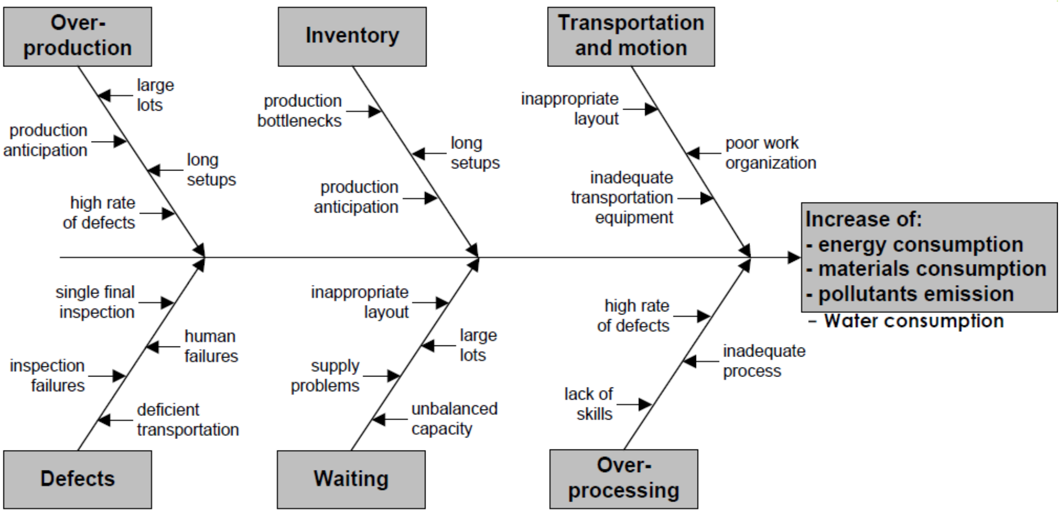

Figure 3 – Production wastes as causes of poor environmental performance
(adopted from Moreira et al. (2010))

Therefore, in conclusion, most studies found identified a positive relationship between lean and eco-efficient production systems, contributing to improve environmental performance (Moreira et al., 2010).

2.4.4 Lean-green models and tools

This section presents the lean-green models encountered from literature review conducted to highlight different models for the lean-green integration, and then the lean-green tools that can be used.

2.4.4.1 Lean-green models

This section presents the existent lean-green models. Main results of literature review revealed that in 83 papers, only 30% recognized a lean-green link (Alves et al., 2016). Even so, lean-green models seem to be emerging, although not explicitly coined with one such designation. This fact appears to corroborate previous findings from the same authors. The synthesis of these results are published on Abreu et al. (2016), Alves et al. (2016) and Abreu et al. (2017). In this latter paper, the literature review returned five lean-green integration models, so just a results synthesis is presented. The lean-green models' essential goal was mostly related to improve the systems productivity while reducing the environmental impacts. Three of them, were not precisely coined lean-green, but indeed merge lean principles and tools, along with environmental concepts. The designation lean-green model was explicitly mentioned in two papers (Pampanelli et al., 2014; Verrier et al., 2016). This designation acceptance level seems low, accordingly Abreu et al. (2017).

The models studied include some usual performance indicators, namely operational, economic and environmental and unusual performance indicators, such as measuring organizational culture or social responsibility. In all models, the ultimate aim was to improve productivity, through reducing wastes and environmental impacts. Two models' proposals, highlighted the need for employees' deeper involvement, as well as, their whole potential empowerment and development, aiming to change and transform attitudes, values, behaviours and outcomes (Abreu et al., 2017).

In addition to the five models reviewed on Abreu et al. (2017), 11 more models were identified, which are summarized in Table 4. The models are portrayed, in terms of reference year, nature, and purpose. Four of them are focused on assessment of the lean-green relationship, while twelve intend to provide a reference model for lean-green implementation. The lean-green reference model for implementation, specifies the steps, or phases, to implement the lean-green approach as a joint endeavour. The lean-green model for assessment stipulates a way, or method, for assessing the maturity level of a lean-green implementation already in place. Therefore, the company can benchmark itself against a prior result, or relative to other companies.

Table 4 - Lean-Green models identified and purpose

Authors	**Year**	**Type of model/framework**	**Purpose**
Azevedo et al. (2012)	2012	Theoretical framework	Implementation
Aguado et al. (2013)	2013	Pull methodology and model	Implementation
Pampanelli et al. (2014)	2014	Lean & Green model	Implementation
Alves & Alves (2015)	2015	Integrated System of Management (ISMA)	Implementation
Verrier et al. (2016)	2016	Lean and Green House & maturity model	Implementation
Hallam & Contreras (2016)	2016	Theoretical	Implementation
Cherrafi et al. (2017)	2017	Interpretive Structural Modelling (ISM) method	Implementation
Belhadi et al. (2018)	2018	Framework	Implementation
Reis et al. (2018)	2018	Lean Green Synergy (LGS)	Assessment
Souza & Alves (2018)	2018	Lean-Integrated Management System for Sustainability Improvement (LIMSSI)	Implementation
Amrina & Zagloel (2019)	2019	Conceptual model of eco-socio-lean production (ESLP)	Assessment
Farias et al. (2019 a)	2019	Conceptual framework	Implementation
Farias et al. (2019 b)	2019	Lean-green index (LG_{index}), a performance measure based on ANP approach	Assessment
Caldera et al. (2019b)	2019	3P Model for lean and green strategy	Implementation
Carvalho et al. (2019)	2019	Two indexes (Lean Index and Green Index)	Assessment
Siegel et al. (2019)	2019	Framework for SMEs	Implementation

Hallam and Contreras (2016) researched the lean and green management relationship in order to develop an integrated management model, which they found that was lacking through their literature review. They proposed a management model integrating lean and green with firm performance. This causal model was grounded on the management model parameters identified in literature, specifically the Ohno's seven wastes, lean tools, product quality, operating costs, product pricing, sales revenues, environmental impact, human resources, green branding, and firm performance.

The authors concluded that operating costs influenced negatively financial performance, although sales revenues positively influenced financial performance. Lean and green management directly influenced these two measures, nonetheless they impacted the antecedents of these calculated values. They argued that a company holistic view was required to comprehend how improvements in one area will impact (positively or negatively) another, therefore enlightening management decision making (Hallam & Contreras, 2016).

Another paper from Cherrafi at al. (2017) identified fifteen barriers in the green lean implementation that can hinder companies' efforts on operational and sustainability level, by means of a systematic literature review. An Interpretative Structural Modelling (ISM) based model was used to determine the relationships among barriers and develop a hierarchy structural model. The authors argued that the model could be used by top management and practitioners to identify, manage, prioritize and address the green lean barriers that might hamper and obstruct the green lean implementation.

Belhadi et al. (2018) proposed a lean and green integration framework, that was implemented in a pumps manufacturing SME. The lean and green implementation methodology in SMEs had three phases: 1) pre-implementation, 2) implementation and 3) post-implementation phase. The results of an implementation demonstrated that there was a strong correlation among operational metrics improvement and green metrics improvement. The authors highlighted this approach usefulness for increasing and strengthening SME's performance.

To assess the lean and green integration, Reis et al. (2018) developed the lean green synergy model, by means of a conceptual framework formulation. The case study was carried out in six properties of the coffee sector, in Colombia. This model was divided in basic and variable concepts. The basic concepts were a set of features independent of the industrial sector, such as the maturity level and the assessment procedure. The variable concepts were a set of features that had to be adapted according to the industrial sector, such as: performance indicators, questionnaire and business features.

After calculating the 20 maturity assessment metrics (10 lean and 10 green), the lean and green maturity was calculated in three different perspectives. Then, the average of these will provided the organization overall maturity level. The authors advocated that this model stimulated the lean and green systems implementation, since it provided production process constant monitoring, identifying improvements and enabling integrated management. In future, this model would be supported through a web platform that is being under development (Reis et al., 2018).

Also, Souza and Alves (2018) developed a model that fostered the synergies generated from the integration of management systems of quality, environment, social responsibility, and occupational health and safety with the lean manufacturing system. The model was consolidated on the resources and energy rational use whereas, simultaneously, engaging and empowering people. A critical analysis was performed and the strengths highlighted were: it was a comprehensive model, focusing on meeting legal requirements and on waste reduction, emphasizing ergonomics and materials and resources reuse, reducing inventories and providing the whole value stream view for employees. The difficulties reported were the organization cultural change required, as well as, the breaking of shop floor paradigms.

Besides Reis et al. (2018), Farias et al. (2019 b) developed a lean and green performance assessment framework and provided a lean-green index (the LG_{index}) to evaluate, in an integrated method, the lean and green systems. For the theoretical framework operationalization, these authors used the Analytical Network Process (ANP) and tested it in a footwear company that had effectively applied lean and green practices. Through this assessment, the lean and green systems were evaluated individually and results were consolidated through the lean-green index in an integrated way. This research was supported by a previous systematic literature review held by Farias et al. (2019 a). Through a content analysis of the articles studied, it was identified environmental and operational criteria and the related lean and green practices. Then, the authors presented a conceptual framework to help comprehend the concepts and relationships engaged in the lean and green performance assessment system. This framework would support the operational and environmental performance assessment through the lean and green practices (Farias et al., 2019 a).

Siegel et al. (2019) researched the green-lean in the manufacturing SMEs context, as they considered this field under a less developed phase. Their systematic review investigated the challenges, success factors, tools and techniques, sustainability aspects, frameworks and benefits of green-lean in manufacturing SMEs. Then, for integrating green and lean in the context of SMEs, they presented a conceptual framework: the framework core, the green-lean integration is in center, the success factors behave as an input to it, whereas SMEs performances in the trade-off are the outputs. The challenges for green-lean integration are the controls, which impact organizational efforts to improve sustainability performance. Finally, the frameworks and tools act as enhancing mechanisms. These authors found that the lack of metrics and measurement were the most common challenge to green-lean implementation.

This same year, Amrina and Zagloel (2019) developed a conceptual model of eco-socio-lean production, as an input-process-output framework, grounded on green-lean business objectives, resources, production process, improvement techniques, and output measurements. The model studied four dimensions: lean, environment, economy and social. It includes 12 eco-socio-lean dimensions, three performance metrics (the green productivity index, the quality index and the eco-socio-lean production integrated index), four improvement strategies (green value stream mapping, material and process re-engineering, visual dashboard and periodic top management *Genchi Genbutsu* ("go to the origin")) to realise two goals: reduce total cost and increase revenue. The authors displayed that the simultaneously synergetic application of lean production with green production would influence organization's sustainable productivity and quality.

As Siegel et al. (2019) work, Caldera et al. (2019b) researched similarly how SMEs might commit in lean and green processes to accomplish sustainable practice regarding the triple bottom line 3Ps, through case study analysis in the Queensland manufacturing sector, in Australia. These authors developed the first 3P model for lean and green strategy, with four steps (explore, prioritise, invest and, monitor and evaluate) to enable the strategic selection of tools from a 3P matrix of tools to undertake for lean and green transition towards sustainable business practice. In this study, eight main drivers were identified.

Carvalho et al. (2019) proposed two indexes: one based on lean and on green to measure companies' performance related with supply chain. The index data was based on European Manufacturing Survey 2012 in Portugal. Factorial analysis was applied to reach the expressions of the indexes.

These findings seem to support some academic's concern in trying to fulfil the existing gap of lean-green models in the literature.

2.4.4.2 Lean-green tools

Lean-green tools that can be used result from the combination of lean tools (see section 2.1.5) with eco-efficiency tools (see section 2.3.4). Companies will have to decide under the tools that best fit their way to lean-green integration, never forgetting the unique specificities of their products and markets.

The U.S. EPA presents three tools to support companies in their journey to lean and environment integration: VSM, *Kaizen* events and 6S (U.S.-EPA, 2007). The 6S (that is 5S+Safety) is applied to generate and maintain a clean, orderly, and safe work environment. 6S is grounded upon the five pillars

(5S) of the visual workplace in TPS, plus another pillar for safety. Frequently, in their lean journey, companies implement 6S first, as it served as the basis of future continual improvement efforts (U.S.-EPA, 2007). The VSM and *Kaizen* were already discussed in section 2.1.5.

Interestingly, the work of Verrier et al. (2016) identified four tools that have positive effects on all lean and green wastes and, at the same time, enhance the employees' involvement: *Gemba* Walk, lean and green Value Stream Mapping, Key Performance Indicators and Visual Management. The authors consider respect for the workforce a pillar that have to be related to lean and green efficiency.

Garza-Reyes et al. (2018) investigated the impact and relationship of five main lean methods, the JIT, TPM, autonomation, VSM and kaizen or continuous improvement had on four usually employed measures for the environmental performance compliance, the material use, energy consumption, non-product output and pollutant releases. A correlation analysis modelled the relationship and effect of the lean methods on the environmental performance, followed by structural equation modelling (SEM) employed as a second confirmation approach to guarantee the results validity.

From the results encountered, JIT and TPM had the highest impact on environmental performance, while kaizen or continuous improvement only displayed an impact on the materials use and pollutant releases. Autonomation and VSM did not exhibited any effect on environmental performance. The authors pointed out that their study would support managers to take better decisions and conceive more efficient strategies for the lean and environmental practices concurrent, or sequential implementation (Garza-Reyes et al., 2018).

Interestingly, Júnior et al. (2018) proposed a lean-green model grounded on the implementation of Single Minute Exchange of Die (SMED) integrated with Carbon Footprint (CF) to analyse eco-efficiency in a Brazilian machining center. The model originality was constructed on eco-efficiency indicators to measure production systems performance towards a cleaner production. Five scenarios through changing machine tools, workers and workpieces were prepared for the case study.

This study results displayed that the SMED application, a lean tool, combined with CF evaluation were acceptable, because there was a substantial reduction into setup times, carbon footprint and improvements in eco-efficiency for all five scenarios being investigated. More than 70% of setup time was reduced during the SMED implementation, which reduced idle times up to 88%, and CF was reduced up to 81% after SMED implementation. The authors ended by mentioning that this lean-green model should be applied by companies with production low-capacity owing to machine availability restrictions (Júnior et al., 2018).

In their panel data study, Sartal et al. (2018) investigate the environmental impact of three lean manufacturing pillars: Just-in-Time, *Jidoka* and Respect for People, from a shop-floor perspective. Their results showed that the final environmental impacts were determined by the leanness level reached by each plant, as well as, by the lean pillar in question: though *Jidoka* and Respect for People had a positive effect on environmental performance, they found a major trade-off among Just-in-Time activities and the green goals.

2.5 Critical literature review

In our changing world, managers must undertake hard decisions on how to position their companies for the long run. At the same time, they have to cope with competition and daily challenges, while aligning with the environmental agenda. Such decisions must weave from internal threats to external advantage, as well as, from being reactive to proactive to place themselves in the globalised spectrum of market demands.

Therefore, companies have to innovate their processes and products to thrive against competitors and cut their expenditures in order to achieve success, prosper and have profit (IPCC, 2019; UNCC, 2019). Furthermore, companies have to improve their way of designing, producing, managing, relating with customers, as well as, with suppliers and never forgetting all stakeholders from surrounding community in which it operates.

In this context, lean production drives companies in this transforming path. As the literature review depicted, lean production, more than a methodology or approach (Treville & Antonakis, 2006; Liker, 2004; Shah & Ward, 2003) is considered by many authors a philosophy, a culture, a mind-set or a way of life (Alves et al., 2017; Dorval et al., 2019; Spear & Bowen, 1999; Womack & Jones, 1996; Yamamoto & Bellgran, 2010). Their principles and practices can be implemented in all sectors of industry, in the service sector, and even in our own personal life, as showed in the case studies reviewed in Amaro et al. (2019).

However, as reported by the same author, many case studies were focused on exploring specific lean approaches in isolation. They did not approach the whole value stream, just a part of it. This means, they were not completely aware of lean principles. Additionally, the companies just apply lean in a productive sector and they need to apply lean principles in all enterprise level areas, including the product development field. Also, it is essential to have more interregional research collaborations and apply lean elements as a group instead of as an individual element (Jasti & Kodali, 2015).

Moreover, there is a guidance lack regarding how companies should identify present and future needs, how should define technologies and resources to meet those needs. Likewise, how should companies balance their responsibilities among all stakeholders is also missing (Hart, 1995; Gimenez et al., 2012). To accomplish these lacks, companies and economies have to balance the pressures to generate economic growth with the global consumption and the environmental burdens associated in a desired equilibrium as documented in the Intergovernmental Panel on Climate Change (IPCC) and the United Nations Climate Change (UNCC) reports (IPCC, 2019; UNCC, 2019).

Related to this subject, Womack & Jones (2005a) highlighted the lean consumption concept because considered that a huge disconnect exists between consumers and providers. Consumers have a larger selection of higher quality goods to choose from and can get these items from a growing number of sources. Nevertheless, consumers are not happier. According the authors, this happen because all around the process of obtaining and using the products, this process generates consumers' frustration and disappointment.

For these authors, lean consumption is "*about providing the full value that consumers desire from their goods and services, with the greatest efficiency and least pain*" (Womack & Jones, 2005a). These authors' book "*Lean Solutions*" illustrates the competitive advantages of extending Lean Thinking far downstream from the organization' walls (Womack & Jones, 2005b). They described, through cases studies two all-embracing business processes beyond production: provision and consumption. Therefore, they focus on process, as an end-to-end view that always takes into account the value as defined by customer, identifying this as a requirement to propose lean solutions, and to sustain them (Womack & Jones, 2005b).

Furthermore, this will be the perfect setting for companies embark in lean-green implementation as an answer to this present challenging world, since the synergies from both initiatives started at almost 25 years ago (Florida, 1996; Maxwell et al., 1993). Lean-green have the right framework, through "doing more with less" (Womack et al., 1990) and "creating more with less" (BCSD, 1993), for leading companies in their way to growth, reducing their environmental impacts, conserving energy and natural resources, being safe for their employees, their communities and, lastly their consumers.

Nevertheless, many companies were not aware of this link because implemented lean but do not recognized the impact of lean benefits on environmental wastes, as Amaro et al. (2019) identified in their 129 reviewed papers. This is the reason that, for example, Maia et al. (2019) introduced in their methodology dimensions to measure company performance, as well as, its sustainability. Many are the organizations that are moving forward to the need of integrating synergistically lean-green concepts. There are initiatives in progress to reduce them, as some examples from Textile and Clothing (Maia et al., 2019; Maia et al., 2013).

However, Garza-Reyes (2015) stated that there was a research lack of lean and green focused at the company level and specially, a lack “on developing measurement methods or models for specific processes and industries”. In this context, it cannot be forgotten, that companies did not have time, nor resources, to allocate to each new independent initiative that emerges. As lean-green concept associates value aggregation and efficiency in operational and environmental terms, emerges as a corollary effect of companies’ challenges to rethink their goals and strategies with the purpose of adding more value, and, simultaneously, contribute to social equity and avoid environmental burdens.

Hallam and Contreras (2016) argued that the lean and green relationship was shortly reported. They depicted that the majority of studies propose highly optimistic outcomes from integrating lean and green, through operational waste reduction, therefore improving environmental performance. Nevertheless, they stated that a lean and green integrated operating model was lacking.

Meanwhile, in the last two years, many are the papers describing studies on the lean-green integration (Chaplin & O’Rourke, 2018; Gandhi et al., 2018; Gupta at al., 2018), and more recently (Belhadi et al., 2018; Caldera et al., 2019b; Dieste et al., 2019; Ghobakhloo et al., 2018; Marco-Ferreira et al., 2019). Worth mentioning, all these papers displayed a positive relationship between lean and green.

Notwithstanding, Farias et al. (2019 b) stated that there was a scarcity of assessment models integrating both approaches, considering lean and green literature. However, more than 15 models were identified and reviewed in section 2.4.4. What several authors pointed out is the need for indicators of performance as metrics for assessing lean and green relations (Duarte & Cruz-Machado, 2017; Johnsen & Drevland, 2016; Verrier et al., 2014), as well as, Garza-Reyes's (2015) work. Further research was required to unveil the real bonds, overlaps and gaps among these approaches (Salvador et al., 2017). This corroborates this thesis author research that lean-green integration needs to be addressed by an indicator, as presented on Abreu et al. (2016), Alves et al. (2016) and Abreu et al. (2017).

Bearing in mind all the above mentioned, this study’s author considers that there is a gap on research concerning lean-green models, particularly, indicators to assess lean-green integration. This indicator should be simple, easy and feasible for companies to use and apply, and regarding to operational, economic, environmental and social performance. In present business markets and challenges, it is important for companies to assess and compare green practices, in order to measure and monitor relevant indicators related to sustainability, as well as, assessing its evolution over time and make informed decision-making related to their business performance. Therefore, the intention was to develop a model, which was translated into one indicator. The model will be described in Chapter 5.

3 Research methodology and methods

This chapter presents a detailed overview of the research methodology selected and the methods selected to develop this study: a survey and case studies.

3.1 Research methodology selection

Saunders et al. (2009) distinguish research methods and research methodology. Research methodology states the theory of how research should be undertaken, whereas research methods mention the techniques and practices employed to obtain and analyse data.

The research undertaken is considered to be applied research, as opposed to fundamental (basic or pure) research, as it addresses subjects that are perceived as important, relevant, comprehensible and of real-world value.

In order to provide foundation on which this research was developed, the methodology undergone began with a critical literature review. The goal was to increase an understanding, as well as, an awareness on relevant research and on emerged trends.

As deductive approach was used, that is, a theory or conceptual framework was developed, which through a research strategy was later tested with data. The purpose of the literature review was to review the most pertinent and significant research. The goal was to evaluate the investigation previously made in order to present and explain the relationships among published research findings (Saunders et al., 2009).

As stated by Jankowicz, the literature review must be a description and critical analysis of what has been written (Jankowicz, 2005). To enhance the review process transparency, was outlined a detailed description on how the search was made.

This includes the list of keywords chosen and databases used (Tranfield et al., 2003). Therefore, research question and objectives were defined, as well as, the parameters of search, and the keywords and search terms were established. The literature search was done searching using the internet, following up references in papers already read and secondary literature. The literature review allowed to link different ideas and to create a coherent and consistent argument in order to set the context and validate the research.

Specifically, the literature review began with a review on sustainability and the relationship to the lean concept. Thus a qualitative methodology was used (Abreu & Alves, 2015). This work was followed by the comparison of existing lean-green models for eco-efficient production, as described in Abreu et al. (2016).

In order to deepen the knowledge, a systematic literature review was made. The goal was to analyse further the breadth of lean-green link awareness, analysing and clarifying it, within the Production and Operations Management field (Alves et al., 2016) and to highlight, compare and analyse the different models for the lean-green integration (Abreu et al., 2017). Additional work, conducted from 2017 to 2019, intended to update such review. The literature review was reported in Chapter 2.

Two research methods were undertaken during the study: survey and case studies, thus mixed methods are being used as suitable choices to unfold the research (Saunders et al., 2009). A survey was used to answer to questions about who, what, where, how much and how many and allowed to collect quantitative data, which was analysed using descriptive statistics. The data collection technique used was a questionnaire (described in 3.2.1). A cross-sectional study was developed on the question under investigation, since it studies a particular phenomenon at a specific time (Saunders et al., 2009). As pointed out by Robson (2002), cross-sectional studies frequently employ a survey method, as they are looking to describe the phenomenon incident or to clarify how factors are connected in different organizations.

Grounded on the analysis of the questionnaire results and on what was reported in the literature review on methodologies to implement lean and to implement green, the model was developed. In chapter 5, the model that exploits synergies of lean-green production is described in detail. Then, the model was implemented in case studies (described in section 3.2.2). The case studies allowed the model validation and the gathering of results to be discussed within this research strategy, taking into account that no company is the same as another and that each company is a single case. The companies' support and collaboration were essential to provide all the necessary information and data for a proper work development.

3.2 Methods selection and justification

This section describes the research methods selected in this study: a survey through a questionnaire conducted to northern companies to assess their awareness on the lean-green link and case studies to validate the model presented in chapter 5.

3.2.1 Survey purpose and structure

This section presents a questionnaire developed to collect data on the lean implementation state in companies in the north of Portugal, its purpose and its structure.

A survey is a method that allows a structured collection of data from a sizeable population. These data are standardized enabling an easy comparison. The quantitative data collected can be analysed quantitatively by means of descriptive and inferential statistics. The data collection technique usually used in surveys is the questionnaire, however it can use other techniques, such as structured observation and structured interviews. This method is typically associated with the deductive approach. As it is used to answer to questions about who, what, where, how much and how many is applied for exploratory and descriptive research (Saunders et al., 2009).

In order to answer to the research question: "Is a lean company more sustainable?" a survey was conducted. The survey was grounded on a questionnaire entitled "Lean Production contributions for company´s sustainability". In this case, the survey was used to investigate the lean implementation state in companies in the north of Portugal, and how this implementation has helped these companies becoming more sustainable. The purpose of the questionnaire was to investigate awareness on lean and green production methodologies and the extent to which its implementation contributed to the improved levels of productivity and sustainability.

Procedures that allow for a good structure and guarantee that there are no deviations in the data analysis phase have been taken into account during its development, ensuring a good response rate and reliability of results, particularly in defining the target population, structure, application of the pilot questionnaire, among others (Saunders et al., 2009).

Another important feature to consider is the nature of the questions and the way they are written, for a good understanding by the respondents. These two points become more important in on-line questionnaires (Saunders et al., 2009). It is likewise essential to ensure anonymity and confidentiality of responses, as well as informing the expected time the respondent will devote to fill the questionnaire.

Then, followed the questionnaire validation, one of the main stages of development, as it allowed to determine whether there was a need to modify the questions or their sequence to reduce and/or eliminate deviations by assessing the questions at semantic and technological level. At the semantic level to check if any of the questions raised doubts in its reading and, consequently, in its interpretation, conditioning or even biasing the answer and at the technological level to check if there was any technical error.

All survey details and results were published in a paper of this thesis' author called "Lean-Green synergy awareness: a Portuguese survey" (Abreu et al., 2018).

3.2.1.1 Structure and validation

In order to meet the requirements demanded for the successful use of a questionnaire, the "Lean Production contributions for company´s sustainability" questionnaire was structured into three parts to facilitate its reading and, consequently, its completion, and in a total of 22 questions. The full questionnaire can be found in Appendix F.

The questions order and flow were made with the purpose of being logical to the respondent, having filter questions and linking phrases. The questionnaire was laid out in order to be easy to read and responses easy to fill in (Saunders et al., 2009) and included open and closed questions.

At the beginning of the survey, we chose to put a text box with information about the subject under study, guaranteeing respondents anonymity and answers confidentiality. Whenever a questionnaire is anonymous, respondents have a greater sense of security and ultimately provide true answers (Saunders et al., 2009).

The questionnaire had three main sections, holding 22 questions in total:

- Section I: was divided into four questions and dedicated to the respondent characterization (name, contact, position and years of work in the company);
- Section II: dedicated to identification and characterization of the company: the company name and location, number of workers, the main activity sector, the main product(s)/service(s) provided, number of years in operation and main market (seven questions);
- Section III: related to the company's management system and the production model characterization (eleven questions). The aim was to know if the management system was certified, identifying the management system and production models implemented; the main concerns of the production model, if the production model implemented was considered to promote sustainability; the benefits achieved by the company; the tools embraced for the environmental performance improvement; the sustainability indicators used; and if the company considered to implement the lean production model. The response had to be justified. Finally, there was an open question, for comments or suggestions.

The questionnaire was converted to electronic format, using the "Lime Survey" tool, version 1.72 (LimeSurvey, 2011).

The phase of survey preparation was subjected to several review periods and successive reformulations, and was only consolidated after the pre-test was applied (Saunders et al., 2009). The pre-test methodology perceives a preliminary evaluation of the survey contents, in order to minimize possible difficulties. The pre-test application was decisive because it was necessary to understand if the survey questions were well understood and interpreted and if there were no vocabulary problems.

The pre-test phase (Saunders et al., 2009) was carried out in two stages. In the first stage, the questionnaire was tested by two academicians who critically evaluated the questions from the standpoint of specificity and clarity of construction. Some items were reviewed based on the feedback received. In the second pre-test the questionnaire was administered to an industrial professional, that was asked to review the questionnaire by searching for ambiguity or others difficulties. After this second pre-test, the questionnaire was once again reviewed based on the received comments so as to make the research instrument more effective.

3.2.1.2 Survey application

The survey was developed at University of Minho, Portugal, and addressed to a database of national and international companies', with activity on the northern region of Portugal, that was provided by the Department of Production and Systems. It is an internal database that somehow represents the link of this institution to the industrial activity in the north of Portugal. The companies pertained to various activity sectors, such as: manufacturing; construction; wholesale and retail trade; automotive vehicle repair; automotive; energy; electronics; lighting and electrical material; water collection; treatment and distribution; sanitation and oil refining.

The questionnaire was sent via email with a cover letter revealing its purpose, the survey link and, the information on the period of time the survey would be active. A first distribution was made in March 2016 and a second one in April 2016. The questionnaire was available on-line for four months, between March and June 2016.

From the 447 questionnaires sent, 357 were successfully delivered. The number of valid questionnaires was 42, achieving a 12% response rate. Given the method used, this can be considered an acceptable response rate (Saunders et al., 2009).

Finally, the data was analysed using the Microsoft Excel® tool and the software SPSS® (V.24). Based on the results it was possible to have an overview of the level of awareness on the lean and green production methodologies and on the respective link, as presented in chapter 4.

3.2.2 Case studies for model validation

The other research instrument used in this research project was the case study. Case study is defined by Robson (2002) as "a strategy for doing research which involves an empirical investigation of a particular contemporary phenomenon within its real life context using multiple sources of evidence". For other authors, this strategy has particular importance when the intention is to gain a rich understanding of the research context and the processes being enacted (Morris & Wood, 1991). The case study strategy is frequently used in exploratory and explanatory research. There are several data collection techniques that can be used and, even used in combination, such as, interviews, observation, documentary analysis and questionnaires (Saunders et al., 2009). Based on two discrete dimensions Yin (2003) differentiates four case study strategies:

- single case vs multiple case;
- holistic case vs embedded case.

A single case is used to represent a critical case or, otherwise, an extreme or unique case. A multiple case study strategy includes more than one case and is justified by the necessity of verifying if the findings of the first case occur in other cases, in order to generalise from these findings. The second dimension relates to the unit of analysis. In a holistic case study, the research is concerned with the organization as a whole. By opposition, in an embedded case, the research is concerned with more than one unit of analysis within an organization, like departments or work groups, or whatever logical sub-units selected (Yin, 2003).

Grounded on survey analysis and on research about existing methodologies to implement lean and to implement green, the proposed model was developed. This model was operationalized through an indicator that aggregated and combined lean production and green production features, the Business Overall Performance and Sustainability Effectiveness (BOPSE) indicator, presented in Chapter 5. Afterwards, the model was implemented using a multiple case study strategy.

In this thesis, the purpose was to validate the model through its application to real cases, with the intention of assessing its relevance and operation. This approach will allow to focus on the indicator analysis and consolidation on the Key and descriptive indicators assessment. Consequently, and in order to assess the BOPSE indicator constructs, it was implemented in three companies from the manufacturing sector, specifically, the automotive sector.

Based on case study definition, it can be said that case study as a research method helps to understand, explore or describe events, in which several factors are simultaneously involved in a real context (Yin, 2003). For the case studies deployment, four stages were applied, as described in Table 5.

Table 5 – Stages of the case study

Case study stages	**Tasks**	**Description**
1. Design the case study	Protocol definition, with the inquiry instrument, the procedures and general rules	1. Overview of the project 2. Field procedures 3. Preliminary research questions 4. Guide for the report
2. Conduct the case study	Prepare for data collection	Company visits, meetings, interviews, collecting the data
3. Analyse case study evidence	Analytic strategy	1. Indicators calculation for each case study 2. Comparison with values attained for the feasibility tests 3. Comparison between case studies
4. Develop conclusions, recommendations and implications	Conclusions based on the evidence	Presentation of the findings in a detailed way

In the case study design (first stage) the protocol was defined, and procedures and general rules were established. The second stage included company visits, meetings, interviews and data collection. In stage three an analysis was made. And finally, on stage four conclusions were issued grounded on the evidences from the data collected. More insights on such stages can be explored in chapter 6.

For the companies' selection, the criteria determined were the interest and availability of the company to participate in the study, its accessibility and its support in data collection. Based on these selection criteria, three companies were chosen, which will be designated as company or case study A, B and C, throughout this thesis.

The detailed characterization of the three companies can be found in chapter 6, as well as the implementation results of the model for its validation.

In order to select the companies for the case studies, for the real-life application, this study's author contacted twelve companies from the automotive sector. This process started in October 2018 and ending in September 2019. First, an email was sent requesting a meeting and the availability to participate in the study. A first company replied, and a meeting was scheduled, still in October, for case study A. Then, for the companies that did not answered to the email, several contacts were established by phone, in order to explain this study and its goals. Two companies scheduled a meeting in January 2019. One of them became case study B. The other company did not send the data needed, and for several months, did not answered to the emails sent nor to the phone calls made. Then, other companies were contacted, some gave their negative feedback immediately. Others, after several months of contacts from this thesis' author, finally gave their feedback, which was a negative one. Then, in September 2019, the last company was contacted, and this turn out to be case study C.

Unfortunately, as abovementioned the majority of the companies did not agree to participate. From the twelve companies contacted, only three companies accepted to participate on the research. The other nine did not want to participate.

The author was surprised by the difficulty and non-availability of companies to participate in this study.

The reasons mentioned by some companies were that "there was no availability" and "they did not have time" to participate. Others considered that "some data was confidential", namely the data on the overall equipment effectiveness and some economic indicators.

4 Awareness of the lean-green link: a perspective

This chapter presents the survey results of a questionnaire on "Lean production contributions for company's sustainability". These results were already published by this thesis' author Abreu et al. (2018).

When necessary, chi-square independence tests (χ^2) were performed to verify the association type (independence or dependence) between variables. When frequencies were too small, this test could not be used. Consequently, to verify the association type the test used was the Fisher Exact test.

4.1 Respondents and companies' characterization

This section presents the respondents profile and companies characterization.

4.1.1 Respondents' profile

Analysis of the section I results (identification of the respondents' function) of the questionnaire show that the respondents' functions within companies varied considerably, ranging from CEO, process engineer, product design director, etc. The profile most represented was the department manager (19%). The other respondents hold varied profiles, such as: production manager (14.3%), head of department (9.5%), industrial manager (7.1%). Nevertheless, it is important to note that three respondents were lean managers (7.1%) and three more were focused on quality and/or environment management (7.1%).

Regarding service years in the company, about 45% of respondents have worked for less than 10 years, 40% worked between 11 and 20 years and 14% were more than 21 and less than 30 years in the company. There was no one working for more than 30 years at the company (Figure 4).

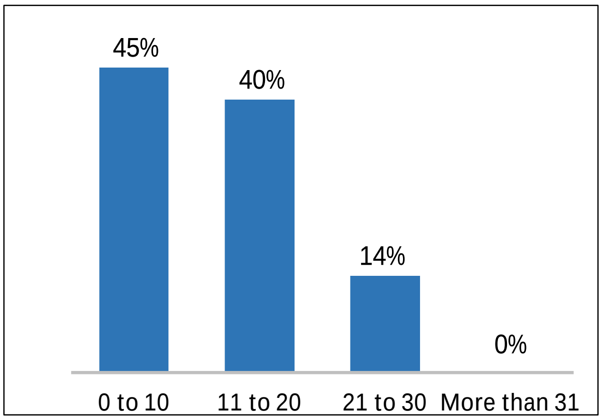

Figure 4 - Number of years in the company

The three lean managers respondents worked in the company for eighteen, seven and four years, respectively. All of them worked in manufacturing industries. The one working for eighteen years belonged to a company responsible for sports goods production and distribution, the one working for seven years belonged to a company responsible for producing electrical cutting and protective equipment (low voltage) and, the one working for four years belonged to a company responsible for producing small metal parts.

4.1.2 Companies' characterization

From the analysis of section II results (company identification / characterization) of the questionnaire, and regarding the numbers of employees in the company, most respondents pertained to large size companies (69%), having 250 workers or more, followed by medium companies with 21% of the total, having 50 to 249 workers, and only 10% were small companies (Figure 5). There were no micro-companies.

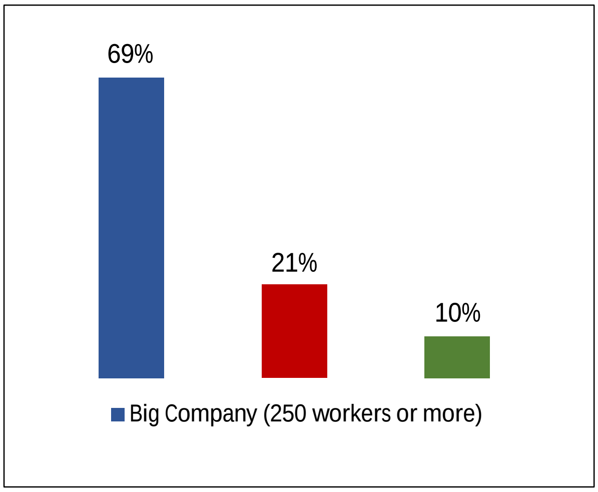

Figure 5 - Number of employees in the company

Concerning the activity sector, it was used the Portuguese ranking of economic activities (CAE), defined by the National Statistics Institute (INE). The most representative sector was Manufacturing, representing 64.3% of the total, followed by the Wholesale and Retail Trade and Motor Vehicle Repair (7.1%); Construction (4.8%) and Withdrawal, Treatment and Water Distribution; Sanitation, Waste Management and Depollution (2.4%), as shown in Figure 6.

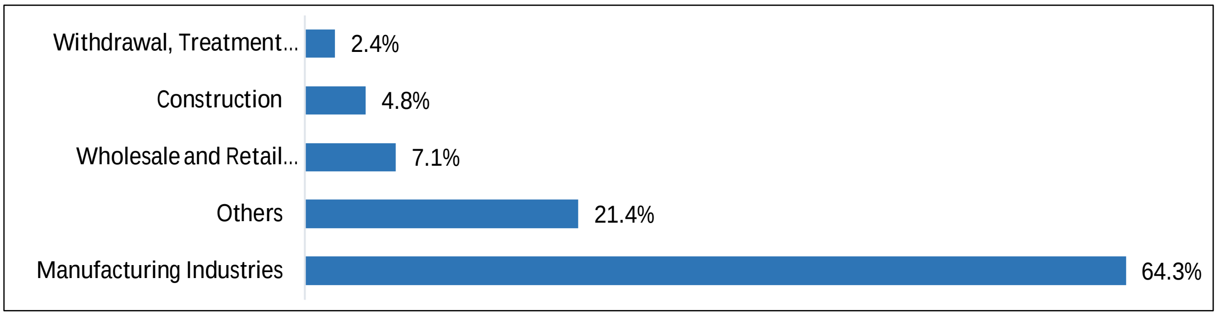

Figure 6 - Activity sector

The “Others sector” represented 21.4% of the total, corresponding to a total of nine companies (Figure 7). Within this last category, most of the companies were from the automotive sector (five companies), the other four companies pertained to different sectors: one to the electronics activity, other to the energy, the other one to the lighting and electrical equipment, and finally the other one to the oil refining activity.

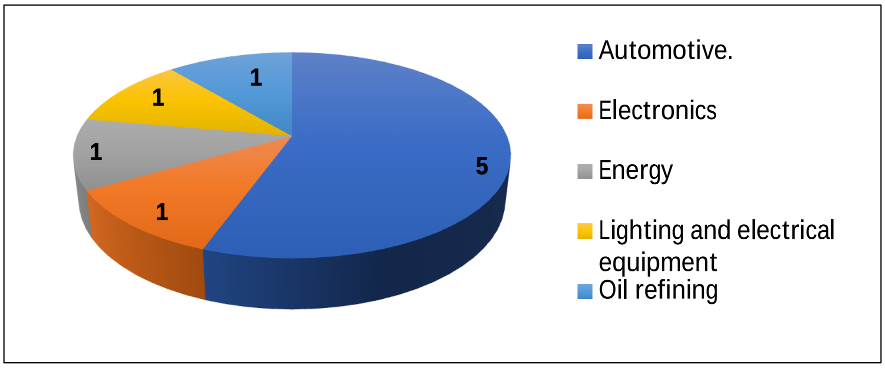

Figure 7 - Characterization of “Others” sector

The majority of the companies has prevailed for more than 30 years on the marketplace (62%), followed by companies in the range of 10 to 30 years (36%) in operation. Only 2% (one company) were less than 10 years old (Figure 8).

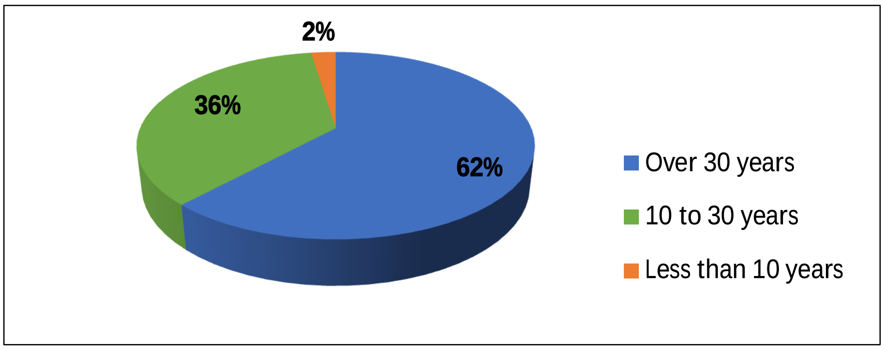

Figure 8 - Company years of operation

The younger company is a medium company, from the Withdrawal, Treatment and Water Distribution; Sanitation, Waste Management and Depollution sector. The management system of this company is certified in quality, environment and occupational health and safety, and worked mainly for the domestic market place.

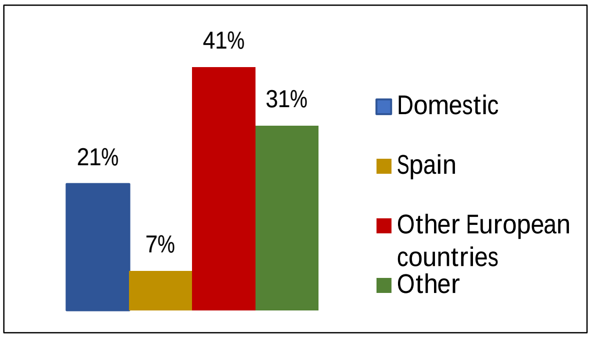

Figure 9 - Main market

Concerning the main market, 69% of the companies were international. Respondents could choose and fill in several options to characterize their market: Domestic, Spain, Other European countries and Other. The most reported main market was Other European countries, with 41%, followed by the Other with 31%, the Domestic with 21%, and the Spanish market with 7% (Figure 9). Regarding the companies that answered to work with the Other market, which were nineteen in total, seven worked worldwide and six with the African market.

4.2 Management system and production model characterization

From the analysis of section III results of the questionnaire, this section presents the results concerning the characterization of the management system, the production models, main concerns and benefits, sustainability awareness and approaches undertaken to improve environmental performance, if companies considered to implement lean production and, lastly the survey findings analysis and discussion.

4.2.1 Management system characterization

Regarding the management system, companies had to answer first to the question "Is the company's management system certified?". Most companies had their management system certified (83.3%), which represented thirty-five companies in a universe of forty-two companies, and the other seven companies were not certified (about 17%) (Figure 10).

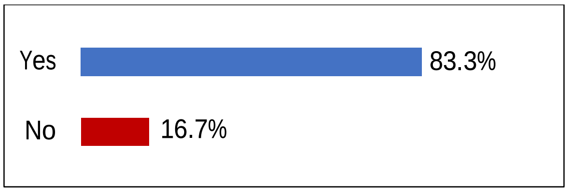

Figure 10 - Number of certified companies

Concerning the management system characterization, respondents had a multiple-choice question with options, which were: ISO 9001 (Quality management) (ISO, 2015b), ISO 14001 (Environment management) (ISO, 2015a), OHSAS 18001/NP 4397 (Occupational health and safety management) (BSI, 2007)/(IPQ, 2008), ISO 26000 (Social responsibility) (ISO, 2010) and Others. From the thirty-five companies certified, most companies were certified according to the quality management system (37.5%), 33.8% were certified according to the environmental management system, 23.8% companies were certified according the health and safety system and 5% certified according to the social management system (Figure 11).

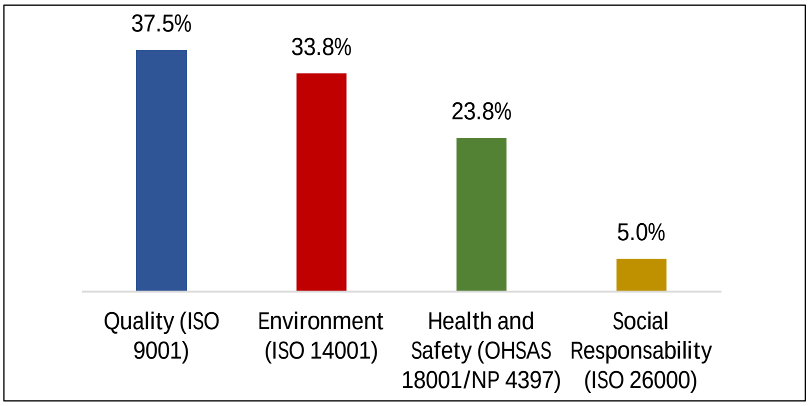

Figure 11 - Management system

Within these companies, fifteen companies had also identified other management systems being implemented, as depicted in Figure 12. As can be seen the ISO/TS 16949 (Particular requirements for the application of ISO 9001:2008 for automotive production and relevant service part organizations) (ISO, 2009) was the other management system most reported, identified by ten companies, with 67%.

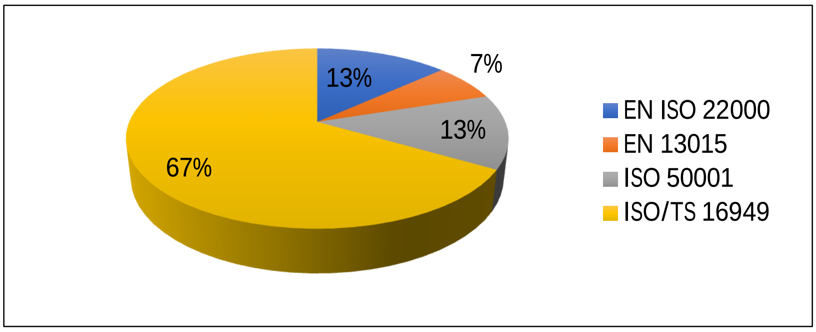

Figure 12 - Other management system identified

The ISO 50001 (Energy management systems - Requirements with guidance for use) (ISO, 2018b) and the ISO 22000 (Food safety management systems - Requirements for any organization in the food chain) (ISO, 2018a) were reported by two companies each, making up 13%. Finally, only one company reported the EN 13015 (Maintenance for lifts and escalators - Rules for maintenance instructions) (EN, 2008), making up 7% of companies.

In order to understand the relationship between management systems, cross comparisons were performed, which revealed that from the thirty companies that identified the ISO 9001 (Quality management) (ISO, 2015b) twenty-four also had chosen the ISO 14001 (Environment management) (ISO, 2015a). Sixteen companies had chosen the OHSAS 18001/NP 4397 (Occupational health and safety management) (BSI, 2007)/(IPQ, 2008) in addition to the identified ISO 9001 (Quality management) (ISO, 2015b). Furthermore, for the thirty companies that had chosen the ISO 9001 (Quality management) (ISO, 2015b), four had chosen, as well, the ISO 26000 (Social responsibility) (ISO, 2010).

4.2.2 Production models, main concerns and benefits

Regarding the characterization of the production model adopted, respondents were asked to identify the production models they considered nearest to the one adopted by the company. The aim was knowing the companies understanding about the production models that exist, among a ten options list (Carmo-Silva et al., 2006), which were: 1) “Taylorist/Fordist” System or Mass production; 2) Toyota Production System; 3) Social-Technical System; 4) Lean Production (Lean Manufacturing, Lean Management) (in English); 5) Just-in-Time System (JIT); 6) Non-Stock Production; 7) Lean Production (in Portuguese); 8) Agile Production; 9) Kaizen System and 10) Kanban System. Some of these designations are related to the same production model, e.g. Toyota Production System and Just-in-Time, or even, repeated, like Lean Production in English, as well as, in Portuguese ("Produção ligeira ou magra"), to understand how the model was better known, in the industrial environment. The results obtained are presented in Figure 13.

The socio-technical system was not chosen by any company. It was found that 74% of the companies identified Lean Production as the production model closest to the one adopted by their company, followed by Kaizen System and Kanban Systems with 55% and 43%, respectively. The Just-in-Time Production is the next production model most identified, with 36%.

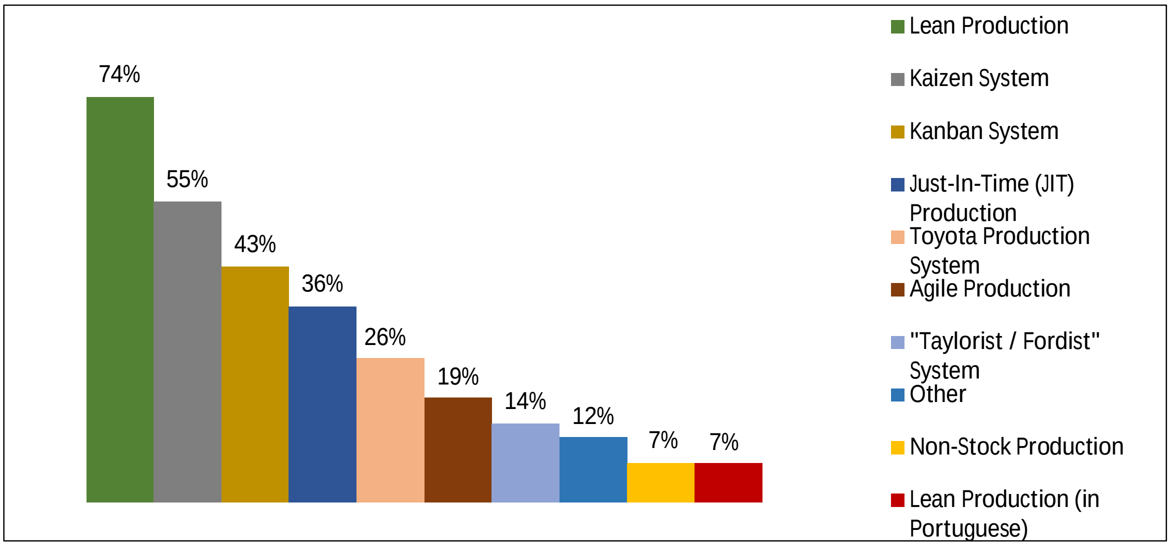

Figure 13 - Production models adopted

Within thirty-one companies that identified Lean Production, in English, only three companies identified simultaneously the designation in Portuguese, what may indicate unfamiliarity of the Portuguese term, compared to the English term awareness.

Only one company identified simultaneously seven models, which were: Toyota Production System, Lean Production, Just-in-Time System (JIT), Non-Stock Production, Lean Production (in Portuguese), Kaizen System and Kanban System. Followed by another, which identified simultaneously six models. Four companies identified simultaneously five production models as the production models adopted by their companies. For the twenty-four companies that identified the kaizen System, four did not identified the Lean Production model as well, and for the eighteen companies that identified the Kanban System, only one did not identified, simultaneously, the Lean Production. These results may show that companies do not perceived as equivalent designations, the various terms used to identify a production model.

Concerning the opinion about the company's production model influence on the company's main concerns, respondents were asked to select the main concerns they considered to be the company's focus among a six options list: 1) environment; 2) people; 3) social responsibility; 4) wastes; 5) costs; and 6) productivity. The results attained are presented in Figure 14.

The most reported concern was productivity with 86%, followed by costs with 81%, and then by people, wastes and environment with 71%, 69% and 55%, respectively. Eight companies identified all the concerns.

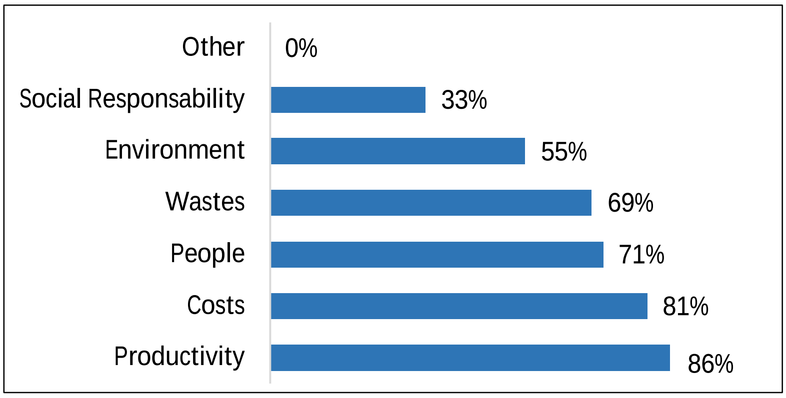

Figure 14 - Production model contribution to company's main concerns

In order to identify the benefits achieved by the companies, given the production model adopted, a set of sixteen possible benefits was presented: 1) Customer delivery time reduction; 2) Waste reduction; 3) Customer satisfaction improvement; 4) Product quality improvement; 5) Increased profits; 6) Increased productivity; 7) Increased employee satisfaction; 8) Stock reduction; 9) Production costs reduction; 10) Water consumption reduction; 11) Energy consumption reduction; 12) Raw materials consumption reduction; 13) Pollutants consumption reduction; 14) Toxic waste reduction; 15) New product development in shorter timeframe and; 16) Increased flexibility to produce different products. Respondents were asked to select those benefits they consider companies had achieved.

According to results shown in Figure 15, the mostly reported benefit was increased productivity (88%), followed by waste reduction and customer satisfaction improvement, both with 79%, then the stock reduction and the production costs reduction with 74% and 71%, respectively.

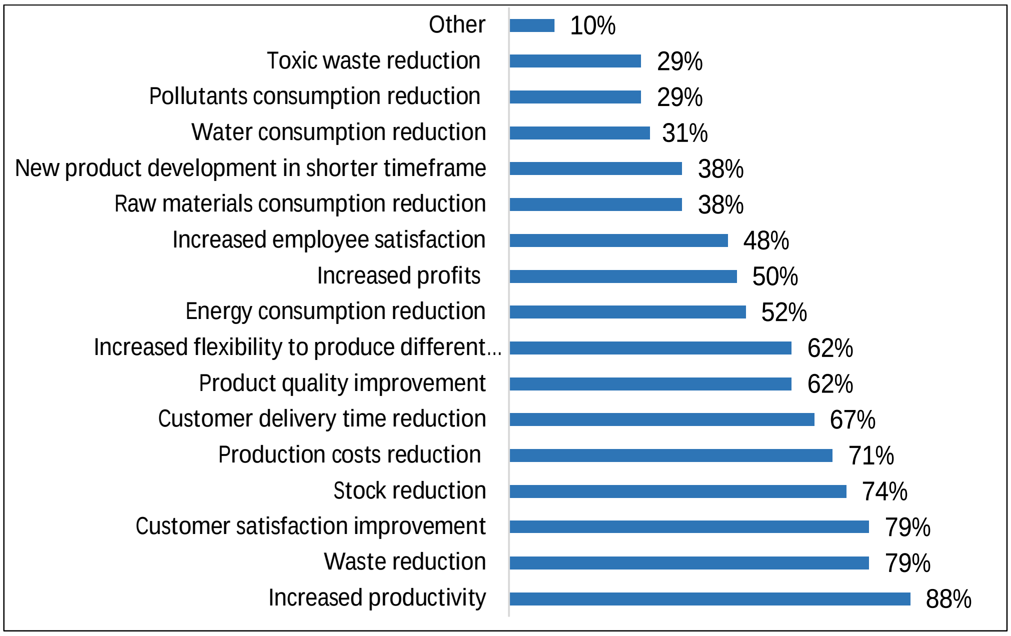

Figure 15 - Benefits achieved by the company

Twelve companies identified eight benefits (the ones with higher percentage). Two thirds of these companies (67%) belonged to the manufacturing activity sector and the other third (33%) belong to the “Others" activity sector. Four companies identified all the benefits, these were big companies, operated in the international market, belonged to the manufacturing industry sector, had their management system certified and reported the Lean production model as the model adopted.

Four companies identified "Other" benefits. One company reported that: "Continually and systematically look at problems as an opportunity to be more efficient by listing and solving them". This company was a big company, operated for more than thirty years in the international market, belonged to the manufacturing industry sector, its main product and/or service was sporting goods production and distribution, identified the Lean production model as the one adopted and its management system was not certified. Other reported "Development of local suppliers", it was a big company, pertaining to the manufacturing industry sector, operated for more than ten and less than thirty years in the international market, identified the Lean production model as the one adopted and their management system was certified. Another company reported "We have production model applied". In spite of this statement, was interestingly to note that for the model adopted, the respondent did not identify any of the models listed for selection, neither identified any concern nor any benefit. And, for the question if the company implemented the Lean Production model, the respondent answered "No". These results seem to show some unawareness or confusion by the respondent, which may be clarified by the fact that respondent’s questionnaire was an intern. This was a medium company, operating for less than ten years in the market, and only in the domestic one and had its management system certified. The last company reported “Increased flexibility to produce different services”. This was a small company, operating for more than thirty years in the domestic market, belonging to the construction sector, which identified the Just-In-Time (JIT) production model as the one adopted and reported that its management system was not certified.

4.2.3 Sustainability awareness and approaches for improvement of environmental performance

Regarding the sustainability, companies were asked if the company’s production model was considered to promote company’s sustainability. Respondents had three options: “Yes”, “No” and “Do not know”. The results obtained are presented in Figure 16.

Figure 16 - Company production model promoted company's sustainability

Overall, 98% of the respondents agreed that the adopted production model promoted the company's sustainability. Only one company answered that did not know. This was a medium company, pertaining to the "Other" sector, producing lighting and electrical material, operating for more than ten and less than thirty years in the domestic and other European countries, having its management system certified and identifying the "Taylorist/Fordist" System as the production model adopted. Although this answer, the respondent selected the "material and energy intensity" as the sustainability indicator used by the company and, reported five benefits achieved, as well as, five approaches to support improvement of environmental performance.

In order to understand the environmental performance improvement process, respondents had to select from a list of eight approaches, the ones that were already in place to support this process. The options were: 1) Life cycle management; 2) Life cycle assessment; 3) Design for environment; 4) Eco-Labelling; 5) Clean production/Pollution prevention; 6) Green Procurement; 7) Environmental Management System and 8) Environmental Supply Chain Management. The respondents had also the possibility to select "No adopted approach" and "Other". The results obtained are presented in Figure 17.

The most reported approach was the environmental management system (79%), having a large difference to the remaining approaches, like clean production/pollution prevention and environmental supply chain management, both with 36%. In average, three approaches were adopted.

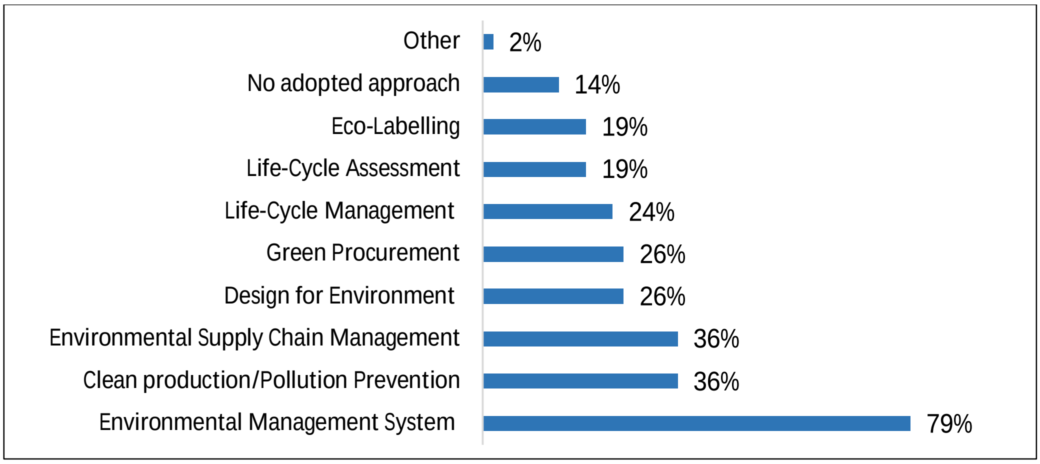

Figure 17 - Approaches used for environmental performance improvement

Three companies selected all the approaches, they were big companies, operating for more than ten and less than thirty years in the international market, belonging to the manufacturing industry sector and having their management system certified. They reported their production model promoted company's sustainability and reported, as well, to implement lean production.

Five companies chose six approaches (the six with the highest percentage). They were big companies, pertaining to manufacturing industry sector and having their management system certified. They reported the lean production model and the Kanban system as the production models adopted. They considered that their production model promoted company's sustainability and reported, as well, to implement lean production. Six companies did not identify any approach.

Only one company identified the "Other" approach, stating that "We use volatile organic compounds (VOC)-free products to provide our services". Interesting to note that this company was the same one that for the benefits reported in the "other" column the statement: "Increased flexibility to produce different services". As already mentioned, it was a small company, operating for more than thirty years in domestic market, belonging to construction sector, which identified the Just-In-Time production model as the adopted and reported that its management system was not certified.

Concerning the sustainability indicators awareness, respondents had to identify the sustainability indicators used in the company among a set of nine options, which were: 1) Energy consumption; 2) Materials consumption; 3) Water consumption; 4) Greenhouse gases emissions; 5) Ozone depleting substances (ODS) emissions and other air emissions; 6) Solid and liquid waste production; 7) Treatment and waste disposal cost; 8) Gases emission cost and 9) Material and energy intensity. The respondents had also the possibility to identify "Other" sustainability indicator. The results obtained are presented in Figure 18.

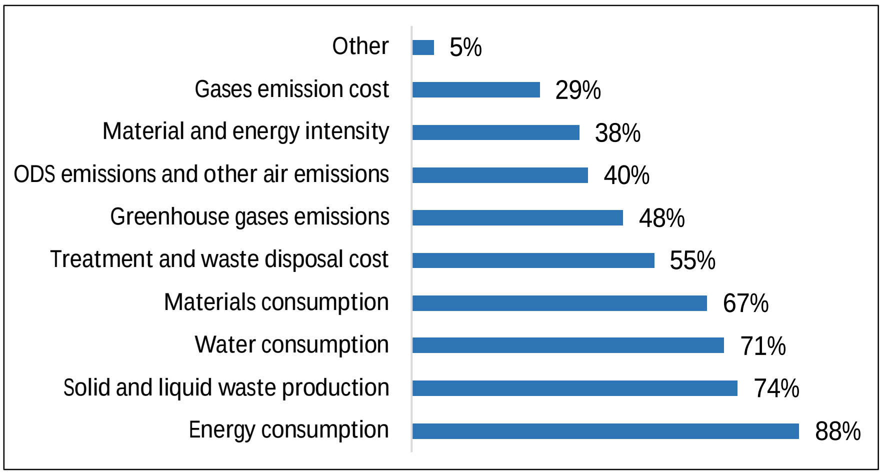

Figure 18 - Sustainability indicators

The most reported indicator was energy consumption with 88%, followed by the solid and liquid waste production with 74%, the water consumption with 71%, materials consumption with 67% and treatment and waste disposal cost with 55%. In average, only five indicators were selected. Four companies selected nine indicators, which represented 10% of the companies. These were big companies, operating in the international market and pertaining 50% to the manufacturing industry sector and the other 50% to the "Other" sector. All these companies had their management system certified, all identified the lean production model as the production model adopted, reported that their production model promoted company's sustainability and, for the question if the company implemented the Lean Production model, they all answered "Yes".

4.2.4 Lean production implementation

The last question was intended to know if the companies implemented Lean Production. In order to clarify what Lean Production is, the following definition was presented: *"Lean production is a production model, with focus on the client, that promotes waste (activities that do not add value from the clients point of view) elimination, timely deliveries of quality products, at low cost and respecting people and the environment."* (Maia et al. 2013, p.184). The results obtained are presented in Figure 19.

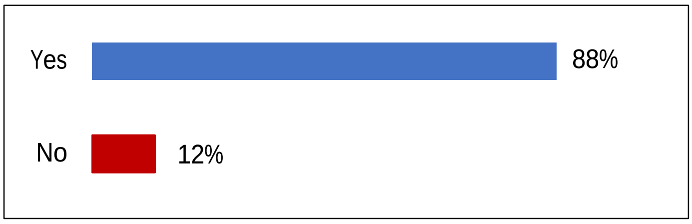

Figure 19 - Lean Production implementation

Most companies reported to implement lean production with 88%, with the remaining 12% reporting that they did not. Some reasons provided for justifying the lack of lean implementation were:

1) "The company has its production units outside the country";

2) "We have no production model applied";

3) "Lean is rarely applied in this activity sector";

4) "The model is not yet 100% implemented";

5) "We partially apply Lean philosophy. We lack some consistent practices to systematically promote it".

4.2.5 Comments and suggestions

The questionnaire ended with an open question for respondents to contribute with any comment or suggestion. Six respondents, from different professional functions in the companies, answered this field. Their comments/suggestions were:

1) *"The company adopts management methods based on Lean methodology.";*
2) *"Since we outsource our production, our biggest concern is more in the mind-set of our partners' CEOs and less in the famous Lean "tools". Without mind-set, there are no tools that are worth us!";*
3) *"Many Design for environment activities must be done during the product pre-development phases. Lean application in mass production products usually becomes unfeasible with the costs involved.";*
4) *"I said that we have achieved several benefits with the implementation of LEAN, but in reality, I believe this is an impossibility, that is, I do not believe that we can ever say that we have improved everything .... the truth is that we have improved a lot, but we see many things yet to improve and, in the future, we will surely discover many more ... it will never end.";*
5) *"The answer options to question 13 are limited and very close to each other. Since you want to fit into the Lean system, your options should include other systems (EFQM, TOC, etc.)".*

It is interesting to note that the 2nd comment is related with a very important feature of every method or methodology implementation, which is the top management way of thinking, support and attitude. The 4th comment expresses the continuous improvement cycle and the fifth lean principle inherent features – pursuit of perfection. The last comment indicates respondent awareness of lean and the lean related production models.

4.3 Discussion and limitations

This discussion begins by highlighting the conclusions followed by the questionnaire limitations, which was distributed in two different time periods, March 2016 and April 2016. It was available on-line for four months. Several results from the survey were identified. The goal was to know how companies see the lean model and its link to sustainability.

From the 10 options given to respondents, regarding the production models, seven were lean related. This was intended to know to what extent the respondents knew lean. Most respondents, however, did not relate the seven options. Therefore, it seems that the respondents struggled to recognize or relate such concepts. For instance, some of the options were related to tools used in the lean context, such as Kaizen, Kanban and JIT.

Relating the companies' concerns, presented in section 4.2.2, the results point out that productivity and costs are still the leading aspects, followed by: people, wastes, environment and, finally, social responsibility. It was interesting to note that wastes and environment appear in 4th and 5th place, respectively. Attending to the benefits achieved by the companies, four of them selected all the 16 benefits listed. These were large international companies from the manufacturing sector, holding a certified management system.

All respondents agree on their production model promoting sustainability (in section 4.2.3). However, this seems rather incongruent with the results on the reported benefits, given that sustainability achieved a low score, while encompassing environmental wastes, e.g. water consumption, toxic waste, among others. Additionally, sustainability indicators (in section 4.2.3) were partly selected by the respondents, which, in average, selected only five indicators and only four companies selected all nine indicators (representing 10%). Attending to this it was difficult to understand how the companies measure such promotion on sustainability. The energy consumption was by far the sustainability indicator most reported. All the companies considered that the production model adopted increased the concern about people, wastes and costs.

Considering the approaches for the environmental performance improvement (section 4.2.3), in average three approaches were adopted by the companies, and only three companies chose all approaches. Five companies selected the six approaches holding the highest percentages. All these companies were big companies from the manufacturing sector, identified lean production and Kanban system as the adopted production model and considered that these promoted the company sustainability.

In spite of the aforesaid, respondents considered that implemented lean, however it was not completely clear from the survey that they knew exactly what lean was. Their answers seemed, in one point, inconsistent. In addition, it is important to report that question number 15 "Do you consider that the company´s production model promotes company´s sustainability?" and question number 19 "Do you consider that the company implements Lean Production?" are independent, i.e. there is no association between them. This conclusion was based on Fisher test that given a $p=0.119$ ($p>0.05$ means they are independent). Therefore, statistically, this result does not allow to infer that the lean production model promotes sustainability. To arrive at a more conclusive outcome it is necessary to deepen the study.

The sample size used and considered valid for the analysis of results can be considered a limitation of this study, as the number of questionnaires received was not the expected one (12%). However, as pointed out in Saunders et al. (2009, p. 364), for questionnaires administered via internet, the likely response rate is variable and the expecting value is 11% or a lower value. Moreover, this questionnaire type was selected with the purpose of enabling the contact of companies from different activity sectors, from different dimensions, and respondents from different positions and functions (Saunders et al., 2009, p. 398).

Additionally, the results statistical analysis had shown a weak response variability, another limitation of the study to highlight. Furthermore, one more study limitation to be pointed out was the subjectivity in results interpretation, because although the majority considered themselves lean adopters, other responses results seem to indicate poor or misleading understandings on lean. However, the data obtained allowed us to gain insight into what companies in northern Portugal know about lean production.

To conclude, survey results exhibited that a great majority of respondents did effectively knew and applied lean strategies. Nevertheless, the study results did not seem to clear out the impression that respondents were not generally aware of lean-green synergy. Probably, this lack of awareness come from of the lack of measurement and use of sustainability indicators.

Therefore, and in order to overcome this lack of awareness of the lean-green synergy, as well as, the lack of measurement and use of sustainability indicators, this thesis author aims to develop an indicator, grounded on a model, to evaluate business performance and sustainability effectiveness. The intention is to develop a simple, easy and feasible model for companies to use and apply. The model is described in the following chapter.

5 BOPSE model development

This chapter describes the development of the model supporting the Business Overall Performance and Sustainability Effectiveness (BOPSE) indicator. The goal of the BOPSE indicator is the assessment of business effectiveness, rooted on operational performance (by means of the overall equipment effectiveness) and on sustainability compliance (by means of the three dimensions of sustainability). This chapter presents the design of the model and the discussion held with experts to help on this design. Then, depicts the tests made to the model. Finally, portrays a discussion.

5.1 Model design

This section thoroughly details the model developed. It was intended by this thesis author, to design a model that relies on an aggregated indicator that integrate companies' performance from a sustainability and an operational perspective. For this it was important to: 1) identify KPIs from current sources; 2) define new nominee KPIs, 3) select suitable KPIs grounded on KPI criteria, and 4) compose the selected KPIs with given weights into a set, as applied by Kibira et al. (2018).

This model aims for a greater companies' lean-green compliance. Therefore, it exploits the lean-green production synergies. It is operationalized by means of an indicator that aggregates and combines lean and green production characteristics. This indicator interweaves several sustainability issues, spread over its three dimensions, with those comprised by the Overall Equipment Effectiveness (OEE) indicator, reviewed in section 2.1.5. Consequently, the BOPSE indicator purpose is to assess the businesses effectiveness, grounded on operational performance and sustainability compliance.

The BOPSE model general scheme is presented in Figure 20. BOPSE also intends to identify both explicit limitations and wider opportunities for the companies' global improvement.

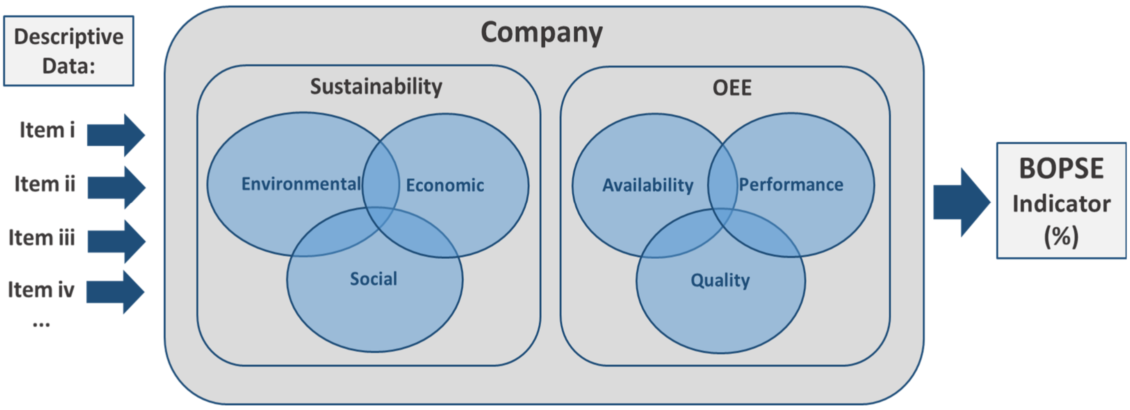

Figure 20 - The BOPSE model general scheme

The BOPSE indicator is calculated through the arithmetic mean of the sustainability and OEE strands, Equation 6.

$$BOPSE = \frac{(Sustainability + OEE)}{2}$$

Equation 6 - BOPSE arithmetic mean

The BOPSE indicator general scheme is presented in Figure 21, with the intention of understanding its constructs.

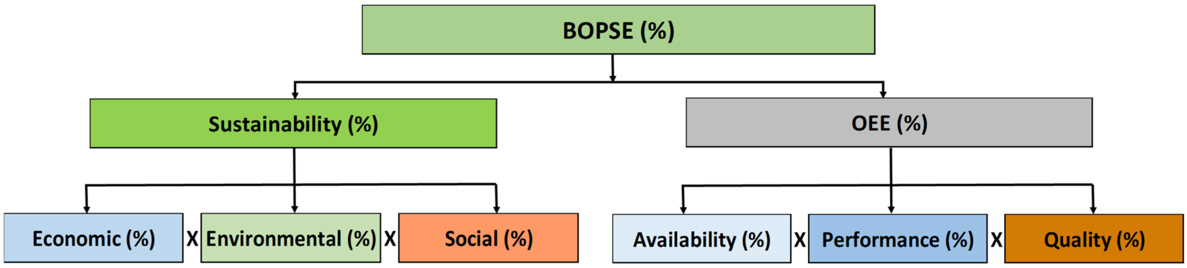

Figure 21 - BOPSE indicator general scheme with the main strands

The sustainability strand is supported by the Triple Bottom Line (3BL) concept, i.e. considering the economic, environmental and social dimensions, as review in section 2.2.1. The OEE strand is calculated considering the availability, performance and quality dimensions, as described in section 2.1.5.

Within each sustainability dimension, key indicators were identified (15 in total), and within each, descriptive indicators were defined (32 in total), as shown in Table 6.

To attain the BOPSE final version, the model design went through several stages. In an early stage, a first version was issued. The second stage included meetings with experts to debate and analyse the relevance of the key and descriptive indicators established. These resulted in a revised version, with rankings definition, some formulas adjusted and the BOPSE formula established. In the third stage, as a result of some testing (based on data from a number of sustainability reports), there was a clear perception that some major adjustments had to be done on several descriptive indicators, so as to produce meaningful results. A fourth stage was then issued, which included a second round of meetings with experts, where some descriptive indicators were refined and justified.

Table 6 - Key indicators and descriptive indicators of sustainability strand

Sustainability dimension	Key Indicators	Descriptive Indicators	
Economic (Eco)	Economic Performance (Eco 1)	Eco 1.1	Net Profit Margin
		Eco 1.2	Research, Development/Innovation
	Market Presence (Eco 2)	Eco 2.1	Standard entry level wage
		Eco 2.2	Local senior management
	Procurement (Eco 3)	Eco 3.1	Spending on local suppliers
Environmental (Env)	Materials (Env 1)	Env 1.1	Materials used
		Env 1.2	Recycled input materials used
	Energy (Env 2)	Env 2.1	Useful energy
		Env 2.2	Renewable energy
	Water (Env 3)	Env 3.1	Water used
		Env 3.2	Recycled and reused water
		Env 3.3	Net water needs reduction
	Biodiversity (Env 4)	Env 4.1	Biodiversity investment
	Emissions (Env 5)	Env 5.1	GHG emissions intensity
		Env 5.2	GHG emissions reduction
	Effluents and Waste (Env 6)	Env 6.1	Spills
		Env 6.2	Hazardous industrial residues
		Env 6.3	Recycled residues
	Environmental Compliance (Env 7)	Env 7.1	Environmental compliance
Social (Soc)	Employment (Soc 1)	Soc 1.1	Effective contracted employees
		Soc 1.2	Female employees
		Soc 1.3	Women in management
		Soc 1.4	Employee turnover
	Occupational Health and Safety (Soc 2)	Soc 2.1	Absenteeism
		Soc 2.2	Accidents rate
		Soc 2.3	Fatalities
	Training and Development (Soc 3)	Soc 3.1	Budget in training and development
		Soc 3.2	Training and development hours
		Soc 3.3	Employees engagement
	Local Communities (Soc 4)	Soc 4.1	Employees engaged in volunteering
		Soc 4.2	Donations
	Socioeconomic Compliance (Soc 5)	Soc 5.1	Socioeconomic compliance
Total	15	32	

To perform the calculations, it was used an excel sheet, considering the formulas presented in following sections. Each dimension and indicator are also presented in a detail way and discussed.

5.1.1 Sustainability strand

After a careful and thoughtful study and analysis of frameworks sustainability, thoroughly reviewed in section 2.2.5 of chapter 2, this thesis author selected the GRI as the inspiring framework to support the sustainability strand. This selection was based on the fact that GRI Sustainability Reporting Standards are the most widely adopted global standards for sustainability reporting, since 1997 (GRI, 1997). Simultaneously, as the GRI mission is to empower decisions to generate social, environmental and economic benefits for all, it supports businesses and governments comprehend and communicate their impact on critical subjects like climate change, human rights, governance and social well-being (GRI, 1997).

Another reason to select the GRI relies on its four-focus action areas as referred in section 2.2.5 of chapter 2., which are:

1) Creating standards and guidance to move forward sustainable development;
2) Harmonizing the sustainability scenery;
3) Leading well-organized and effective sustainability reporting and;
4) Managing effective use of sustainability information to enhance performance.

Therefore, attending to the abovementioned substantiations, and to the fact that sustainability reporting, through GRI, is a key platform to communicate the sustainability performance and impacts, either positive or negative, this was the reason why it was selected as the inspiring framework for development of the sustainability strand from the BOPSE indicator.

The sustainability strand interrelates the three dimensions: economic, environmental and social and, being calculated as a product of each individual dimension, Equation 7.

$$Sustainability\ (\%) = Economic\ (\%)\ x\ Environmental\ (\%)\ x\ Social\ (\%)$$

Equation 7 - Sustainability strand

Each dimension has the same degree of importance, i.e. the same weight, within the sustainability strand. Key indicators were identified to describe each dimension (Table 6, section 5.1). Each dimension is calculated through the simple arithmetic mean of the results obtained in the key indicators that comprise it. These calculation formulas resulted from the analysis and discussion with the experts, depicted in section 5.2, of chapter 5. Therefore, the calculation will be Equation 8, Equation 9 and Equation 10.

$$Eco = \frac{\sum_{i=1}^{k} Eco_i}{k}, k = 3$$

Equation 8 - Economic dimension formula

$$Env = \frac{\sum_{i=1}^{l} Env_i}{l}, l = 7$$

Equation 9 - Environmental dimension formula

$$Soc = \frac{\sum_{i=1}^{m} Soc_i}{m}, m = 5$$

Equation 10 - Social dimension formula

For each key indicator, descriptive indicators have been selected (see Table 6), as the most relevant and representative (Abreu et al., 2019). Therefore, each key indicator is calculated by the simple arithmetic mean of the descriptive indicators that compose it or, in some cases, by a single descriptive indicator. Each descriptive indicator arises from the aggregation of essential information about the practices in sustainability terms. Each was specifically characterized, considering the following features:

1) Description of the indicator;
2) Identification of what it measures;
3) Calculation formula;
4) Value range or ranking;
5) Trend, identifying if the correlation is positive or negative (i.e. if a greater result is better, or otherwise, worse in sustainability terms); and
6) Justification for the indicator and/or definition of the ranking.

As already mentioned, for the sustainability strand calculation, each dimension and key indicators have the same weight. Dissimilarly, rankings were established for 27 descriptive indicators, since the ranks and its calculation could not be made directly, due to activity sector specificities and differences, as well as, due to normalization requirements.

The defined rankings are presented in Appendix H, in Table 81. For the purpose of this study, the rankings were developed aiming the automotive sector. For 27 descriptive indicators, performance intervals were defined to establish the rankings adapted to sector specificities. These performance intervals were set, so that the descriptive indicator value will always range between a low performance (set at 60%), a medium or reasonable performance (set at 80%), through an acceptable or high performance (set at 100%). These instantiations of the BOPSE model required wise judgment, in order to maintain temporal validity and sector wide comparability.

Each descriptive indicator is characterized in the following sections and a summary is presented in Appendix G, from Table 66 till Table 80.

5.1.1.1 Economic dimension

The economic dimension is characterized by three key indicators and five related descriptive indicators, as presented in Table 7. The key indicators are the Economic Performance (Eco1), the Market Presence (Eco 2) and the Procurement (Eco 3). These key indicators were inspired in the GRI standards (GRI, 2016) and were selected after a careful thoughtful analysis, considering which indicators should describe each key indicator, in a simple and easy way.

Table 7 - Key and descriptive indicators of economic dimension

Sustainability dimension	Key Indicators	Descriptive Indicators	
Economic (Eco)	Economic Performance (Eco 1)	Eco 1.1	Net Profit Margin
		Eco 1.2	Research, Development/Innovation
	Market Presence (Eco 2)	Eco 2.1	Standard entry level wage
		Eco 2.2	Local senior management
	Procurement (Eco 3)	Eco 3.1	Spending on local suppliers

Also important for this analysis was the constant thought that the model should be both straightforward and meaningful for companies to use.

This thesis author selected the Economic Performance (Eco 1), the Market Presence (Eco 2) and the Procurement (Eco 3) as the most significant and relevant, among the six topic-specific economic GRI standards (GRI, 2016). This decision was grounded on the following evidences, namely:

1) Consultation of sustainability reports from companies;
2) Most representative indicators in the sustainability reports analysed;
3) Investigation of which topic-specific economic standards in GRI would be most representative on companies' environmental performance;
4) Easiness of gathering data and, to end;
5) Previous work experience.

5.1.1.1.1 Economic Performance

Within the Economic Performance (Eco 1) two descriptive indicators were selected among the four disclosures included in the topic-specific GRI 201: Economic Performance (GRI, 2016), which were:

1) Net profit margin (Eco 1.1);
2) Research, development/innovation (Eco 1.2).

These two indicators were selected because aggregate the essential information within this key indicator. It is calculated as Equation 11.

$$Eco\ 1 = \frac{Eco\ 1.1 + Eco\ 1.2}{2}$$

Equation 11 - Economic performance formula

A summary of this key indicator is presented in Appendix G, Table 66.

The net profit margin (Eco 1.1) indicator, presented in Table 8, measures the proportion of net profit relative to the revenues. Net profit margin essentially measures the amount of each euro of sales that a company has left over after paying all of its expenses.

Table 8 - Net profit margin (Eco 1.1) indicator

Eco 1.1	**Net profit margin (Npm)**
Description	Percentage of net profit measures the proportion of the total amount of net profit relative to the total amount of revenues (in €).
Equation	$Npm = \frac{Total\ amount\ of\ net\ profit}{Total\ amount\ of\ revenues} x100$
Range/Ranking	< 1% 60% (low) >1% to 5% 80% (medium) >5% 100% (high)
Trend	The higher, the better
Justification	Based on: New York University Stern School of Business (NYU Stern, 2019).

The New York University Stern School of Business, publishes the net profit margins by activity sector (NYU Stern, 2019). The values encountered varied from 1.82% for the Auto & Truck, and 4.92% for the Auto Parts. Based on that, the ranking was defined in three levels of performance, as seen in Table 8, being smaller than 1% the lowest ranking, corresponding to a low performance of 60%. Higher than 5% corresponds to the high performance, so obviously the higher the indicator the better. The defined ranking can be found in Appendix H, in Table 81.

The research, development and innovation (Eco 1.2) measures the proportion of the amount spent on research, development and innovation relative the total amount of revenues (in €). A summary is presented in Table 9. The Eurostat data (Eurostat, 2019d) showed that, in 2018, the research and development global expenditure (as a % of GDP), in Portugal was 1.35%. For the EU (considering the 28 countries) it was 2.12%.

Table 9 - Research, development and innovation (Eco 1.2) indicator

Eco 1.2	**Research, Development and Innovation (RDI)**
Description	Percentage of research, development and innovation measures the proportion of the amount on research, development and innovation relative to the total amount of revenues (in €).
Equation	$RDI = \frac{Total\ amount\ of\ RDI}{Total\ amount\ of\ revenues} x\,100$
Range/Ranking	0% to 1% 60% (low) >1% to 3% 80% (medium) >3% 100% (high)
Trend	The higher, the better
Justification	Based on: Eurostat data (Eurostat, 2019d) and (Eurostat, 2019a).

The countries with the highest values of expenditure in research and development were the Sweden with 3.31%, then Austria with 3.17%, followed by Germany with 3.13%. The EU target for 2020 for gross domestic expenditure on research and development, is 3% of GDP (Eurostat, 2019a). Bearing in mind these values, the ranking was defined in three levels of performance, as shown in Table 9, ranging from

0% to 1% for the low, between 1% and 3% for medium, and higher than 3% for high performance. Thus, the higher the better. The ranking is presented in Appendix H, in Table 81.

5.1.1.1.2 Market Presence

Within the Market Presence (Eco 2) two descriptive indicators were selected among the two disclosures included in the topic-specific GRI 202: Market Presence (GRI, 2016), which where:

1) Standard entry level wage (Eco 2.1);
2) Local senior management (Eco 2.2).

These two indicators were considered to aggregate the essential information within the key indicator. It is calculated as Equation 12. The key indicator is presented in Appendix G, Table 67.

$$Eco\ 2 = \frac{Eco\ 2.1 + Eco\ 2.2}{2}$$

Equation 12 - Market presence formula

The standard entry level wage (Eco 2.1), presented in Table 10, measures the proportion of the entry level wage relatively to the local minimum wage (in €). This indicator portrays the company position relative to wages policy.

Table 10 - Standard entry level wage (Eco 2.1) indicator

Eco 2.1	**Standard entry level wage (Selw)**
Description	Percentage of standard entry level wage measures the proportion of the entry level wage relative to local minimum wage (in €).
Equation	$Selw = \frac{Entry\ level\ wage}{Local\ minimum\ wage}\ x\ 100$
Range/Ranking	100% to 110% 60% (low) >110% to 120% 80% (medium) >120% 100% (high)
Trend	The higher, the better
Justification	Based on: minimum wage established by law (Guerreiro, 2019b).

In order to define coherent ranking, it was considered that the company must not only comply with the minimum wage values established by law, but also exceed these values. For instance, the minimum wage in 2018 was 580€ (Guerreiro, 2019b). Grounded on this, the ranking was defined in three levels of performance, as shown in Table 10, ranging from 100% to 110% for the low, between 110% and 120% for medium, and higher than 3% for high performance. Therefore, the higher the better. The ranking is presented in Appendix H, in Table 81.

The local senior management (Eco 2.2), presented in Table 11, measures the proportion of top managers hired from the local community relative to the total number of top managers. It portrays the company impact in surrounding community.

Table 11 - Local senior management (Eco 2.2) indicator

Eco 2.2	**Local senior management (Lsm)**
Description	Percentage of senior management hired locally, measures the proportion of the number of top managers hired from the local community relative to the total number of top managers.
Equation	$Lsm = \frac{Number\ of\ top\ managers\ from\ local\ community}{Number\ of\ top\ managers}\ x\ 100$
Range/Ranking	0% to 40% 60% (low) >40% to 80% 80% (medium) >80% 100% (high)
Trend	The higher, the better
Justification	This indicator was defined based on experience and the assumption that each company should engage and develop the local community.

In order to define a rational ranking, this indicator was established based on experience, common sense and the assumption that each company should engage and develop the local community. The ranking was defined in three levels of performance, as depicted in Table 11. It ranges from 0% to 40% for the low, between 40% and 80% for medium, and higher than 80% for high performance, so, the higher the value the better. The ranking is in Appendix H, in Table 81.

5.1.1.1.3 Procurement

Within procurement (Eco 3) one descriptive indicator was selected from the single disclosure in the topic-specific GRI 204 (GRI, 2016), which was Spending on local suppliers (Eco 3.1). This indicator aggregated the fundamental information within this key indicator, as seen in Appendix G, Table 68. It is calculated as Equation 13.

$$Eco\ 3 = Eco\ 3.1$$

Equation 13 – Procurement formula

The spending on local suppliers (Eco 3.1), presented in Table 12, measures the proportion of expenditures on local suppliers relative to the total suppliers' expenditure (in €). This is intended at involving and developing the community within which the company operates.

Table 12 - Spending on local suppliers (Eco 3.1) indicator

Eco 3.1	**Spending on local suppliers (Sls)**
Description	Percentage of spending on local suppliers measures the proportion of expenditures on local suppliers relative to the total suppliers' costs (in €).
Equation	$$Sls = \frac{Spending\ on\ local\ suppliers}{Global\ spending\ on\ suppliers}\ x\ 100$$
Range/Ranking	0% to 35% 60% (low) >35% to 70% 80% (medium) >70% 100% (high)
Trend	The higher, the better
Justification	This indicator has been defined based on experience and on the assumption that given the activity sector, sometimes a company has to comply with the group buying policies.

The ranking was defined in three levels of performance, as depicted in Table 12, ranging from 0% to 35% for the low, between 35% and 70% for medium, and higher than 70% for high performance. Thus, the higher the better. The ranking can be found in Appendix H, in Table 81.

5.1.1.2 Environmental dimension

The environmental dimension is characterized by seven key indicators and 14 related descriptive indicators, as presented in Table 13.

Table 13 - Key and descriptive indicators of environmental dimension

Sustainability dimension	Key Indicators	Descriptive Indicators	
Environmental (Env)	Materials (Env 1)	Env 1.1	Materials used
		Env 1.2	Recycled input materials used
	Energy (Env 2)	Env 2.1	Useful energy
		Env 2.2	Renewable energy
	Water (Env 3)	Env 3.1	Water used
		Env 3.2	Recycled and reused water
		Env 3.3	Net water needs reduction
	Biodiversity (Env 4)	Env 4.1	Biodiversity investment
	Emissions (Env 5)	Env 5.1	GHG emissions intensity
		Env 5.2	GHG emissions reduction
	Effluents and Waste (Env 6)	Env 6.1	Spills
		Env 6.2	Hazardous industrial residues
		Env 6.3	Recycled residues
	Environmental Compliance (Env 7)	Env 7.1	Environmental compliance

Once again inspired in the GRI, the seven selected key indicators were considered to be the most meaningful and relevant ones among the eight topic-specific environmental GRI standards (GRI, 2016). This decision was based on the five aspects, namely:

1) Consultation of sustainability reports from companies;
2) Most representative indicators in the sustainability reports analysed;
3) Investigation of which topic-specific economic standards in GRI would be most representative on companies' environmental performance;

4) Easiness of gathering data and, to end;

5) Previous work experience.

5.1.1.2.1 Materials

Within the Materials (Env 1), two descriptive indicators were selected among the three disclosures included in the topic-specific GRI 301: Materials (GRI, 2016), which were:

1) Materials used (Env 1.1);
2) Recycled input materials used (Env 1.2).

These two descriptive indicators were considered to aggregate the essential information within this key indicator, in Appendix G, Table 69. It is calculated as, Equation 14.

$$Env\ 1 = \frac{Env\ 1.1 + Env\ 1.2}{2}$$

Equation 14 - Materials formula

As represented in Table 14, the descriptive indicator materials used (Env 1.1) measures the proportion of the total materials incorporated in products, relative to the total input materials purchased by the company (in Ton). Total input materials include the following material types: raw materials, associated process materials (required for the manufacturing process but are not part of the final product, ex: lubricants), semi-manufactured goods or components and materials for packaging (paper, cardboard and plastics) (GRI, 2016).

Table 14 - Materials used (Env 1.1) indicator

Env 1.1	**Materials used (Mu)**
Description	Percentage of materials used measures the proportion of the total materials incorporated in the final product, relative to the total input materials purchased by the company (in Ton).
Equation	$Mu = \frac{Total\ materials\ incorporated\ in\ final\ product}{Total\ input\ materials}\ x\ 100$
Range/Ranking	Min: 0% Max: 100%
Trend	The higher, the better
Justification	Percentage obtained by direct calculation. This percentage will be high, as most input materials will be incorporated into the final product.

This percentage will be obtained by direct calculation and will range from 0% to 100%. The higher the value the better. Its aim is to encourage measures on reducing material waste and auxiliary substances.

The recycled input materials used (Env 1.2) is presented in Table 15. It measures the proportion of the total recycled input materials, relative to the total input materials purchased by the organization (in Ton).

Table 15 - Recycled input materials used (Env 1.2) indicator

Env 1.2	**Recycled input materials used (Rim)**
Description	Percentage of recycled input materials measures the proportion of the total recycled input materials, relative to the total input materials purchased by the organization (in Ton).
Equation	$Rim = \frac{Total\ recycled\ input\ materials\ used}{Total\ input\ materials}\ x\ 100$
Range/Ranking	0% to 25% 60% (low) >25% to 50% 80% (medium) >50% 100% (high)
Trend	The higher, the better
Justification	Based on: Eurostat data (Eurostat, 2019c).

Recycled input materials are material which substitute virgin materials and that are not by-products and non-product outputs manufactured by the company (GRI, 2016). This indicator gives insight about the total recycled materials incorporated in the final product.

The author searched information concerning this item. Eurostat reported that recycling rates in EU are “steadily growing” (Eurostat, 2019c). In 2016, EU recycled around 55% of all waste. The ranking was defined in three levels of performance, as portrayed in Table 15. It ranges from 0% to 25% for the low performance, between 25% to 50% for the medium, and higher than 50% for high performance. The trend will be the higher the better because the more the company recycles the better. The ranking is presented in Appendix H, in Table 81.

5.1.1.2.2 Energy

Within Energy (Env 2), two descriptive indicators were selected among the five disclosures included in the topic-specific GRI 302: Energy (GRI, 2016), which were:

1) Useful energy (Env 2.1);
2) Renewable energy (Env 2.2).

Such two indicators were considered to aggregate the important information within this key indicator, in Appendix G, Table 70, being calculated as Equation 15.

$$Env\ 2 = \frac{Env\ 2.1 + Env\ 2.2}{2}$$

Equation 15 - Energy formula

Table 16 presents the useful energy (Env 2.1) that it measures the proportion of energy consumption in the factory, relatively to the total energy consumption by the company (in GJ). This percentage gives insight about the share of energy used to manufacture the actual product.

Table 16 - Useful energy (Env 2.1) indicator

Env 2.1	**Useful energy (Ue)**
Description	Percentage of useful energy measures the proportion of energy consumption in the factory, relatively to the total energy consumption by the company (in GJ).
Equation	$Ue = \frac{Energy\ consumption\ in\ the\ factory}{Total\ energy\ consumption}\ x\ 100$
Range/Ranking	Min: 0% Max: 100%
Trend	The higher, the better
Justification	Percentage obtained by direct calculation. The largest share of energy consumed in this sector (automotive) will be given by the production area. Based on: Environmental Status Report, from APA (APA, 2019, p. 33).

The considerations in the table resulted from data in the 2019 Environmental Status Report, from Portuguese Environment Agency (APA). Energy imports in 2017 increased by 8.1% over the previous year, while domestic production decreased by 12.7%. In 2017, final energy consumption increased by 1.2% and primary energy consumption increased by 3.7%, due to consumption increases in natural gas and coal. Energy dependency also increased, standing at 79.7% (APA, 2019).

It will be obtained by direct calculation and will range from 0% to 100%. This percentage will be obtained by direct calculation and will range between 0% and 100%. Thus, the higher the better, as the largest share of energy consumed in this sector (automotive) will be given by the production area.

Table 17 portrays renewable energy (Env 2.2). It measures the proportion of renewable energy used relative to the total energy consumption by the company (in GJ). Renewable energy sources can comprise geothermal, wind, solar, hydro, and biomass (GRI, 2016). It gives insight about the share of renewable energy incorporated in the actual product.

Table 17 - Renewable energy (Env 2.2) indicator

Env 2.2	**Renewable energy (Re)**
Description	Percentage of renewable energy measures the proportion of renewable energy used relative to the total energy consumption by the company (in GJ).
Equation	$Re = \frac{Renewable\ energy\ used}{Total\ energy\ consumption}\ x\ 100$
Range/Ranking	0% to 25% 60% (low) >25% to 50% 80% (medium) >50% 100% (high)
Trend	The higher, the better
Justification	This percentage gives insight about the total recycled energy incorporated in the final product. Based on: Eurostat (Eurostat, 2019a) and APA (APA, 2019).

In order to define a reasonable ranking, it was consulted data in Eurostat and APA. In Eurostat Statistics Illustrated: the renewable energy share in gross final energy production increased from 11% to 16%, from 2008 till 2014. In 2017, Portugal had a share of 28.1% and the EU (28) a share of 17.5% (Eurostat, 2019a). Also, in 2019 Environmental Status Report, from APA: the incorporation of renewable energy sources into gross final energy consumption was 28.1% (APA, 2019).

The ranking was defined in three levels of performance, as portrayed in Table 17. The trend will be the higher the better. The ranking is in Appendix H, in Table 81.

5.1.1.2.3 Water

Within Water (Env 3), three descriptive indicators were selected among the five disclosures included in the topic-specific GRI 303: Water and Effluents (GRI, 2018, p. 2), which were:

1) Water used (Env 3.1);
2) Recycled and reused water (Env 3.2);
3) Net water needs reduction (Env 3.3).

These indicators gathered the significant information within this key indicator, in Appendix G, Table 71. It is calculated as Equation 16.

$$Env\ 3 = \frac{Env\ 3.1 + Env\ 3.2 + Env\ 3.3}{3}$$

Equation 16 - Water formula

The water used (Env 3.1), presented in Table 18, measures the proportion of water consumption in the factory, relative to the total water consumption in the company (in m3). It gives insight about the share of water consumption used to manufacture the actual product.

Table 18 - Water used (Env 3.1) indicator

Env 3.1	**Water used (Wu)**
Description	Percentage of water used measures the proportion of water consumption in the factory, relative to the total water consumption by the company (in m3).
Equation	$Wu = \frac{Water\ consumption\ in\ the\ factory}{Total\ water\ consumption}\ x\ 100$
Range/Ranking	0% to 25% 60% (low) >25% to 50% 80% (medium) >50% 100% (high)
Trend	The higher, the better
Justification	This percentage gives insight about the total water consumption in the factory. The largest share of water consumed in this sector (automotive) should be given by the production area.

This percentage provides an indication of the company's relative size and importance as a user of water. Considering the above mentioned, Table 18 presents the ranking defined in three levels of performance. The trend will be the higher the better. The ranking is in Appendix H, in Table 81.

The recycled and reused water (Env 3.2), portrayed in Table 19, measures the proportion of total volume of water recycled and reused, relative to the total water consumption (in m3). It gives insight about the total recycled and reused water incorporated in the product.

Table 19 - Recycled and reused water (Env 3.2) indicator

Env 3.2	**Recycled and reused water (Rrw)**
Description	Percentage of recycled and reused water measures the proportion of total volume of water recycled and reused, relatively to the total water consumption (in m3).
Equation	$Rrw = \frac{Total\ recycled\ and\ reused\ water}{Total\ water\ consumption}\ x\ 100$
Range/Ranking	0% to 25% 60% (low) >25% to 50% 80% (medium) >50% 100% (high)
Trend	The higher, the better
Justification	This percentages gives insight about the total recycled and reused water incorporated in the product.

This percentage is a measure of efficiency and establishes the company's achievement in reducing its total water withdrawals and discharges. An increased in water reuse and recycling will reduce water consumption, treatment, and disposal expenditures (GRI, 2018). This indicator was established grounded on the fact that each company should reduce its impact in local community within it operates.

The ranking was defined in three levels of performance, as portrayed in Table 19. The trend will be the higher the better. The ranking is in Appendix H, in Table 81.

The net water needs reduction (Env 3.3), presented in Table 20, measures the evolution of the current year water consumption relative to the previous year water consumption (in m3). Current year water consumption is the total water consumption in the year of the reporting period. The total water consumption is equal to the total water withdrawal minus the total water discharge. This percentage gives insight about the evolution of net water needs in the company.

Table 20 - Net water needs reduction (Env 3.3) indicator

Env 3.3	**Net water needs reduction (Nwnr)**
Description	Percentage of net water needs reduction measures the evolution of the current year water consumption relative to the previous year water consumption (in m3). The previous year water consumption is the total water consumption in the previous year and the current year water consumption is the total water consumption in the year of reporting.
Equation	$Nwnr = \frac{Previous\ year\ water\ consumption - Current\ year\ water\ consumption}{Previous\ year\ water\ consumption}\ x\ 100$
Range/Ranking	<1% 60% (low) >1% to 3% 80% (medium) >3% 100% (high)
Trend	The higher, the better
Justification	This percentages gives insight about net water needs evolution in the company. The total water consumption is equal to the total water withdrawal minus the total water discharge.

This indicator was established based on the assumption that each company should reduce its impact in the local community which operates. The ranking was defined in three levels of performance, as portrayed in Table 20, considering a high performance when the net water needs reduction is higher than 3%. The trend will be the higher the better. The ranking is in Appendix H, in Table 81.

5.1.1.2.4 Biodiversity

Within Biodiversity (Env 4), one descriptive indicator was selected between the four disclosures included in the topic-specific GRI 304: Biodiversity (GRI, 2016), which was Biodiversity (Env 4.1). This indicator aggregated the important information within this key indicator, as seen in Appendix G, Table 72. It is calculated as Equation 17.

$$Env\ 4 = Env\ 4.1$$

Equation 17 - Biodiversity formula

Biodiversity investment (Env 4.1) that is portrayed in Table 21, measures the proportion of total amount invested in biodiversity relative to the total amount of revenues (in €). It gives insight about company's concerns related with natural ecosystems protection, and maintenance.

Table 21 - Biodiversity investment (Env 4.1) indicator

Env 4.1	**Biodiversity investment (Bi)**
Description	Percentage of biodiversity investment measures the proportion of total amount invested in biodiversity relative to the total amount of revenues (in €).
Equation	$Bi = \frac{Total\ amount\ invested\ on\ biodiversity}{Total\ amount\ of\ revenues}\ x\ 100$
Range/Ranking	0% to 0.02% 60% (low) >0.02% to 0.05% 80% (medium) >0.05% 100% (high)
Trend	The higher, the better
Justification	Based on: European Environment Agency (EEA) (EEA, 2019) and the Environmental Status Report, from APA (APA, 2019).

In an attempt to define rational rankings, this thesis' author consulted the European Environment Agency (EEA). In 2006, the EU expenditure on the Life project was 0.066 % of the total EU budget (EEA, 2019). The 2019 Environmental Status Report, from APA, did not reported any data related to investment in biodiversity (APA, 2019). Considering this, the ranking was defined as shown in Table 21. The ranking is in Appendix H, in Table 81.

5.1.1.2.5 Emissions

In Emissions (Env 5), two descriptive indicators were selected among the seven disclosures included in the topic-specific GRI 305: Emissions (GRI, 2016), which were:

1) GHG emissions intensity (Env 5.1);
2) GHG emissions reduction (Env 5.2).

These two descriptive indicators were considered because combined fundamental information within this key indicator, in Appendix G, Table 73. The formula is in Equation 18.

$$Env\ 5 = \frac{Env\ 5.1 + Env\ 5.2}{2}$$

Equation 18 - Emissions formula

Table 22 presents the GHG emissions intensity (Env 5.1). It measures the total GHG emissions (in Kg CO2e), relative to the total amount of revenues (in €). It indicates the amount of GHG emissions per unit of € realised. This indicator gives insight about the company's efficiency, as well as, its comparison to other companies.

Table 22 - GHG emissions intensity (Env 5.1) indicator

Env 5.1	**GHG emissions intensity (GHGei)**
Description	Percentage of GHG emissions intensity measures the total GHG emissions (in Kg CO2e), relative to the total amount of revenues (in €).
Equation	$GHGei = \frac{Total\ GHG\ emissions}{Total\ amount\ of\ revenues}$
Range/Ranking	0 Kg/€ to 0.2 Kg/€ 100% (high) >0.2 Kg/€ to 0.4 Kg/€ 80% (medium) >0.4 Kg/€ 60% (low)
Trend	The lower, the better
Justification	Based on: 2019 Environmental Status Report, from APA (APA, 2019).

In an attempt to define reasonable rankings, this thesis author consulted the 2019 Environmental Status Report, from APA. In 2016, the carbon intensity emitted by Portugal was 0.39kg (or 390g) CO2eq. per euro of GDP at 2010 prices. This value was 4.4% less than the previous year (APA, 2019).

With regards to this, the ranking was defined in three levels of performance, as portrayed in Table 22, considering a high performance when the emissions range from 0kg to 0.2kg per euro realized. The trend will be the lower the better. The ranking is in Appendix H, in Table 81.

Table 23 depicts the GHG emissions reduction (Env 5.2). It measures the evolution of the current emissions year relative to the previous year emissions (in t CO2 e). This gives insight about the evolution of the GHG emissions in the company.

Table 23 - GHG emissions reduction (Env 5.2) indicator

Env 5.2	**GHG emissions reduction (GHGer)**
Description	Percentage of reduction of GHG emissions measures the evolution of the current emissions year relative to the previous year emissions (in t CO2 e).
Equation	$GHGer = \frac{Previous\ year\ emissions - Current\ year\ emissions}{Previous\ year\ emissions}\ x\ 100$
Range/Ranking	< 1% 60% (low) >1% to 5% 80% (medium) >5% 100% (high)
Trend	The higher, the better
Justification	Based on: Europe 2020 Strategy (Eurostat, 2019b) and APA report (APA, 2019).

The Europe 2020 Strategy was consulted to define reasonable rankings. The GHG emissions target should be 20% lower than 1990 levels (Eurostat, 2019b). Therefore, a 20% reduction over 30 years (2020-1990) means that this reduction was on average less than 1% annually. The 2019 Environmental Status Report, from APA was consulted. The target for 2020/2030, in comparison to 2005, is guaranteeing a trajectory of reduction of national GHG emissions, to reach goals of -18% to -23% in 2020 (68 to 72 Mt CO2 eq.) (APA, 2019). The ranking defined in three levels of performance, as showed in Table 23, considers a low performance when the emissions reduction is less than 1%, so the trend will be the higher the better. The ranking is in Appendix H, in Table 81.

5.1.1.2.6 Effluents and Waste

Within Effluents and Waste (Env 6), three descriptive indicators were selected among the five disclosures included in the topic-specific GRI 306: Effluents and Waste (GRI, 2016), which were:

1) Spills (Env 6.1);
2) Hazardous industrial residues (Env 6.2);
3) Recycled residues (Env 6.3).

The three descriptive indicators combined the essential information within this key indicator, in Appendix G, Table 74. It is calculated as Equation 19.

$$Env\ 6 = \frac{Env\ 6.1 + Env\ 6.2 + Env\ 6.3}{3}$$

Equation 19 - Effluents and waste formula

The spills (Env 6.1), presented in Table 24, measures the proportion of total volume of spills relative to the total effluents discharged (in m3). Spill is an accidental release of a hazardous substance that can disturb human health, land, flora, water bodies, and ground water (GRI, 2016). Total effluents discharged is the sum of treated and untreated wastewater water discharged.

Table 24 - Spills (Env 6.1) indicator

Env 6.1	**Spills (Sp)**
Description	Percentage of spills measures the proportion of total volume of spills relative to the total effluents discharged (in m3).
Equation	$Sp = \frac{Total\ volume\ of\ spills}{Total\ effluents\ discharged}\ x\ 100$
Range/Ranking	0% 100% (high) >0% to 0.1% 80% (medium) >0.1% 60% (low)
Trend	The lower, the better
Justification	Spill is an accidental release of a hazardous substance that can affect human health, land, vegetation, water bodies, and ground water. Material of spill, can be: oil spills (soil or water surfaces), fuel spills (soil or water surfaces), spills of wastes (soil or water surfaces), spills of chemicals (mostly soil or water surfaces), and other (to be specified by the company) (GRI, 2016). Total effluents discharged are the sum of water discharged without need for treatment plus treated water plus washings plus spills plus effluent discharged into the natural environment.

In an attempt to define a reasonable ranking, this indicator was established grounded on the fact that each company should reduce its impact within the community in which operates. In the investigation made, the data found only reported the number of spills and their volumes.

Table 25 describes the hazardous industrial residues (Env 6.2). It measures the proportion of total hazardous residues weight relative to the total residues weight produced by the company (in Ton).

Table 25 - Hazardous industrial residues (Env 6.2) indicator

Env 6.2	**Hazardous industrial residues (Hir)**
Description	Percentage of hazardous industrial residues (waste) measures the proportion of total hazardous residues (waste) weight relative to the total waste weight produced by the company (in Ton).
Equation	$Hir = \frac{Total\ hazardous\ industrial\ residues}{Total\ residues}\ x\ 100$
Range/Ranking	0% to 2% 100% (high) >2% to 10% 80% (medium) >10% 60% (low)
Trend	The lower, the better
Justification	Total residues are the sum of non-hazardous residues plus hazardous residues plus any other type of residue. Based on sustainability reports: Navigator (Navigator, 2017); EDP (EDP, 2018); Lameirinho (Lameirinho, 2018) and Sonae (Sonae, 2018) and on Environment Statistics (INE, 2018).

It gives insight about the total hazardous industrial residues produced by the company. Total residues are the sum of non-hazardous residues plus hazardous residues. It gives insight about company's pollution impact in its community.

With the purpose of defining a reasonable ranking, this indicator was grounded on data from sustainability reports. Hazardous industrial residues: Navigator had 0.15% (Navigator, 2017); EDP had 0.94% (EDP, 2018); Lameirinho had 1.4% (Lameirinho, 2018) and Sonae had 2.53% (Sonae, 2018). Interestingly, in 2017, the manufacturing industry was the main waste generating industry, contributing to 29.9% of the total waste generated (INE, 2018). Considering this, the ranking was defined in three levels of performance, as showed in Table 25. The trend will be the lower the better. The ranking is in Appendix H, in Table 81.

The recycled residues (Env 6.3), portrayed in Table 26, measures the total of recycled residues relative to the total residues weight produced by the company (in Ton). This indicator accounts the percentage of waste that is sent for recycling or other destinations by the company.

Table 26 - Recycled residues (Env 6.3) indicator

Env 6.3	**Recycled residues (Rr)**
Description	Percentage of recycled residues (waste) measures the total of recycled residues (waste) relative to the total residues (waste) weight produced by the company (in Ton).
Equation	$Rr = \frac{Recycled\ residues}{Total\ residues}\ x\ 100$
Range/Ranking	0% to 60% 60% (low) >60% to 85% 80% (medium) >85% 100% (high)
Trend	The higher, the better
Justification	Based on: "Car production and Sustainability" (VDA, n.d.) and sustainability reports: Navigator (Navigator, 2017).

So as to define a reasonable ranking, this author searched data concerning this subject. 80% of production waste of German automakers was recycled, as reported in "Car production and Sustainability" (VDA, n.d.). Also, data was searched in sustainability reports. In 2017, Navigator recycled 84% of its residues (Navigator, 2017). The ranking defined in three levels of performance, is presented in Table 26. The high performance will be when the range is higher than 85%. Therefore, the trend will be the higher the better. The ranking is in Appendix H, in Table 81.

5.1.1.2.7 Environmental Compliance

Within the Environmental Compliance (Env 7) key indicator, one descriptive indicator was identified among the single disclosures included in the topic-specific GRI 307: Environmental compliance (GRI, 2016), which was Environmental compliance (Env 7.1). This indicator aggregated the fundamental information within this key indicator, as seen in Appendix G, Table 75. It is calculated as Equation 20.

$$Env\ 7 = Env\ 7.1$$

Equation 20 - Environmental compliance formula

Table 27 depicts the environmental compliance (Env 7.1). It measures the number of environmental non-compliance cases, in a year. Environmental compliance comprises the non-compliance cases with laws and regulations in the environmental area. It considers the significant fines and non-monetary sanctions, along with, the cases carried out by dispute resolution mechanisms (GRI, 2016).

Table 27 - Environmental compliance (Env 7.1) indicator

Env 7.1	**Environmental compliance (Ec)**
Description	Environmental compliance measures the number of environmental non-compliance cases, in a year.
Equation	$Ec = Number\ of\ environmental\ non - compliance\ cases$
Range/Ranking	0 to 2 environmental non-compliance cases 100% (high) >2 to 5 environmental non-compliance cases 80% (medium) >5 environmental non-compliance cases 60% (low)
Trend	The lower, the better
Justification	Environmental compliance includes the non-compliance cases with laws and regulations in the environmental area. It considers the significant fines and non-monetary sanctions, as well as, the cases brought through dispute resolution mechanisms (GRI, 2016, p. 6).

In an attempt to define a reasonable ranking, this indicator was based on the fact that each company purpose is to have a good image in the market, as a transparent and reputable company, reducing its impact in the local community in which operates. The ranking was defined in three levels of performance, as presented in Table 27. The high performance will be when the number of non-compliance cases range till 2. Thus, the trend will be the lower the better. The ranking is in Appendix H, in Table 81.

5.1.1.3 Social dimension

The social dimension is characterized by five key indicators and 13 related descriptive indicators, as presented in Table 28.

Table 28 - Key and descriptive indicators of social dimension

Sustainability dimension	Key Indicators	Descriptive Indicators	
Social (Soc)	Employment (Soc 1)	Soc 1.1	Effective contracted employees
		Soc 1.2	Female employees
		Soc 1.3	Women in management
		Soc 1.4	Employee turnover
	Occupational Health and Safety (Soc 2)	Soc 2.1	Absenteeism
		Soc 2.2	Accidents rate
		Soc 2.3	Fatalities
	Training and Development (Soc 3)	Soc 3.1	Budget in training and development
		Soc 3.2	Training and development hours
		Soc 3.3	Employees engagement
	Local Communities (Soc 4)	Soc 4.1	Employees engaged in volunteering
		Soc 4.2	Donations
	Socioeconomic Compliance (Soc 5)	Soc 5.1	Socioeconomic compliance

Once more inspired in the GRI, the five selected key indicators were considered to be the most expressive and relevant ones among the 19 topic-specific social GRI standards (GRI, 2016). This decision was based on the five aspects, namely:

1) Consultation of sustainability reports from companies;
2) Most representative indicators in the sustainability reports analysed;
3) Investigation of which topic-specific economic standards in GRI would be most representative on companies' environmental performance;
4) Easiness of gathering data and, to end;
5) Previous work experience.

Also, this decision was grounded on the assumption that companies do not want to be recognized as a company that does not complies with the rules nor the fundamental human rights.

5.1.1.3.1 Employment

Within the Employment (Soc 1) four descriptive indicators were identified among the three disclosures included in the topic-specific GRI 401: Employment (GRI, 2016), which were:

1) Effective contracted employees (Soc 1.1);
2) Female employees (Soc 1.2);
3) Women in management (Soc 1.3);
4) Employee turnover (Soc 1.4).

These four descriptive indicators were considered to aggregate the important information within this key indicator, presented in Appendix G, Table 76. It is calculated as Equation 21.

$$Soc\ 1 = \frac{Soc\ 1.1 + Soc\ 1.2 + Soc\ 1.2 + Soc\ 1.4}{4}$$

Equation 21 - Employment formula

Table 29 presents the effective contracted employees (Soc 1.1). It measures the number of employees with an effective contract relative to the total number of employees. It gives an insight about company policy regarding human resources.

This percentage will be obtained by direct calculation and will range between 0% and 100%. The trend will be the higher the better.

Table 29 - Effective contracted employees (Soc 1.1) indicator

Soc 1.1	**Effective contracted employees (Ece)**
Description	Percentage of effective contracted employees measures the number of employees with an effective contract relative to the total number of employees.
Equation	$Ece = \frac{Number\ of\ effective\ contracted\ employees}{Total\ number\ of\ employees}\ x\ 100$
Range/Ranking	Min: 0% Max: 100%
Trend	The higher, the better
Justification	Percentage obtained by direct calculation.

The female employees (Soc 1.2), depicted in Table 30, measures the number of female employees relative to the total number of employees. It gives an insight about company policy regarding gender equality.

Table 30 - Female employees (Soc 1.2) indicator

Soc 1.2	**Female employees (Fe)**
Description	Percentage of female employees measures the number of female employees relative to the total number of employees.
Equation	$Fe = \frac{Number\ of\ female\ employees}{Total\ number\ of\ employees}\ x\ 100$
Range/Ranking	0% to 25% 60% (low) >25% to 50% 80% (medium) >50% 100% (high)
Trend	The higher, the better
Justification	Based on sustainability report from EDP (EDP, 2017, p. 43).

In order to define a reasonable ranking, this author searched data in reference companies. EDP company had 24% of female employees (EDP, 2017, p. 43). The rankings were defined in three levels of performance, as shown in Table 30. A low performance will be when the number of female employees is less than 25%, therefore, the trend will be the higher the better. The ranking is in Appendix H, in Table 81.

Table 31 depicts the women in management (Soc 1.3). It measures the number of women in management relative to the total number of employees in management. As Soc 1.2, this indicator gives an insight about company policy regarding gender equality.

In an attempt to define the ranking, data was searched in the 2019 INE report of “Sustainable Development Goals - Indicators for Portugal - Agenda 2030”. In 2018, the proportion of women in managerial positions compared to men, for “Top managers of first degree” was 39% (INE, 2019a, p. 130). In 2016, EDP had 25% of women in management (EDP, 2016, p. 37). Considering these values, the ranking was defined in three levels of performance, with the same ranges as Soc 1.2. The ranking is presented in Appendix H, in Table 81.

Table 31 - Women in management (Soc 1.3) indicator

Soc 1.3	**Women in management (Wim)**
Description	Percentage of women in management measures the number of women in management relative to the total number of employees in management.
Equation	$Wim = \frac{Number\ of\ women\ in\ management}{Total\ number\ of\ employees\ in\ managment}\ x\ 100$
Range/Ranking	0% to 25% 60% (low) >25% to 50% 80% (medium) >50% 100% (high)
Trend	The higher, the better
Justification	Based on: 2019 INE report, of "Sustainable Development Goals - Indicators for Portugal – Agenda 2030" (INE, 2019a) and sustainability report from EDP (EDP, 2016).

The employee turnover (Soc 1.4), presented in Table 32, measures the proportion of employees who left the organization relative to the total number of employees. It gives an insight about the levels of uncertainty and dissatisfaction within employees.

Table 32 - Employee turnover (Soc 1.4) indicator

Soc 1.4	**Employee turnover (Et)**
Description	Percentage of employee turnover measures the proportion of employees who left the organization relative to the total number of employees.
Equation	$Et = 1 - \frac{Number\ of\ employees\ who\ left\ the\ organization}{Total\ number\ of\ employees}\ x\ 100$
Range/Ranking	Min: 0% Max: 100%
Trend	The higher, the better
Justification	Based on: Social report from attorney general's office (prosecutor's office) (MP, 2018). Therefore, the relative Et is inversely related to the Et (1-Et).

The data was searched in attorney general's office from prosecutor's office. Its 2018 report presented a turnover rate of 14% (MP, 2018). In view of these values, the relative value of this indicator will be calculated inversely, as shown in Table 32. It will range between 0% and 100%. This indicator trend will be the higher the value is the better.

5.1.1.3.2 Occupational Health and Safety

Within the Occupational Health and Safety (Soc 2), three descriptive indicators were identified among the three disclosures included in the topic-specific GRI 403: Occupational Health and Safety (GRI, 2018), which were:

1) Absenteeism (Soc 2.1);
2) Accidents rate (Soc 2.2);

3) Fatalities (Soc 2.3).

These three descriptive indicators were considered to combine the significant information within this key indicator, depicted in in Appendix G, Table 77. It is calculated as Equation 22.

$$Soc\ 2 = \frac{Soc\ 2.1 + Soc\ 2.2 + Soc\ 2.3}{3}$$

Equation 22 - Occupational health and safety formula

Table 33 portrays the absenteeism (Soc 2.1). It measures the proportion of total number of days in absence of all employees, relative to the total number of workable days in a year. It gives an insight about the levels of dissatisfaction within employees.

Table 33 - Absenteeism (Soc 2.1) indicator

Soc 2.1	**Absenteeism (Ab)**
Description	Percentage of absenteeism measures the proportion of total number of days in absence (or lost) of all employees, relative to the total number of workable days. Total number of workable days = Annual number of working days x Total number of employees.
Equation	$Ab = \frac{Total\ number\ of\ days\ in\ absence\ (or\ lost)}{Total\ number\ of\ workable\ days}\ x\ 100$
Range/Ranking	0% to 5% 100% (high) >5% to 10% 80% (medium) >10% 60% (low)
Trend	The lower, the better
Justification	Based on: The 2018 report of attorney general's office from prosecutor's office (MP, 2018) and Eurofound data (EUROFOUND, 2010).

In order to define a rational ranking, data was searched concerning this subject. The 2018 report of attorney general's office from prosecutor's office depicted an absenteeism rate of 4.86% (MP, 2018). Eurofound also published that, in Portugal, the absenteeism rate has remained stable, at about 7%, from 2003 till 2007 (EUROFOUND, 2010). Considering this, the ranking was defined in three levels of performance. A high performance will range from 0% to 5%, therefore, the higher the value the better. The ranking is presented in Appendix H, in Table 81.

The accidents rate (Soc 2.2), presented in Table 34, measures the total number of work-related injuries by the working hours of 100 full-time employees (for a small company) or 500 full-time employees (for a big company), in one year, relative to the total number of hours worked by all employees. It gives an insight about the extent of harm suffered by employees.

Data was searched in sustainability reports, in an attempt to define a reasonable ranking for. In 2017, the company Navigator had 9.5 accidents per million hours worked (Navigator, 2017), and the company Lameirinho had 10.7 accidents per million hours worked (Lameirinho, 2018).

Table 34 - Accidents rate (Soc 2.2) indicator

Soc 2.2	**Accidents rate (Ac)**
Description	Accidents rate measures the total number of work-related injuries by the working hours of 100 full-time employees (for a small company) or 500 full-time employees (for a big company), in one year, relative to the total number of hours worked by all employees.
Equation	$Ac = \frac{Number\ of\ work-related\ injuries}{Number\ of\ hours\ worked}\ x\ (200.000\ or\ 1.000.000)$
Range/Ranking	0 to 10 100% (high) >10 to 30 80% (medium) >30 60% (low)
Trend	The lower, the better
Justification	A rate based on 200.000 hours worked indicates the number of work-related injuries per 100 full-time workers over a one-year timeframe, based on the assumption that one full-time worker works 2.000 hours (20 hours in 50 weeks of work) per year. For example, a rate of 1 means that, on average, there is one work-related injury for every group of 100 full-time workers over a one-year timeframe. A rate based on 1.000.000 hours worked indicates the number of work-related injuries per 500 full-time workers over a one-year timeframe (GRI, 2018). Based on sustainability reports: Navigator (Navigator, 2017); Lameirinho (Lameirinho, 2018).

The ranking was defined in three levels of performance. A low performance will be when the accidents rate is higher than 30 accidents, thus, the trend will be the lower the better.

Table 35 portrays the fatalities (Soc 2.3). It measures the number of fatalities work related relative to the total number of work-related injuries. It gives an insight about the fatalities occurred in the reporting period. Data was searched on sustainability report. Fortunately, most sustainability reports examined did not reported any fatality. However, in 2015, EDP had a 2.04% of fatalities (EDP, 2015).

Table 35 - Fatalities (Soc 2.3) indicator

Soc 2.3	**Fatalities (Fa)**
Description	Percentage of fatalities measures the number of work-related fatalities relatively to the total number of work-related injuries.
Equation	$Fa = \frac{Number\ of\ work\ related\ fatalities}{Number\ of\ work-related\ injuries}\ x\ 100$
Range/Ranking	0% to 5% 100% (high) >5% to 10% 80% (medium) >10% 60% (low)
Trend	The lower, the better
Justification	Based on sustainability reports: EDP (EDP, 2015).

The ranking was defined in three levels of performance. A high performance will be when the fatalities ranges from 0% to 5%, therefore, the trend will be the lower the better.

5.1.1.3.3 Training and Development

Within the Training and Development (Soc 3), three descriptive indicators were identified among the three disclosures included in the topic-specific GRI 404: Training and Education (GRI, 2016), which were:

1) Budget in training and development (Soc 3.1);
2) Training and development hours (Soc 3.2);
3) Employees engagement (Soc 3.3).

These three descriptive indicators were considered to aggregate the essential information within this key indicator, depicted in in Appendix G, Table 78. Equation 23 presents its calculation.

$$Soc\ 3 = \frac{Soc\ 3.1 + Soc\ 3.2 + Soc\ 3.3}{3}$$

Equation 23 - Training and development formula

The budget in training and development (Soc 3.1), presented in Table 36, measures the proportion of the company investment in training and development relative to the total amount of revenues (in €). It gives an insight about the company's commitment in developing and training its employees.

Table 36 - Budget in training and development (Soc 3.1) indicator

Soc 3.1	**Budget in training and development (Btd)**
Description	Percentage of budget in training and development measures the proportion of the company investment in training and development relative to the total amount of revenues (in €).
Equation	$Btd = \frac{Investment\ in\ training\ and\ development}{Total\ amount\ of\ revenus}\ x\ 100$
Range/Ranking	0% to 0.02% — 60% (low) >0.02% to 0.5% — 80% (medium) >0.5% — 100% (high)
Trend	The higher, the better
Justification	Based on sustainability reports: Galp (Galp, 2018); EDP (EDP, 2018) and Bosch (Bosch, 2016).

Data was searched in sustainability reports, so as to define a rational ranking for. In the 2018 sustainability report, Galp had 0.02% of investment in training and development (Galp, 2018). In 2018 report from EDP the investment was 0.03% (EDP, 2018). The Bosch reported a value of 0.17% (Bosch, 2016).

The rankings were defined in three level of performance, as depicted in Table 36. The indicator trend will be better as higher the value is.

Table 37 presents the training and development hours (Soc 3.2). It measures the proportion of total number of training and development hours of employees relative to the total number of working hours. As the Soc 3.1, it gives an insight about the company's commitment in developing and training its employees.

Aiming to define a rational ranking, data was searched in sustainability reports. In 2018 sustainability report, Galp had 0.87% of training and development hours (Galp, 2018). EDP had 0.01% (EDP, 2018). The company Lameirinho had 0.4% (Lameirinho, 2018).

Table 37 - Training and development hours (Soc 3.2) indicator

Soc 3.2	**Training and development hours (Tdh)**
Description	Percentage of training and development hours measures the proportion of total number of training and development hours of employees relative to the total number of working hours.
Equation	$$Tdh = \frac{Total\ number\ of\ training\ and\ development\ hours}{Total\ number\ of\ working\ hours}\ x\ 100$$
Range/Ranking	0% to 2% 60% (low) >2% to 4% 80% (medium) >4% 100% (high)
Trend	The higher, the better
Justification	Based on sustainability reports: Galp (Galp, 2018); EDP (EDP, 2018); Lameirinho (Lameirinho, 2018) and Guerreiro (2019a).

Also, employees are entitled to a minimum of 35 hours of continuous training in a year (Guerreiro, 2019a). Thus, this implies that the minimum percentage of training in a year will be 2%, considering that 35 hours are equivalent to 1 week in 48 weeks of work, with 4 weeks of annual vacation. Given this information, the ranking was defined, as depicted in Table 37. The indicator trend will be better as higher the value is.

Table 38 depicted the employees' engagement (Soc 3.3). It evaluates the employees' satisfaction, motivation and commitment with company's values. This percentage will be attained in the company's questionnaire or other similar assessing method. The indicator trend will be the higher the better.

Table 38 - Employees engagement (Soc 3.3) indicator

Soc 3.3	**Employees' engagement (Ee)**
Description	This value is obtained by a questionnaire (or similar) assessing the employees' satisfaction, motivation and commitment with company's values.
Equation	__
Range/Ranking	Min: 0% Max: 100%
Trend	The higher, the better
Justification	Percentage obtained in the company questionnaire (or similar).

5.1.1.3.4 Local Communities

Within the Local Communities (Soc 4), two descriptive indicators were identified among the two disclosures included in the topic-specific GRI 413: Local Communities (GRI, 2016), which were:

1) Employees engaged in volunteering (Soc 4.1);
2) Donations (Soc 4.2).

It was considered that these two descriptive indicators combined the essential information within this key indicator, presented in in Appendix G, Table 79. Equation 24 depicts its calculation.

$$Soc\ 5 = \frac{Soc\ 5.1 + Soc\ 5.2}{2}$$

Equation 24 - Local communities' formula

The employees engaged in volunteering (Soc 4.1), presented in Table 39, measures the proportion of employees engaged in volunteering relative to the total number of employees in the company. It gives insight about the employees' commitment in contributing for the local community.

Table 39 - Employees engaged in volunteering (Soc 4.1) indicator

Soc 4.1	**Employees engaged in volunteering (Eeiv)**
Description	Percentage employees engaged in volunteering measures the proportion of employees engaged in volunteering relative to the total number of employees in the company.
Equation	$Eeiv = \frac{Number\ of\ employees\ in\ volunteering}{Total\ number\ of\ employees}\ x\ 100$
Range/Ranking	0% to 10% 60% (low) >10% to 25% 80% (medium) >25% 100% (high)
Trend	The higher, the better
Justification	Based on sustainability reports: Galp (Galp, 2018) and EDP (EDP, 2018).

In an attempt to define a reasonable ranking, data was searched in sustainability reports. In 2018, Galp had 24.92% of employees engaged in volunteering (Galp, 2018). EDP had an engagement of 20% (EDP, 2018). In view of this, the ranking was defined, as presented in Table 39. A high performance will be an engagement higher than 25%, thus the trend will be better as higher the value is.

Table 40 portrays the donations (Soc 4.2). It measures the proportion of total amount of donations relative to the total amount of revenues (in €). This percentage gives insight about the company commitment in contributing for its local community.

Table 40 - Donations (Soc 4.2) indicator

Soc 4.2	**Donations (Do)**
Description	Percentage of donations measures the proportion of total amount of donations relative to the total amount of revenues (in €).
Equation	$Do = \frac{Total\ donations}{Total\ amount\ of\ revenues}\ x\ 100$
Range/Ranking	0% to 0.01% 60% (low) >0.01% to 0.2% 80% (medium) >0.2% 100% (high)
Trend	The higher, the better
Justification	Based on sustainability reports: Galp (Galp, 2018); EDP (EDP, 2018); Navigator (Navigator, 2017); Lameirinho (Lameirinho, 2018); and Sonae (Sonae, 2018).

Data was searched in sustainability reports, to define a reasonable ranking. In 2018, Galp gave 0.01% to donations (Galp, 2018), EDP gave 0.17% (EDP, 2018) and Navigator gave 0.12% (Navigator, 2017). Additionally, Lameirinho gave 0.2% (Lameirinho, 2018) and Sonae gave 0.13% (Sonae, 2018). In view of this, the ranking was defined, as presented in Table 40. A high performance will be a donations value higher than 0.02%, therefore the trend will be better as higher the value is.

5.1.1.3.5 Socioeconomic Compliance

Within the Socioeconomic compliance (Soc 5) key indicator, one descriptive indicators was identified among the single disclosure included in the topic-specific GRI 419: Socioeconomic compliance (GRI, 2016), which was Socioeconomic compliance (Soc 5.1). This descriptive indicator gathered the fundamental information within this key indicator. It is presented in Appendix G, Table 80. Equation 25 presents it:

$$Soc\ 5 = Soc\ 5.1$$

Equation 25 - Socioeconomic compliance formula

The socioeconomic compliance (Soc 5.1), is presented in Table 41. It measures the number of socioeconomic non-compliance cases, in a year. Socioeconomic compliance comprises the non-compliance cases with laws and regulations in the social and economic area. It considers the significant fines and non-monetary sanctions, along with, the cases carried out by dispute resolution mechanisms (GRI, 2016).

Table 41 - Socioeconomic compliance (Soc 5.1) indicator

Soc 5.1	**Socioeconomic compliance (Sec)**
Description	Socioeconomic compliance measures the number of socioeconomic non-compliance cases, in a year.
Equation	$Sec = Number\ of\ socioeconomic\ non-compliance\ cases$
Range/Ranking	0 to 2 socioeconomic non-compliance cases 100% (high) >2 to 5 socioeconomic non-compliance cases 80% (medium) >5 socioeconomic non-compliance cases 60% (low)
Trend	The lower, the better
Justification	Socioeconomic compliance includes the non-compliance cases with laws and regulations in the social and economic area. It considers the significant fines and non-monetary sanctions, as well as, the cases brought through dispute resolution mechanisms (GRI, 2016).

In order to define a reasonable ranking, this indicator was grounded on the fact that each company purpose is to have a good image in the market, as a transparent and reputable company, reducing its impact in the local community in which operates. The ranking was defined in three levels of performance, as presented in Table 41. The low performance will be when the number of non-compliance cases is higher than 5 non-compliance cases. Thus, the trend will be the lower the better.

5.1.2 OEE strand

The Overall Equipment Effectiveness (OEE) strand is calculated as a product of the availability, performance and quality, as already reviewed in section 2.1.5 of chapter 2. The Equation 26 presents the OEE strand formula.

$$OEE\ (\%) = Availability\ (\%)\ x\ Performance\ (\%)\ x\ Quality\ (\%)$$

Equation 26 - Overall Equipment Effectiveness strand

The OEE reveals the most important sources of productivity losses (called the six big losses) within three primary categories, and refines them into metrics that provide an instrument for measuring where the organization stands, and how to improve. The OEE objective is to identify these losses and improve them. Each component has the same degree of importance, i.e. the same weight, within the OEE strand.

The OEE provides a benchmark and/or baseline and a way to track progress in waste elimination within manufacturing processes. An OEE percentage of 100% means perfect production, which translates into manufacturing of only good parts, as fast as possible, with no down time.

Consequently, besides being a performance indicator, the OEE is also used for capacity planning, process control, process improvement and calculation of production losses costs, highlighting the seven lean wastes (Ohno, 1988). Therefore, the OEE was selected for being considered a good lean indicator, since it is an appropriate measure for manufacturing organizations. Furthermore, OEE aims to identify the six big losses within manufacturing systems and can be used either at machine, process line or factory levels (Bamber et al., 2003). According to Zackrisson et al. (2017) the OEE, and specially its constituent parts, are examples of indicators related to sustainability, which may be valuable at the shop floor level (Zackrisson et al., 2017). In view of the foregoing, this was the reason why the OEE was chosen to account for the lean part in the BOPSE indicator. The OEE is described in section 2.1.5.

5.2 Discussion with experts

After decision of indicators for the model, a discussion with experts was necessary to construct it. The experts were chosen from areas related with indicators comprised in the model. The experts' discussion was made in two stages, through several meetings held to debate and analyse the relevance of the key and the descriptive indicators developed for the model, described in section 5.1. The meetings were held in University of Minho. The years of experience and the meeting year are in Table 42.

Table 42 - Experts meetings characterization

Experts area	Years of experience	When
Economic	11	2018
Mathematics	10	2018
Waste valorisation	15	2018
Social, health and safety	20	2019
Lean-green and sustainability	20	2018; 2019
Waste recovery	17	2019

In the first stage consultation, the purpose was to analyse and discuss which descriptive indicators should be comprised within each key indicator, in order to evaluate its suitability and significance. The purpose and main results from the meetings are in Table 43.

After these meetings, changes were made to the BOPSE descriptive indicators to incorporate the main conclusions achieved.

Table 43 - Meetings purpose and conclusions from first consultation

Expert area	Why	Main results
Economic	To analyse which key and descriptive indicators should comprise the BOPSE economic dimension to characterize it and discuss the calculation formulas.	Key indicators were considered suitable to characterize the economic dimension. For the selected descriptive indicators involving monetary values, it was concluded that they should be compared to the same denominator: the revenues value.
Lean-green and Sustainability	To analyse which key and descriptive indicators should comprise the BOPSE environmental dimension to characterize it and discuss the calculation formulas.	Key indicators were considered suitable to characterize the environmental dimension. Some calculation formulas of descriptive indicators were changed to better characterize them. It was concluded that rankings had to be defined for descriptive indicators in order to normalize and assure their comparability.
Social, Health and Safety	To analyse which key and descriptive indicators should comprise the BOPSE social dimension to characterize it and discuss the calculation formulas.	Key indicators were considered suitable to characterize the social dimension. Some calculation formulas of descriptive indicators were changed to better characterize them.
Mathematics	To analyse the calculation of the BOPSE model, if should be calculated by the arithmetic mean of the sustainability and OEE strands or if should be a product.	The conclusion was that the BOPSE should be calculated by an arithmetic mean. The reason was because sustainability and OEE strands were already a product. If the BOPSE was also a product, it will be too demanding and severe for companies.
Waste valorisation	To analyse the suitability of the BOPSE model and the descriptive indicators selected, considering the knowledge in carrying out sustainability reports.	Descriptive indicators were considered essential and relevant to effectively characterize the BOPSE.

For the second stage consultation, which happened after the real cases application, the experts consulted were from lean-green, sustainability, and waste recovery areas. The purpose and main results from the meetings are in Table 44.

Table 44 - Meetings purpose and conclusions from second stage consultation

Expert area	Why	Main results
Lean-Green and Sustainability	Discuss the key and descriptive indicators selected for each sustainability dimension. To discuss the defined rankings for the descriptive indicators, attending the performance levels previously established.	The selected key indicators were considered suitable to characterize the sustainability strand. Within the descriptive indicators, 3 were eliminated and 1 was included attending to its relevance and meaning. The model was reduced from 34 to 32 descriptive indicators. Indicators eliminated: reclaimed products in Materials (Env 1), indirect GHG emissions in Emissions (Env 5) and water discharge in Effluents and Waste (Env 6). One descriptive indicator was included in Water (Env 3): Net water needs reduction. For 27 descriptive indicators were defined rankings in order to normalize and assure comparability between the indicators (in Appendix H).
Waste recovery	Analyse the suitability of BOPSE and descriptive indicators selected, considering the knowledge in the environmental and waste area.	The selected descriptive indicators were considered essential and relevant indicators to effectively characterize the BOPSE. However, it was pointed out that the BOPSE had 34 descriptive indicators, and that the data gathering requirements could be difficult for companies that had never prepared a sustainability report.

Then, considering the above mentioned, the BOPSE final version presented in section 5.1 was established.

5.3 BOPSE indicator test

The BOPSE indicator was tested through sustainability reports and through sensitivity and feasibility tests, presented in the following sections.

5.3.1 Sustainability reports

The application of the BOPSE indicator to a company was issued as an assignment of Eco-Efficient Industrial Production course unit from the Masters in Industrial Engineering, in the 2018/2019 academic year.

Six groups were formed and each chose a company. The teams fetched the respective sustainability report or contacted the company directly. The team tested the BOPSE indicator with the available data (see Table 45). Two groups (from company 3 and 5) went to the company to know more about the sustainability report. Other groups have interacted with the companies in order to clarify aspects reported on the sustainability report. One of the students worked in company 5, which has facilitated data gathering. The data on environmental descriptive indicators, were harder to achieve.

Only two companies (out of six) calculated the OEE. OEE was estimated at 98.6% for the company 3. The OEE of company 6 was estimated at 48.5%. This company pertained to the service sector. The BOPSE was calculated and the values obtained were 52% and 28% for companies 3 and 6, respectively.

Table 45 - Results on the sustainability dimension (six companies)

Company / Dimension	1	2	3	4	5	6
Economic (%)	60	40	29	68	48	59
Environmental (%)	19	39	61	50	49	35
Social (%)	14	13	31	19	40	32
Sustainability (%)	**2**	**2**	**5**	**7**	**9**	**7**

The main conclusions from this work were that some descriptive indicators needed to be adjusted, namely the social ones. For these, there was the need to adjust the calculation formula. Also, it was necessary to define differential rankings, in order to normalize and enable comparisons to be made among companies. Another result from the study was that OEE data is more readily available in companies, which are lean advocates, namely companies working within the automotive sector.

To assure BOPSE calculation, it was important to choose a sector where the OEE was already established and used. Therefore, this reinforced the decision to select companies from the automotive sector.

5.3.2 Sensitivity and feasibility tests

Tests were performed to evaluate the sensitivity and feasibility of the BOPSE indicator. These tests had in mind the performance intervals defined for the differential rankings, as presented in Appendix H, Table 81. The objective was to observe how each key indicator, dimension and sustainability and OEE strands were impacted by using specific data at the descriptive indicators level. Additionally, its impact on the BOPSE calculation. Table 46 presents the indicative level of performance for most descriptive indicators.

Table 46 - Settled level of performance

Performance	Descriptive indicator level (%)
Low	60
Medium	80
High	100

To perform the tests, values were assigned to each descriptive indicator, namely a low (60%), a medium (80%) and a high performance (100%) level. The respective key indicators were then estimated, which resulted in the corresponding level of performance. The same was applied at the dimension level, with credible results. This meant that the calculation and values were providing reliable results.

Similarly, the OEE components were settled for a low (60%), a medium low (80%), and a high performance (100%). However, at the strand level, low performance levels of its dimensions, results in a past delay of performance. As can be seen, in Table 47, when the sustainability dimensions are set for low (60%) to medium (80%) performance, sustainability performance decreases substantially, assuming values of 51%

and 22%, respectively. With OEE settled for each performance level, the BOPSE was calculated. The BOPSE values reflected this effect, and for the medium performance the value was 66% and for the low one, the value was 41%.

Table 47 - Tests summary for high, medium and low performance levels for main dimensions of BOPSE

BOPSE elements	High performance (%)	Medium performance (%)	Low performance (%)
OEE (A*P*Q)	**100**	**80**	**60**
Availability (A)	100	93	84
Performance (P)	100	93	84
Quality (Q)	100	93	84
Sustainability (Eco*Env*Soc)	100	51	22
Economic (Eco)	100	80	60
Environmental (Env)	100	80	60
Social (Soc)	100	80	60
BOPSE = (Sustainability + OEE)/2	**100**	**66**	**41**

Additionally, some tests were performed considering the OEE value for a "world class firm", which according to Nakajima (1988), cited in Jonsson & Lesshammar (1999) should be higher than 84%, since the availability would be higher than 90%, the performance higher than 95% and the quality higher than 99%. Table 48 presents the results obtained considering an OEE of 85%.

Table 48 - Tests summary for high, medium and low performance levels, with OEE for world class firms

BOPSE elements	High performance (%)	Medium performance (%)	Low performance (%)
OEE (A*P*Q)	**85**	**85**	**85**
Availability (A)	90	90	90
Performance (P)	95	95	95
Quality (Q)	99	99	99
Sustainability (Eco*Env*Soc)	100	51	22
Economic (Eco)	100	80	60
Environmental (Env)	100	80	60
Social (Soc)	100	80	60
BOPSE = (Sustainability + OEE)/2	**92**	**68**	**53**

A world class firm (OEE=85%) with a low sustainability performance (22%) is expected to have a BOPSE of about 53%. If its sustainability performance is medium, then the BOPSE is likely to amount to 68%. A top sustainability performance firm with a high sustainability performance is likely to exhibit a BOPSE of about 92%.

Then, tests were performed considering the OEE value for a typical manufacturing firm, which according to Vorne Industries (2008) will be 60%, the worldwide average rate. Table 49 presents the results found considering an OEE of 60%.

Table 49 - Tests summary for high, medium and low performance levels, with OEE for typical manufacturing

BOPSE elements	High performance (%)	Medium performance (%)	Low performance (%)
OEE (A*P*Q)	**60**	**60**	**60**
Sustainability (Eco*Env*Soc)	100	51	22
BOPSE = (Sustainability + OEE)/2	**80**	**56**	**41**

A typical manufacturing firm (OEE=60%) with a low sustainability performance (S=22%) is expected to have a BOPSE of about 41%. Under a medium sustainability performance (S=51%) the BOPSE is expected to rise to about 56%. A top sustainability score (S=100%) will shift the BOPSE to about 80%.

Tests were also performed considering a low OEE performance (OEE=40%). Table 50 portrays the results obtained considering an OEE of 40%.

Table 50 - Tests summary for high, medium and low performance levels, with a low OEE performance

BOPSE elements	High performance (%)	Medium performance (%)	Low performance (%)
OEE (A*P*Q)	**40**	**40**	**40**
Sustainability (Eco*Env*Soc)	100	51	22
BOPSE = (Sustainability + OEE)/2	**70**	**46**	**31**

It is not uncommon that manufacturing firms have an OEE of about 40%. Those companies are probably starting a lean journey towards improved operations. Firms under such circumstances and holding a low sustainability performance (S=22%) will likely hold a BOPSE of about 31% and it will grow to about 46% and 70% if they, respectively, hold a medium or top sustainability performance.

Furthermore, some tests were performed considering the possibility of a company not being able to provide data on some descriptive indicators. In this circumstance, the descriptive indicator was accounted non-applicable (na). When this happen, i.e. the descriptive indicator is not considered, the corresponding key indicator equation is, automatically, readjusted to the existing descriptive.

Table 51 illustrates one such case. On the right side of the table Soc 1.4 was not possible to estimate, correspond, Soc 1 was averaged by ignoring Soc 1.4 which has resulted in a score of 69%. When compared to initial situation (table left side) of 71%.

Table 51 - Calculation example for Employment key indicator (Soc 1), considering all data provided (table left side) and partly provided data (table right side)

All data provided		Partly provided data	
Employment (Soc 1)	**71%**	**Employment (Soc 1)**	**69%**
Number of effective contracted employees	557	Number of effective contracted employees	557
Total number of employees	830	Total number of employees	830
Effective contracted employees (Soc 1.1)	67%	**Effective contracted employees (Soc 1.1)**	67%
Number of female employees	347	Number of female employees	347
Total number of employees	830	Total number of employees	830
Female employees (Soc 1.2)	80%	**Female employees (Soc 1.2)**	80%
Number of women in management	1	Number of women in management	1
Total number of employees in management	11	Total number of employees in management	11
Women in management (Soc 1.3)	60%	**Women in management (Soc 1.3)**	60%
Number employees who left company	198	Number employees who left company	na
Total number of employees	830	Total number of employees	830
Employee turnover (Soc 1.4)	76%	**Employee turnover (Soc 1.4)**	na

It is important to note, however, that a maximum number of omitted data must be defined in order to keep the BOPSE indicator valid.

5.4 Discussion

From the literature review on lean-green models, presented in section 2.4, it was found that there was a gap on research concerning indicators on lean-green models, and that they should be simple and feasible for companies to use. Therefore, during the model development process, several facts were taken into account: that it should be straightforward, easy to use and the number of indicators comprised should be suitable, essential and pertinent. The ultimate purpose was that BOPSE model should be relevant and properly characterized.

In a first version of the model, 34 descriptive indicators were identified. After some meetings with experts, as described in section 5.2, the BOPSE model was adjusted to incorporate the foremost conclusions realised:

1) Evaluation of each key indicator relevance: they were considered to be the required and suitable;
2) Evaluation of each descriptive indicator importance: they were considered to be the required and suitable;
3) Some environmental and social calculation formulas were changed to better characterize the indicator;
4) Rankings were defined in order to ensure indicators comparability;
5) Calculation of BOPSE: an arithmetic mean of sustainability and OEE;

6) Evaluation of BOPSE suitability: BOPSE key and descriptive indicators were considered essential to characterize it.

The BOPSE was also tested through sustainability reports and through sensitivity and feasibility tests. The aim was to assess the BOPSE applicability and understand the effect that the performance intervals for the rankings defined had in the key indicators, dimensions, strands and, in the BOPSE itself.

For the rankings' definition, it was hard and difficult to find information in the proper format. It was necessary to search for data concerning the same descriptive indicator in different sources. Rankings were defined for descriptive indicators to normalize them, guaranteeing their comparability.

In the BOPSE model design stage, the incorporation of more additional indicators was considered. Some of these were ruled-out based on reasoning that they would translate into a model much more complex to understand and more laborious to use. During this design, a reflection was made on whether the sustainability and OEE strands should have different weightings. This was put aside, because it was decided that they should have equal weight in order to provide a fair assessment and without favouring any of the strands. Additionally, the possibility of establishing different weights for the sustainability dimensions was debated. In the end, it was decided to emulate the structure of the formula established for the OEE, so as to keep it coherent and simple. The BOPSE is a simple arithmetic mean of sustainability and OEE, that can be used to provide the real status of a company.

The BOPSE model was compared against the four assessment models, previously identified in section 2.4.4.1. Criteria used to compare the models were the identification of which concepts or methods were grounded on and the KPI and key environmental performance indicators (KEPI) used, as presented in Table 52.

Table 52 - Assessment models characterization and comparison

Authors/Designation	**Year**	**Based on:**	**Number of KPI & KEPI**
Reis et al. (2018)/ LGS	2018	CMMI	20 performance indicators (10 lean and 10 green)
Farias et al. (2019 b)/ LG_{index}	2019	ANP	6 operational, 5 environmental (3 repeated)
Carvalho et al. (2019)/ L_{index} & G_{index}	2019	GLPI and PCA	Lean index (9 variables), green index (5 variables)
Amrina & Zagloel (2019)/ ESLP	2019	3 SD pillars	12 eco-socio-lean dimensions, 3 performance metrics, and 4 improvement strategies, to achieve 2 objectives
Abreu et al. (2019)/ BOPSE	2019	GRI and OEE	18 key indicators, 32 descriptive indicators

The model from Reis et al. (2018) was applied on a set of six specialty coffee producing companies, in Colombia. This model was based on the Capability Maturity Model Integration (CMMI). The model was divided in basic and variable concepts, either independent of the industrial sector, or adapted according to the industrial sector. After calculating the 20 maturity assessment metrics (10 lean and 10 green), the lean and green maturity was calculated in three different perspectives. Then, the average of these provided the organization overall maturity level.

The model did not mention any of the three pillars of sustainable development, nor the eco-efficiency concept. Regarding the BOPSE model, the model of Reis et al. (2018) did not report any standard indicators like the OEE or the GRI. However, some lean and green indicators considered fell within the scope of some GRI topic-specific disclosures, for example materials, energy and water consumption and emissions.

Farias et al. (2019 b) labelled their model Lean-Green index (LGindex). The model developed a lean and green performance assessment framework and provided a lean-green index to evaluate, in an integrated method, the lean and green systems. For the theoretical framework operationalization, the Analytical Network Process (ANP) was used. The model is composed by 11 key performance indicators, six operational and five environmental. Though three of the environmental performance indicators were repeated from the ones in the operational side. The model did not reference the three pillars of sustainable development, nor the eco-efficiency paradigm. Concerning the BOPSE model, the model of Farias et al. (2019 b) did not describe any standard indicators like the OEE or the GRI.

Carvalho et al. (2019) proposed two indexes, the lean index and the green index, within the supply chain. The lean and green composite indexes were composed by 14 key performance indicators. For the lean composite index were selected nine practices and for the green composite index five. These indexes were based on the Green Logistics Performance Index (GLPI) (Lau, 2011) and Principal Component Analysis (PCA) methodology. The index data was based on European Manufacturing Survey 2012 in Portugal. Factorial analysis was applied to reach the expressions of the indexes. Then, the indexes were assessed. This model did not mention the three pillars of sustainable development, nor the eco-efficiency concept. Relating to the BOPSE model, this model did not state any standard indicators like the OEE or the GRI.

To conclude, Amrina and Zagloel (2019) developed a conceptual model of eco-socio-lean production (ESLP), as an input-process-output framework, grounded on green-lean business objectives, resources, production process, improvement techniques, and output measurements. The model studied four dimensions: lean, environment, economy and social. It includes 12 eco-socio-lean dimensions, three performance metrics, four improvement strategies to realise two goals: reduce total cost and increase revenue. This model mentioned the three pillars of sustainable development. However, the eco-efficiency concept was not addressed. The model did not refer to any standard indicators like the OEE or the GRI.

The BOPSE model is grounded on established standard indicators, namely the OEE for the lean paradigm and some GRI indicators for the green paradigm. It interweaves the three pillars of sustainable development, and thus the eco-efficiency elements, to assess the sustainability performance and the production losses to assess the operational performance. The proposed version of the BOPSE model is seamlessly less intricate, which, hopefully, will translate to a wider use and dissemination. The model is tentatively simple enough for smaller companies, i.e. SME, to find it practical and economical to use. The model also incorporates a great deal of familiar concepts and indicators, such as those incorporated in OEE and GRI, that should make it easier to understand and implement, given that they may already exist in the company.

6 Validation of the BOPSE Model

This chapter describes the process undertaken for the model validation. This validation was made through its application in three real cases.

6.1 Deployment to case studies

It was considered necessary to validate the BOPSE indicator in Portuguese manufacturing companies. For this validation, the case study protocol, defined in section 3.2, was applied. Three case studies were used, in order to test the BOPSE indicator in a real context, and evaluate its significance, operationally and applicability. The case studies' feedback was essential to analyse the relevance of key and descriptive indicators. The BOPSE general suitability was also analysed aiming its consolidation.

As already mentioned in section 3.2.2, the case studies were selected among companies pertaining the automotive sector. This sector was chosen because it belongs to an industry that provides jobs for 12 million people, accounting for four percent (4%) of the European Union's GDP and representing the largest private investor in research and development (R&D), with more than €50 billion invested annually (European Commission, 2019).

In Portugal, the auto sector (including car and component production) represents, as well, four percent (4%) of total GDP in a total of 29 000 companies. It employs 124 000 direct jobs and represents a business volume of €23.7 thousand million. This sector is responsible for 11% of total exports (INE, 2019b).

In 2018 and within this activity sector, the weight of automotive components industry in national economy represented eight percent (8%) of the manufacturing sector, providing 55 000 jobs, in 235 companies and accounting a business volume of €11.3 thousand million (AFIA, 2019).

Bearing in mind all these facts and reported by AFIA (2019), the motivation to select the case studies among this activity sector was grounded on the following circumstances:

1) Components industry represented almost half of business volume of the automotive sector;
2) In 2018, almost half of the companies were located north of the Douro River;
3) The fact that OEE calculation is well established in this sector.

The procedure used to obtain the BOPSE indicator in the case studies was:

1) Collect the data from the companies for the descriptive indicators they had;
2) Insert the data in the excel sheet;

3) Calculate the 15 key indicators;
4) Calculate the three sustainability dimensions;
5) Calculate the sustainability strand (product of its three dimensions);
6) Calculate the three components of OEE;
7) Calculate OEE (product of its three components);
8) Calculate BOPSE.

It is not obligatory to calculate sustainability and then OEE, it could be calculated in inverse order.

6.1.1 Case studies' characterization

This section characterizes briefly the three case studies selected, describing some important facts related with them. The case studies were named A, B and C due to the confidentiality agreement, and are all companies from the North of Portugal.

Case study A belongs to a multinational group that is one of the world's largest producers of automotive components, with 67 factories in 19 countries. The group has a total of 30 000 employees, approximately. The group supplies every major car manufacturer. Its 2018 sales were 10.5 billion dollars. The company published a 2018-2019 sustainability report, that depicts its results since the baseline year of 2015 till 2017.

Case study B belongs to a group that manufactures car seat covers for major market companies such as Audi, VW, BMW and Porsche. The group has over 6 000 employees, spread over four countries, and in 2018 its sales achieved €348 million.

Case study C belongs to a group that is a global automotive supplier, with 47 locations in the world. The group has more than 7 000 employees and four technology centres, in Portugal, Germany and USA. In 2018 its revenues were €831 million.

Table 53 presents a summary of the various features that characterize the companies: foundation year; activity sector; product type; national or multinational company; main markets; company dimension; total number of employees and certifications held. These data were obtained through documentation consultation and interviews.

Table 53 - Characterization of the case studies A, B and C

Characteristics	Case study A	Case study B	Case study C
Foundation year	2014 (in Portugal)	1988	1980
Activity sector	Automotive components and parts supplier	Automotive components	Automotive components
Product type	Motor vehicle components	Car seat covers	Chassis, powertrain and body in white
Multinational	Yes	Yes	Yes
Main markets	Europe, America and others	Europe and America	Europe, Asia, Africa and North and South America
Company size	Big	Big	Big
Employees nr.	830	3022	257
Certifications	ISO 9001, ISO/TS 16949 and ISO 14001	ISO/TS 16949 and ISO 14001	ISO/TS 16949 and ISO 14001

6.1.2 Case study A

The first contact with case study A was with the Product Manager. The visit to the company facilities took place in March 2018. The goal was to meet the company, its production process and products. This study was presented and the company showed availability to participate in it. After visiting the plant and the shop floor it was agreed to schedule a future meeting. This meeting was scheduled in October with the previous Product Manager. When the meeting happened, the Product Manager had another position - Senior Operations Manager.

In this meeting, the study's goals and the BOPSE indicator were presented and detailed. A summary of the questionnaire "Lean Production contributions for company's sustainability" results, see chapter 4, was also presented. The goal was to give an insight about companies' knowledge concerning the lean model and its links with sustainability.

At the end of the meeting, it was agreed to send an excel data sheet to collect the data required for the indicator's calculation. The data sheet was sent and, afterwards the company was diligent and sent its data at the end of November. Based on confidentiality requirements, the original data for each descriptive indicator is not presented.

Having received the data, the descriptive indicators were calculated considering the differential rankings defined in section 5.1, then the key indicators were calculated. The sustainability and OEE strands were then calculated, and the BOPSE indicator estimated. Table 54 presents the sustainability results attained for case study A.

It is important to mention that within the sustainability strand, the social dimension with 89% was the one with the highest value. Being followed by the environmental and economic dimensions, with 77% each. Hence, the value for social dimension was well above the medium performance (80%). The sustainability strand was 53%, i.e. slightly better than the reference value for medium performance firms (51%) (Table 47 and Table 48, in section 5.3.2). The reported OEE was 78% (A=82%; P=97% and Q=98%).

Table 54 - Sustainability calculation for case study A

SUSTAINABILITY			
ECONOMIC (5)	**77%**	**ENVIRONMENTAL (14)**	**77%**
Economic Performance (Eco. 1)	90%	**Materials (Env. 1)**	80%
Net profit margin (Eco 1.1)	100%	Materials used (Env 1.1)	na
Research, Development and Innovation (RDI) (Eco 1.2)	80%	Recycled input materials used (Env 1.2)	80%
Market Presence (Eco. 2)	80%	**Energy (Env. 2)**	79%
Standard entry level wage (Eco 2.1)	80%	Useful energy (Env 2.1)	99%
Local senior management (Eco 2.2)	80%	Renewable energy (Env 2.2)	60%
Procurement (Eco. 3)	60%	**Water (Env. 3)**	60%
Spending on local suppliers (in €) (Eco 3.1)	60%	Water used (Env 3.1)	na
SOCIAL (13)	**89%**	Recycled and reused water (Env 3.2)	60%
Employment (Soc. 1)	71%	Net water needs reduction (Env 3.3)	na
Effective contracted employees (Soc 1.1)	67%	**Biodiversity (Env. 4)**	60%
Female employees (Soc 1.2)	80%	Biodiversity Investment (Env 4.1)	60%
Women in management (Soc 1.3)	60%	**Emissions (Env. 5)**	80%
Employee turnover (Soc 1.4)	76%	GHG emissions intensity (Env 5.1)	100%
Occupational Health and Safety (Soc. 2)	100%	GHG emissions reduction (Env 5.2)	60%
Absenteeism (Soc 2.1)	100%	**Effluents and Waste (Env. 6)**	80%
Accidents rate (Soc 2.2)	100%	Spills (Env 6.1)	100%
Fatalities (Soc 2.3)	100%	Hazardous industrial residues (Env 6.2)	60%
Training and development (Soc. 3)	84%	Recycled residues (Env 6.3)	80%
Budget in training and development (Soc 3.1)	80%	**Environmental Compliance (Env.7)**	100%
Training and development (Soc 3.2)	100%	Environmental compliance (Env 7.1)	100%
Employees engagement (Soc 3.3)	71%		
Local Communities/Society (Soc. 4)	90%		
Employees engaged in volunteering (Soc 4.1)	100%		
Donations (Soc 4.2)	80%		
Socioeconomic Compliance (Soc.5)	100%		
Socioeconomic compliance (Soc 5.1)	100%		

The BOPSE calculation, amounted to 65%, as shown in Figure 22. This result positions case study A just below the medium performance mark (66%), as shown in Table 47, in section 5.3.2. However, this BOPSE value was only 3% below the BOPSE obtained for medium performance in the second tests summary (see Table 48), which was 68%, and that resulted from a world class firm's OEE of 85% (Jonsson & Lesshammar, 1999).

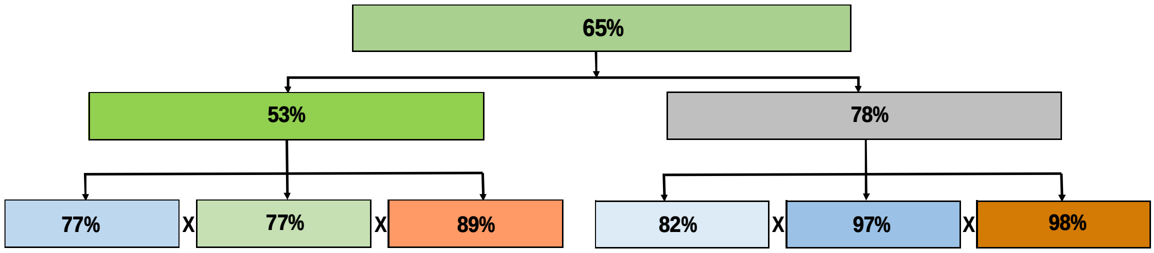

Figure 22 - BOPSE calculation and result for case study A

Comparing the OEE values for case study A with the ones of a world class firm, it was seen that availability value was 8% below, the performance 2% above and, finally, the quality 1% below, which gave an OEE of 78%.

In Table 54 there are three non-applicable (na) descriptive indicators, being the reason for this reported as:

1) "Materials used": the company could not account the total materials incorporated in final product, relative to the total input materials purchased;
2) "Water used": the company could not provide data on water consumption in the factory, relative to the total water consumption. It had only a single water counter for the all company. Thus, production and administrative areas could not be accounted for separately;
3) "Net water needs reduction": as it was a new introduced descriptive indicator, it was not possible to obtain the respective value.

6.1.3 Case study B

The first contact with case study B took place in November 2018, by email. The company agreed to participate and provided the contact of the Corporate Operations Manager. A meeting was scheduled in January 2019. The study's goals and the BOPSE indicator were presented and explained. Likewise, a summary of the questionnaire "Lean Production contributions for company's sustainability" and respective results was also presented to case study A.

After the meeting, an excel data sheet was sent. The data sheet was returned by March 2019.

The descriptive indicators were then accounted based on the differential rankings presented in section 5.1. The key indicators and the strands were accounted, and the BOPSE indicator estimated. Table 55 presents the results for case study B. The social dimension held the highest value, accounting for 79%, followed by the environmental dimension with 73%. The economic dimension was the one that accounted the lowest value (70%).

The reported OEE was 51% for case study B (A=75%; P=75%; Q=90%) which indicates that the company still has a way to go regarding the improvement of its operations. In fact, OEE performance was 20% below the respective reference levels, considering a world class firm.

Table 55 - Sustainability calculation for Case study B

SUSTAINABILITY			
ECONOMIC (5)	**70%**	**ENVIRONMENTAL (14)**	**73%**
Economic Performance (Eco. 1)	70%	**Materials (Env. 1)**	na
Net profit margin (Eco 1.1)	80%	Materials used (Env 1.1)	na
Research, Development and Innovation (RDI) (Eco 1.2)	60%	Recycled input materials used (Env 1.2)	na
Market Presence (Eco. 2)	60%	**Energy (Env. 2)**	65%
Standard entry level wage (Eco 2.1)	60%	Useful energy (Env 2.1)	70%
Local senior management (Eco 2.2)	60%	Renewable energy (Env 2.2)	60%
Procurement (Eco. 3)	80%	**Water (Env. 3)**	60%
Spending on local suppliers (in €) (Eco 3.1)	80%	Water used (Env 3.1)	na
SOCIAL (13)	**79%**	Recycled and reused water (Env 3.2)	60%
Employment (Soc. 1)	75%	Net water needs reduction (Env 3.3)	na
Effective contracted employees (Soc 1.1)	69%	**Biodiversity (Env. 4)**	60%
Female employees (Soc 1.2)	100%	Biodiversity Investment (Env 4.1)	60%
Women in management (Soc 1.3)	na	**Emissions (Env. 5)**	100%
Employee turnover (Soc 1.4)	56%	GHG emissions intensity (Env 5.1)	100%
Occupational Health and Safety (Soc. 2)	93%	GHG emissions reduction (Env 5.2)	na
Absenteeism (Soc 2.1)	100%	**Effluents and Waste (Env. 6)**	93%
Accidents rate (Soc 2.2)	80%	Spills (Env 6.1)	100%
Fatalities (Soc 2.3)	100%	Hazardous industrial residues (Env 6.2)	100%
Training and development (Soc. 3)	67%	Recycled residues (Env 6.3)	80%
Budget in training and development (Soc 3.1)	80%	**Environmental Compliance (Env.7)**	60%
Training and development (Soc 3.2)	60%	Environmental compliance (Env 7.1)	60%
Employees engagement (Soc 3.3)	60%		
Local Communities/Society (Soc. 4)	60%		
Employees engaged in volunteering (Soc 4.1)	60%		
Donations (Soc 4.2)	60%		
Socioeconomic Compliance (Soc.5)	100%		
Socioeconomic compliance (Soc 5.1)	100%		

The BOPSE value attained for case study B was 46%, as presented in Figure 23. The overall BOPSE performance was below the medium performance mark (66%).

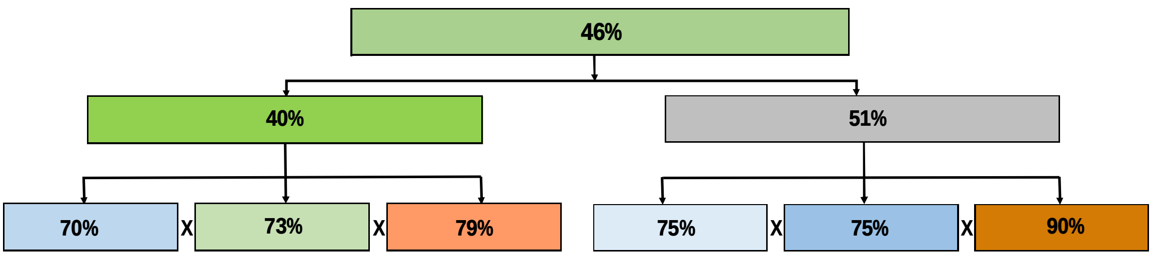

Figure 23 - BOPSE calculation and result for case study B

Table 55 shows six non-applicable (na) descriptive indicators:

1) “Materials used”: the company did not provide the total materials incorporated in final product, neither the total input materials purchased;
2) “Recycled input materials used”: the company did not incorporate recycled input materials in its products, however, as the company did not provide the value for the total input materials purchased, this descriptive indicator could not be accounted;
3) “Water used”: the company did not provide the water consumption in the factory, relatively to the total water consumption, because it accounted only all water consumption;
4) “Net water needs reduction”: as it was a newly introduced descriptive indicator, it was not possible to attain the value;
5) “GHG Emissions reduction”: the company did not provide the GHG emissions for the previous year of the data sent, that would be the 2017 emissions;
6) “Women in management”: the data sent revealed misinterpretation of the indicator aim, and so, after well-thought-out, this author considered that it was better to not account this descriptive indicator.

The reasons for the classification of non-applicable are presented above.

Three contacts by email, were made, requesting the values that were missing. The data was never received despite the efforts made.

The availability (OEE strand) had to be estimated, since the company did not provide it either. In order to understand the influence of this OEE element in the overall BOPSE calculation, Table 56 presents some simulation tests.

Table 56 - BOPSE calculation, simulating three different values for availability

SUSTAINABILITY (Eco*Env*Soc) (%)	**40**	**SUSTAINABILITY (Eco*Env*Soc) (%)**	**40**	**SUSTAINABILITY (Eco*Env*Soc) (%)**	**40**
OEE (A*P*Q) (%)	54	**OEE (A*P*Q) (%)**	57	**OEE (A*P*Q) (%)**	61
Availability (%)	**80**	Availability (%)	**85**	Availability (%)	**90**
Performance (%)	75	Performance (%)	75	Performance (%)	75
Quality (%)	90	Quality (%)	90	Quality (%)	90
BOPSE = (Sustainability + OEE)/2 (%)	**47**	**BOPSE = (Sustainability + OEE)/2 (%)**	**49**	**BOPSE = (Sustainability + OEE)/2 (%)**	**51**

In this simulation, one might see that only when the availability value is aligned with an “world-class firm” (90%), the BOPSE estimated raised to 51%. Nevertheless, and considering the others OEE elements sent by the company, it would be too optimistic to view this as a realistic value. Having in mind the other OEE elements, this author assumed that the availability value would range between 75% or 80%, therefore the OEE would range from 51% to 54%, and consequently the BOPSE value would range from 46% to 47%.

6.1.4 Case study C

Case study C was suggested by a professor of University of Minho, that knew the company and provided the contact. The first interaction with case study C took place in September 2018, by email. The company shown interest in participating in the study.

During a meeting, the study's goals and the BOPSE indicator were explained and a summary and results of the questionnaire. The aim was to provide awareness on companies' knowledge concerning the lean model and its links to sustainability. The company informed that the kind of data required would be provided by their facility, located in the inner center of the Portugal.

Interestingly, case study C is a company that had set in motion an ecological footprint reduction project recently, and the person responsible for it was the contact person.

It took about a month for them to send the required data. Several emails were sent, requesting for the economic data, and assuring the company that their confidentiality would be guaranteed, nevertheless, the company did not send these values. As another way of assuring the company's confidentiality, this author sent the descriptive indicators formulas that incorporated economic data. Nonetheless, and despite this effort, case study C, still, did not send the values. This author was surprised by the fact that, even though, having no direct access to the economic data, the company seemed to have some reservations in sending the required calculations.

Having collected the data sent, the possible descriptive indicators were accounted based on the differential rankings presented in section 5.1, as in the previous cases. The corresponding key indicators were then accounted, followed by sustainability and the OEE strands, and then, the BOPSE indicator. In order to complete the calculation, this author estimated the economic dimension at 60%.

Table 57 presents the sustainability results obtained for case study C. The social dimension (82%) scored the most. The environmental dimension was 77% and the economic dimension was estimated at 60%.

The OEE was reported to be 81%, grounded on the following components: Availability=84%; Performance=97%; Quality=99%.

Table 57 - Sustainability calculation for Case study C

SUSTAINABILITY			
ECONOMIC (5)	**60%**	**ENVIRONMENTAL (14)**	**77%**
Economic Performance (Eco. 1)	na	**Materials (Env. 1)**	60%
Net profit margin (Eco 1.1)	na	Materials used (Env 1.1)	na
Research, Development and Innovation (RDI) (Eco 1.2)	na	Recycled input materials used (Env 1.2)	60%
Market Presence (Eco. 2)	na	**Energy (Env. 2)**	60%
Standard entry level wage (Eco 2.1)	na	Useful energy (Env 2.1)	na
Local senior management (Eco 2.2)	na	Renewable energy (Env 2.2)	60%
Procurement (Eco. 3)	na	**Water (Env. 3)**	80%
Spending on local suppliers (in €) (Eco 3.1)	na	Water used (Env 3.1)	100%
SOCIAL (13)	**82%**	Recycled and reused water (Env 3.2)	60%
Employment (Soc. 1)	87%	Net water needs reduction (Env 3.3)	na
Effective contracted employees (Soc 1.1)	100%	**Biodiversity (Env. 4)**	na
Female employees (Soc 1.2)	80%	Biodiversity Investment (Env 4.1)	na
Women in management (Soc 1.3)	80%	**Emissions (Env. 5)**	na
Employee turnover (Soc 1.4)	89%	GHG emissions intensity (Env 5.1)	na
Occupational Health and Safety (Soc. 2)	93%	GHG emissions reduction (Env 5.2)	na
Absenteeism (Soc 2.1)	100%	**Effluents and Waste (Env. 6)**	87%
Accidents rate (Soc 2.2)	80%	Spills (Env 6.1)	100%
Fatalities (Soc 2.3)	100%	Hazardous industrial residues (Env 6.2)	100%
Training and development (Soc. 3)	68%	Recycled residues (Env 6.3)	60%
Budget in training and development (Soc 3.1)	na	**Environmental Compliance (Env.7)**	100%
Training and development (Soc 3.2)	60%	Environmental compliance (Env 7.1)	100%
Employees engagement (Soc 3.3)	75%		
Local Communities/Society (Soc. 4)	60%		
Employees engaged in volunteering (Soc 4.1)	60%		
Donations (Soc 4.2)	na		
Socioeconomic Compliance (Soc.5)	100%		
Socioeconomic compliance (Soc 5.1)	100%		

The sustainability strand score was almost in the middle of the reference values for the medium and low performances (51% and 22%) (Table 47 and Table 48 in section 5.3.2). Figure 24 presents the BOPSE calculation. As seen, the BOPSE value attained was 60%. The sustainability strand was 38% and OEE strand 81%. The reported OEE scored 81%, being only 4% below the value for a world class firm.

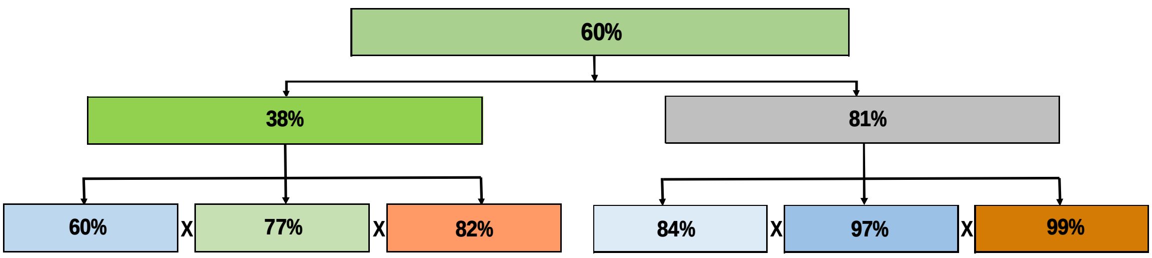

Figure 24 - BOPSE calculation and result for case study B

The BOPSE was estimated at 60%, which was below the values obtained for the medium performance, held previously.

In Table 57 there are 13 descriptive indicators that were accounted as non-applicable (na). From them, five involved economic data that was not sent. Four were dependent on availability of economic data:

“Biodiversity Investment”; “GHG Emissions intensity”; “Budget in training and development” and, lastly, “Donations” that could not be calculated, because their formulas involved economic data.

The remaining four, not dependent on economic, were:

1) “Materials used”, the company did not account the total materials incorporated in final product, relative to the total input materials purchased, as in the previous cases;
2) “Useful energy”, the company could not measure energy consumption in the factory, relative to the total energy consumption, because it could not measure energy consumption separately;
3) “Net water needs reduction”, as it was a recently new introduced descriptive indicator, it was not possible to obtain its value;
4) “GHG Emissions reduction” the company did not send the GHG emissions for the previous year of the data sent, that would be the 2017 emissions.

As previously mentioned, it was not possible to account the economic dimension for case study C. Therefore, this author thesis estimated it for a low, medium and high performance, with the purpose of understanding its impact in the BOPSE calculation, as presented in Table 58.

Table 58 - BOPSE calculation considering a low, a medium and a high performance for economic dimension

SUSTAINABILITY (Eco*Env*Soc) (%)	38	SUSTAINABILITY (Eco*Env*Soc) (%)	51	SUSTAINABILITY (Eco*Env*Soc) (%)	63
OEE (A*P*Q) (%)	81	OEE (A*P*Q) (%)	81	OEE (A*P*Q) (%)	81
Availability (%)	84	Availability (%)	84	Availability (%)	84
Performance (%)	97	Performance (%)	97	Performance (%)	97
Quality (%)	99	Quality (%)	99	Quality (%)	99
BOPSE = (Sustainability + OEE)/2 (%)	59	BOPSE = (Sustainability + OEE)/2 (%)	66	BOPSE = (Sustainability + OEE)/2 (%)	72

In these tests, one may observe that when the economic dimension was settled for the low performance, with 60%, the sustainability strand was estimated at 38%, thus the BOPSE value was 59%. When the economic dimension was settled for the medium performance, with 80%, the sustainability strand was 51%, hence the BOPSE value was 66%. Finally, when the economic dimension was settled for the high performance, with 100%, the sustainability strand was 63%, therefore the BOPSE value was 72%. Having these results in mind, and the fact that the values accounted for the environmental and social dimensions were nearly the medium performance value (80%), this author considered that the economic dimension value would be around the medium performance too. Thus, the sustainability and BOPSE values would be 51% and 66%, respectively.

Nevertheless, it is important to acknowledge as well the fact that there were some faults in data availability regarding the environmental dimension, involving six descriptive indicators.

6.2 Discussion

The results of the BOPSE model in three case studies are presented in Table 59.

Table 59 - BOPSE case studies comparison, considering an economic low performance for case study C

Strands	Case study A	Case study B	Case study C
Sustainability (%)	**53**	**40**	**38**
Economic (%)	77	70	60
Environmental (%)	77	73	77
Social (%)	89	79	82
OEE (%)	**78**	**51**	**81**
Availability (%)	82	75	84
Performance (%)	97	75	97
Quality (%)	98	90	99
BOPSE	**65**	**46**	**59**

Case study A was the one with the highest BOPSE value, with 65%, followed by case study C, with 59%. This case represents a company that belongs to a big multinational group that is one of the world's largest producers of automotive components, therefore has a stable process. Its OEE was near 80% and its sustainability strand presented the highest value from the case studies. This company has already published a sustainability report in 2018-2019, reporting its initiatives since 2015 till 2017. Previous visits to the company and contacts through supervisions of Industrial Engineering and Management students' internships of this thesis supervisors reinforced the concern of this company with social and sustainability aspects.

Case study B had the lowest score, with 46%, which can be explained by the lowest percentages for both strands. These values could be a reflection of the company current state, namely: the company is on a process of growth, which demands more human resources that need to be trained; the changes happening generate high levels of stress; and thus, a turnover of 56% might explain these results. Furthermore, previous visits and contacts through supervisions of Industrial Engineering and Management students' internships since 1996 showed a company with a growth but unstable behaviour due to the changes of company partners.

Case study C had the highest OEE, notwithstanding its sustainability strand was the lowest one. This can be explained by the fact that this company did not send the economic data, due to its own confidentiality requirements and thus this value had to be estimated (considering 60% as a low performance). However, as pointed out in section 6.1.4, if a medium performance (80%) for the economic dimension is estimated, the sustainability strand will have a value of 51%, a much more interesting one. And, in this circumstance, the BOPSE value will be 66%, being a much more attractive score, than the 59% presented in Table 59. Table 60 shows this assumption for case study C.

Table 60 - BOPSE case studies comparison, considering an economic medium performance for case study C

Strands	Case study A	Case study B	Case study C
Sustainability (%)	**53**	**40**	**51**
Economic (%)	77	70	80
Environmental (%)	77	73	77
Social (%)	89	79	82
OEE (%)	**78**	**51**	**81**
Availability (%)	82	7	84
Performance (%)	97	75	97
Quality (%)	98	90	99
BOPSE	**65**	**46**	**66**

These values seem to portray a trend in the sustainability values. One might say that a company with an interesting (good) sustainability performance will have a score above 50%. Concerning the BOPSE value, a company with a good performance will have a score above 65%. At the same time, the fact of not having all values for the calculation of all descriptive indicators is a limitation from this work, because it was required to estimate some values and make assumptions.

Interestingly, all the case studies revealed some difficulty in providing specific data, namely the environmental ones, i.e. the ones related to the following indicators: materials used and net water needs reduction. Two companies did not provide the indicators of GHG emissions reduction, nor the water used.

The results of the real cases influenced the BOPSE indicators. This was followed by a second experts' consultation, depicted in section 5.2. The conclusions were:

1) Key indicator relevance: they were considered to be the required and suitable;
2) Evaluation of each descriptive indicator importance: each descriptive indicator significance was discussed, three were eliminated and one was incorporated. This last one was the net water needs reduction indicator considering its fundamental information and suitability;
3) Rankings were defined for 27 descriptive indicators;
4) Calculation of BOPSE: an arithmetic mean of sustainability and OEE;
5) Evaluation of BOPSE suitability: BOPSE key indicators were considered fundamental and some descriptive were not;
6) BOPSE final version was stabilized encompassing 32 descriptive indicators.

The expert's validation allowed to evaluate the meaning and relevance of each key and descriptive indicator, in the first stage consultation (section 5.2). In the second stage consultation, after the real cases application, the BOPSE was adjusted for its final version, comprising 32 descriptive indicators in the sustainability strand. This demands a total of 45 input data. Nevertheless, it is worth to mention that some of them is repeated, for example, the total amount of revenues is used six times: in the economic performance in two indicators (net profit margin and research, development and innovation); in biodiversity investment; in GHG emissions intensity; in budget in training and development; and in donations. This also happen with some environmental and social indicators.

Companies that already publish sustainability reports, and measure the OEE indicator, will greatly reduce the time and effort required to collect the data and calculate the BOPSE. Companies having the OEE measure, but not the sustainability one, will have to collect the data for the sustainability strand. Likewise, companies that do not possess OEE nor sustainability data will have to collect all the data for the sustainability and OEE strands. Therefore, the BOPSE evaluation is possible for companies holding different levels of lean-green implementation.

This study was held in three case studies, nevertheless, to overcome its lack of generalization due to the strategy used, i.e. case studies, it should be applied to more companies (Yin, 2003). Further studies through additional case studies could help generate a portfolio of sustainability and BOPSE scores that would give an insight to support the definition of reference values.

This lack of generalization was pointed out in the work of Faulkner and Badurdeen (2014), which validated the methodology proposed in a single industry case. Also, Helleno et al. (2017) reports this in their work where the conceptual method proposed for assessment of sustainable manufacturing processes was applied, as well, in three case studies. As well, the work of Maia (2018), which developed a methodology to implement Lean Production in the textile and clothing industry was through case studies application in three companies, pointed out the same limitation.

7 Conclusion

This section presents the conclusions and main contributions. The research limitations are also addressed, along with some suggestions for future work.

7.1 Conclusions and main contributions

This thesis motivation arose from the fact that global consumption and, accordingly, production as well, are pressuring the environment, and challenging its global balance. The increasingly recurrent extreme climatic events, the climate change phenomenon, along with others, seem to be the consequence of long-term excessive use of natural resources. The societies, the companies and the people, play an important role on overcoming those challenges.

Companies' production processes impact the environment on a daily basis. Each company choice and decision will influence the entire value chain, considering the full life cycle perspective. They have been proposing strategies to overcome these challenges, by addressing not only the performance, but the environment as well. However, such strategies have to be balanced and coordinated, in order to provide high quality green products. Attending to this, lean and green concepts, which have had in fact a role on improving companies' sustainability and operations, each of which in their own way. Nevertheless, the integration of both could be synergistically linked, with predictably unmatched results.

The literature review has identified and characterized a set of lean-green models and indicators. Some of those were intrinsically more theoretical, while others were implemented in case studies. Such models rely on a mixed combination of concepts, such as lean, sustainability and eco-efficiency. The main criticism found, on the reported models, relate to the need of a simpler and meaningful integration model, that could be easily deployed by companies, so as to measure and monitor the prime indicators, i.e. the combined effectiveness of leaner and greener industrial activity.

The research also revealed that most companies focus on implementing lean production only. Moreover, they were not fully aware of the eventual environmental benefits that lean might bring. The survey conducted in the context of this research has just that. Furthermore, the survey exposed that companies were not addressing their knowledge about lean and green to support decisions. This lack of awareness was due to missing integrated indicators that express the company status. This was corroborated by the literature review.

Attending to this, the author developed a model that integrated lean and green strands. The OEE indicator was considered to be a good candidate to measure performance within the lean strand, given that OEE is, a well-known indicator for companies undertaking the lean endeavour. For the green strand, the pillars of sustainability were considered adequate: economic, social and environmental. It was decided to call it Business Overall Performance and Sustainability Effectiveness (BOPSE). To construct this indicator, the author has exchanged ideas and maintained a dialogue with experts in a number of fields, so as to define meaningful indicators, representative criteria and proper calculus, for such different dimensions.

The OEE was chosen given its widespread use, and popularity, for measuring performance in companies. Even companies that do not have a good lean maturity level, they would still be capable of using OEE. The sustainability indicators were mostly inspired in those found in the GRI, because it is a standard for sustainability reporting. After the construction of the BOPSE, it was validated in three case studies, each of which representing a manufacturing firm from the North of Portugal. The validation showed that a company with a good sustainability performance strand would have a score above 50%, while a BOPSE value of about 65% would be considered to hold a good lean-green performance.

The developed model, that includes a lean-green indicator to assess simultaneously lean and green practices in the companies, requires the quantification of all indicators, which reveals the status of the company on the economic, social, environmental and operational bottom levels. This will enable to visualize immediately the weaknesses of the company, and predictably to make decisions and act quickly so as to overcome them. In this way, they could identify improvement opportunities and prioritize the most suitable actions, for their business.

Considering the results obtained and bearing in mind the research question: “Is a lean company more sustainable?”, there is some evidence, not fully conclusive though, that lean companies are indeed more sustainable. The results of the case studies seem to provide some level of positive evidence, given that the highest sustainability scores, were attained by companies that were already on a lean journey for several years, and their processes were considered stable. Nevertheless, there is a need to apply this model to more case studies in order to corroborate one such evidence.

The BOPSE final version is a meaningful integration model, operationalized by an indicator grounded on well know concepts and indicators, such as those of OEE and GRI, that should make it easier to understand and implement. It is simple enough to be practical and economical to use, even for SME. It can be used by companies having different levels of lean implementation and sustainability practices. Such differences will be translated to the BOPSE scores. The ones with higher BOPSE score will likely be the ones with more stable processes and more sustainable practices. The ones with lower BOPSE score, will have the possibility to identify improvement opportunities and act accordingly.

The BOPSE model is an intelligible lean-green assessment model, with an integrated and ready-to-use indicator developed as an answer to overcome the research gap identified. The final version of the BOPSE model will hopefully have a wide use and dissemination.

The research will contribute to the evolution and dissemination of knowledge on lean and green production and resulting synergies. This research might be used to identify some company weaknesses related to performance and sustainability matters, therefore providing some opportunities for improvement on the overall competitiveness.

The research might also be used to support the definition of reference values for sectors of the economy, given a sufficient number of cases using the BOPSE model. In turn, its wider use might provide precious information for validation and eventual improvement of the model.

Ultimately, the work will contribute to evolve and disseminate knowledge on lean and cleaner operations, aiming to improve competitiveness of Portuguese companies.

7.2 Limitations

The BOPSE indicator was designed to be simple attending to the use of well-known indicators such OEE and others. Nevertheless, it demands a number of data items to fill the indicators values, sometimes, not immediately available, as was possible to realize when the case studies were developed. Current indicators measurement is considered a limitation because, as seen in the case studies, companies struggle to obtain them. For example, that was the case of useful energy, water used, biodiversity, spills, budget for training and development, among others.

The author is aware that many companies, probably, do not have skilled people to collect such data. Additionally, some companies could need support to apply the BOPSE. These could assume the form of helping tutorials or an IT tool. Therefore, a limitation of the developed work is not providing this with the model.

Another limitation of this research is to interpret results and make conclusions obtained from a survey because the sample used was restricted to the North of Portugal, as referred in the section 4.3. Additionally, the research strategy used for the validation is a qualitative one, which does not allow for immediate generalizations, as already referred in section 6.2. Even more, only three cases were used and from these, just one provided comprehensive data. Because of this, some values for the calculation of all descriptive indicators were and some assumptions were made. This is, obviously, a limitation of this work.

7.3 Future work

Lean-green paradigm is an up-to-date theme in academic research. This research area is advancing fast as proved by the many frameworks, models and indicators reviewed. As time goes by, a researcher on this area need to be all the time updating the literature review to keep up the pace. So, one of the suggestions for future work is to compare the different models, including BOPSE, attending to different criteria, like learning time of the model and time and resources to apply the models in the companies, collect data time and difficulties in doing that, among others.

Attending to the limitations of the survey developed in this research, a suggestion is to extend this to more activity sectors and countries to obtain results statistically significant.

Also, it would be important to develop a standardized instruction on how to use the indicator or, more useful, an IT tool to collect and calculate the indicators. Nowadays, Industry 4.0 promotes OEE as a data-driven optimization tool for capturing value at scale in discrete manufacturing. As some sustainability indicators were difficult to obtain, it is suggested to invest in tools that help to collect them.

At the same time, to promote the systematic collection of data and measurement of the indicators, it will be needed a mindset change that must be leaded by leaders trained for such endeavor. For that, they need to understand their fundamental role in developing a culture of problem solvers, in interrelating with their organization, aiming at shaping behaviours for building trust and respect. In this way, leaders will develop the right environment for change, making their middle managers accountable for leading continuous improvement and problem solving, and consequently, developing new capabilities to attain measurable and sustainable performance and results.

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Appendices

Appendix A: Lean tools

Table 61 - Purpose and description of some lean tools

Nr.	Tool	Purpose	Description
1	Method 5S	Reduce waste of time and movement and optimize productivity, by maintaining an orderly workplace in any type of business or operation (Hirano, 1995).	The 5S steps: Sort (*Seiri)*, Set in Order (*Seiton*), Shine (*Seiso*), Standardize (*Seiketsu*), and Sustain (*Shitsuke*), provide a system for eliminating what is not needed, organizing the remaining items, cleaning and inspecting the workplace, writing standards for maintaining the first three steps, and sustaining a productive work environment, through self-discipline and autonomous teams.
2	Just-In-Time (JIT)	Level production, spreading production evenly over time to foster a smooth flow among processes (Liker, 2004).	JIT is one of the TPS two pillars and means producing the right item at the right time and in the right amount. It signifies pulling parts through production based on customer demand instead of pushing parts through production based on projected demand.
3	Autonomation (*Jidoka*)	Prevent defects and problems, introducing automatic mechanisms into the equipment to operate without human intervention or monitoring (Shingo, 1985).	*Jidoka* is the Japanese word for the other TPS pillar, defined by Toyota as “automation with a human mind.” This means that workers and machines have the ability to identify errors and take quick countermeasures for correction.
4	Cellular Manufacturing	Simplify workflows and concentrate on a single product or a small family of products. Improve quality, inventory, flexibility, productivity, safety, use of space and morale (Liker, 2004).	Production work stations and equipment are arranged in a sequence that supports a smooth flow of materials and components through the production process one-piece at a time, at a rate determined by customers' needs.
5	Continuous Flow	Coordinate production by guaranteeing synchronized, continuous flow through the value stream (Womack & Jones, 1996).	Create a continuous flow of materials, throughout the entire process at a constant rate, without waiting, without stock gatherings and without unnecessary movements. The emphasis is on the entire value stream effectiveness.
6	Visual Management	Provide immediate informations, visually, allowing correct decisions and managing the work and activities (Shingo, 1989), (Grief, 1995).	Uses an extensive diversity of signs, signals and controls to manage workers and processes, creating a work environment that is self-explaining, self-ordering, and self-improving.
7	Continuous Improvement (*Kaizen*)	Improve processes through experiences of trial an error. Its focus is on eliminating waste and improving productivity (Imai, 1986).	*Kaizen* means change for the better and is the Japanese word for continuous improvement and is a process that involves all workers in teams. The teams use diagnostic technics, such as value stream mapping and “the 5 Why’s”.
8	*Kanban*	Schedule production and minimize work-in-process, whereas encouraging improvement.	*Kanban* is the Japanese word for “card” and means visual signal. It can be a card, labelled container, computer order, or other device used to send a signal when items are needed by a downstream process.

9	Production Levelling (*Heijunka*)	Smooth demand variability on processes (Monden, 1998).	*Heijunka* is the Japanese word for Production Smoothing and means adapting production to variable demand by distributing the production volume and mix evenly over time. It establishes a steady demand rate for each product from the marketplace.
10	Standard Work	Guarantee that all workers perform their tasks in the same way, reducing variations in work method (Monden, 1998).	Standard work, practiced at Toyota, is the documentation of methods and standard sequences that provide the best practice for any manufacturing operation, in order to increase the consistency and repeatability.
11	One-piece-flow	Reduce internal inventory to a work cell, forcing improvements and work balance (Sugimori et al., 1977).	One-piece-flow means that only a single piece is moved through operations from step to step with no accumulation of inventory in between either, one piece at a time. Leading to near perfect balance and coordination.
12	Mistake Proofing devices (*Poka-Yoke)*	Improve human reliability, preventing the occurrence of mistakes or defects (Shingo, 1985).	*Poka* means inadvertent error and *yoke* means prevention. Poka-yoke signifies implementing simple low-cost mistake proofing devices that detect abnormal situations before they happen or once they happen stop production to prevent defects.
13	Total Productive Maintenance (TPM)	Prevent equipment from malfunctioning, ensuring uptime and improving process capability (Suzuki, 1994).	TPM focuses on proactive and preventive maintenance to maximize the equipment overall effectiveness (OEE), creating a shared responsibility for equipment that stimulates more involvement by plant floor workers.
14	Overall Equipment Effectiveness (OEE)	Improve the effectiveness of manufacturing processes (Nakajima, 1988).	Places the most important sources of manufacturing productivity losses into three categories: downtime losses, speed losses and quality losses. It is calculated as: OEE = Availability x Performance x Quality
15	Single Minute Exchange of Dies (SMED)	Reducing the time it takes to complete a changeover (setup time) of equipment or production line (Shingo, 1985a).	SMED means reduce changeover time to less than ten minutes. It uses work simplification and other techniques to analyse each setup and reduce time and other waste. Leads to more predictable setups and improve quality.
16	Value Stream Mapping (VSM)	Visually map the production flow (Rother & Shook, 2003).	VSM represents the entire value chain, since material delivery from suppliers until final product delivery to customer. It is a material and information flow mapping that employs standard symbols to represent items and processes, identifying all the value added and non-value-added steps or activities.

Appendix B: Sustainable manufacturing tools

Table 62 - Purpose and description of some sustainable manufacturing tools (adapted from US-EPA)

Nr.	Tool	Purpose	Description
1	Electronics Product Environmental Assessment Tool (EPEAT)	Searchable global registry for greener electronics, used by purchasers, manufacturers, resellers and others to find and promote environmentally desirable products.	EPEAT is the global ecolabel for the IT sector, managed by the Green Electronics Council (GEC). EPEAT online registry lists sustainable products from a comprehensive range of manufacturers and provides independent verification of manufacturers' claims.
2	ENERGY STAR Energy Tracking Tool (ETT)	For SMEs manufacturing companies to have a custom data tracking system for evaluating progress.	ENERGY STAR ETT provides manufacturers a method for tracking energy use, establishing baselines, setting energy and emissions reduction goals, and assessing progress on the way to achieving goals.
3	EPA Chemical Screening Tool for Exposures & Environmental Releases (ChemSTEER)	ChemSTEER is a computer-based software program used to estimate workplace exposures and environmental releases for chemicals manufactured and used in industrial/commercial settings.	ChemSTEER evaluates occupational inhalation and dermal exposure to chemical throughout industrial and commercial manufacturing, processing, and use operations. It estimates chemical releases to air, water, and land that are associated with chemical involved.
4	EPA Lean Manufacturing and Environment Toolkits	Improve product quality and customer responsiveness, and reduce cost (US-EPA, 2007).	EPA developed several toolkits that display how manufacturers can use lean methods to reduce environmental wastes, while meeting quality products on time and at minimum cost.
5	General Services Administration (GSA): Sustainable Facilities Tool	Simplify building practices, comparing options for renovation projects from government and private-sector managers.	It provides sustainable guidance for facility managers, procurement professionals, leasing specialists, and project managers, as it compares building options for renovation projects.
6	Global Environmental Management Initiative (GEMI)	GEMI: Sustainable Development (SD) Planner and Sustainable Development Gateway helps companies assess progress towards sustainable development.	GEMI SD Planner™ and SD Gateway is a detailed, comprehensive planning software used to establish baseline performance, assess opportunities, set goals, develop action plans and evaluate progress towards the sustainable development objectives defined.
7	Institute for Industrial Productivity's Industrial Efficiency Technology Database (IETD)	IETD aims to catalyse the adoption of technologies and practices in industry to improve productivity and profits while reducing energy consumption and CO2 emissions.	IETD is a database on technology, policy, financing and supply chain initiatives publicly available, to support decision makers in evaluating cost-effectiveness of energy efficiency investment options in energy-intensive sectors (cement, iron, and steel sectors, and on electric motor driven systems).
8	Life Cycle Assessment (LCA): Principles and Practice	Allow to systematically estimate the cumulative environmental impacts that result from product Life cycle various phases.	EPA's LCA 101 document provides an overview for LCA, with overall uses and main technique description. Is a decision-making tool that integrates in decision-making processes the life cycle based environmental performance considerations.
9	OECD Sustainable Manufacturing Toolkit	Assist companies measuring their environmental performance at plant or facility level (OECD, 2011).	It comprises an internationally set of indicators to support companies measuring and evaluating their environmental performance. It provides a starting point for companies to improve their production processes and products efficiency.
10	Sustainable Manufacturing 101 Module	Guide companies, mainly SMEs manufacturers, to identify opportunities for savings and value improvements through the production cycle and supply chain.	This module is a training document to explain key concepts, approaches, strategies, terminology, and regulations related to sustainable manufacturing.

Appendix C: Procedures to assist cleaner production initiatives

Table 63 - Purpose and description of some procedures to assist cleaner production initiatives

Nr.	Tool	Purpose	Description
1	Environmental Impact Assessment (EIA)	Assess the impact of proposed major development project (UNEP, 1988).	EIA is a comprehensive evaluation of the effects of human development activities or non-action on the several environment components, performed during the planning phase.
2	Life-cycle assessment (LCA)	Allow to systematically estimate the cumulative environmental impacts that result from product Life cycle various phases (US-EPA, 1993).	LCA is a decision-making tool that identifies environmental costs and assesses the environmental consequences of a product, process or service, throughout its entire life cycle, from cradle to grave.
3	Environmental Technology Assessment	Help to understand the likely impact of the use of a new technology by an industry, region, country or society (UNCTAD, 1993).	It analyses the effects of a technology on environment, specifically on human health, ecological systems and resources.
4	Chemical Assessment	Evaluate and assess the hazards a chemical imposes on human health and the quality of the environment (OECD, 1989).	It determines the chemical potential to cause harm owing to its inherent toxicity and/or ecotoxicity. Frequently, is a part of a risk audit.
5	Environment Audit	Assist with and substantiating compliance with local, regional, and national laws and regulations, and with company policy and standards (UNEP-IEO, 1990).	Is a management tool comprising a systematic, documented, periodic and objective evaluation of how well environmental organization, management and equipment are performing. Sometimes called eco-audit.
6	Waste Audit	Account the wastes from an industry, a plant, a process or a unit operation (UNEP-IE/UNIDO, 1991).	It requires the derivation of a material balance for every scale of operation. It results in the identification of all wastes, their origin, quantity, composition and their potential for reduction. Other used terms are: waste and emissions audit, waste and emission prevention assessment, and waste minimization audit.
7	Energy Audit	Identify costs and quantities of energy inputs used, the annual and seasonal trends in energy use and costs, and the energy use per unit of output (UNEP-IE/IPIECA, 1991).	In this audit a plan of action is formulated and implemented, being followed by the evaluation and continuous improvement of the energy management programme. This last one follows the same procedure as the one for a waste audit procedure.
8	Risk Audit	Identify all areas of vulnerability and specific hazards at site and plant level, examining and assessing the standards of all facets of a particular activity, in detail (UNEP-IE/PAC, 1992).	In this audit a plan of action is formulated and implemented, being followed by the evaluation and continuous improvement of the risk management programme. This last one follows the same procedure as the one for a waste audit procedure.

Appendix D: Sustainability tools

Table 64 - Purpose and description of some sustainability tools (US-EPA, 2013)

Nr.	Tool	Purpose	Description
1	Environmental impact assessment (EIA)	Inform public decision-making about the environmental consequences of implementing larger projects (EPA, n.d.-a).	EIA is a process of identifying and evaluating the likely environmental impacts of a proposed project or development, taking into account inter-related socio-economic, cultural and human-health impacts, both beneficial and adverse.
2	Strategic environmental assessment (SEA)	SEA is conducted before a corresponding EIA is undertaken. It intends to provide a high level of environment protection and promote sustainable development (EPA, n.d.-b).	SEA is a process in which environmental considerations are entirely integrated into the preparation of plans and programmes (e.g. on land use, transport, energy, waste, agriculture, etc) prior to their final adoption.
3	Environmental management system (EMS)	Develop and implement its environmental policy and manage its environmental aspects with balance of socioeconomic needs with environmental protection and pollution prevention (ISO, 2015a).	EMS comprises the organizational structure, responsibility, practices, procedures, processes and resources to implement and manage the environmental themes of an organization, while ensuring compliance with its stakeholders' policies, standards and expectations.
4	Corporate social responsibility (CSR)	Guidance for businesses and organizations operate in a socially responsible way (ISO, 2010).	Through ISO 26000 guidance, organizations can achieve corporate social responsibility by accounting, in an ethical and transparent way their relationship to society and environment by following 7 core subjects: organizational governance; human rights; labour practices; the environment; fair operating practices; consumer issues, and community involvement and development. Thus, organizations will contribute to sustainable development.
5	Life-cycle assessment (LCA)	Allow to systematically estimate the cumulative environmental impacts that result from product Life cycle various phases (ISO, 2016).	LCA is a decision-making tool that identifies environmental costs and assesses the environmental consequences of a product, process or service, throughout its entire life cycle, from design through disposal.
6	Material flow analysis (MFA)	Allow to identify problems and quantify the impact of potential measures as a decision-support tool in resource management, waste management, and environmental management (Brunner & Rechberger, 2004).	MFA is a systematic assessment of the flows and stocks of materials within a system defined in space and time, connecting the sources, the pathways, and the intermediate and final sinks of a material. Attending to the law of matter conservation, the MFA results would be a material balance comparing all inputs, stocks, and outputs of a process.
7	Ecological footprint (EF)	Allow to measure the demand on and supply of nature (GFN, 2019b).	EF measures the ecological resources required to produce the natural resources, which a population consumes, and to absorb and treat the waste generated, particularly carbon emissions.
8	Carbon footprint (CF)	Allow to measure the carbon dioxide emitted into the atmosphere (EPA, 2019).	CF measures total amount of greenhouse gases that are emitted into the atmosphere each year by a person, family, building, organization, or company.
9	Design for Environment (DfE)	Reduce environmental impact of products and services throughout its life-cycle (BCSD Portugal, 2013)	DfE integrates environmental considerations in a systematic way into the product and design process.

Appendix E: Eco-efficiency tools

Table 65 - Purpose and description of some eco-efficiency tools (BCSD Portugal, 2013)

Nr.	Tool	Purpose	Description
1	Life-cycle assessment (LCA)	Allow to systematically estimate the cumulative environmental impacts that result from product Life cycle various phases.	LCA is a decision-making tool that identifies environmental costs and assesses the environmental consequences of a product, process or service, throughout its entire life cycle, from design through disposal.
2	Life-cycle management (LCM)	Achieve continuous environmental improvements from a life-cycle perspective.	LCM is an integrated and flexible framework of concepts, techniques and procedures to address the environmental, economic, technological and social aspects of products and organizations.
3	Design for Environment (DfE)	Reduce environmental impact of products and services throughout its life-cycle.	DfE integrates environmental considerations in a systematic way into the product and design process.
4	Eco-Labelling	Encourage demand (and supply) of products and services that are environmentally friendly ("green" products or services).	Eco-labelling provides verifiable, accurate and unambiguous information on products and services environmental aspects. The criteria for "green" products recognition vary by product class (17 classes) and is defined using a "cradle-to-grave" strategy (life-cycle perspective).
5	Clean Production/ Pollution Prevention	Increase Eco-efficiency and reduce the risk to humans and the environment.	The continued use of an integrated preventive environmental strategy applied to processes, products and services, considering: waste minimization and prevention; pollution prevention or reduction at source; environmental management; toxic and hazardous materials substitution; process and product modifications; and internal reuse of waste.
6	Green procurement	Products and services procurement have less impact on environment than others with similar performance requirements.	Comprises: incorporation of environmental considerations and pollution prevention principles as an integral part of the usual procurement process; evaluation of total environmental impact throughout the products and services life-cycle; compilation of comprehensive, accurate and meaningful information on products and services environmental performance to facilitate strong environmental decision-making.
7	Environmental Management System (EMS)	Develop and implement its environmental policy and manage its environmental aspects with balance of socioeconomic needs with environmental protection and pollution prevention.	EMS comprises the organizational structure, responsibility, practices, procedures, processes and resources to implement and manage the environmental themes of an organization, while ensuring compliance with its stakeholders' policies, standards and expectations.
8	Environmental Supply Chain Management (ESCM)	Develop the EMS both in internal operations and throughout the supply chain.	Programs that extend environmental concerns, upstream and downstream of the company, through EMS, DfE programs, restrictive materials lists, component take-back commitments, life-cycle requests for data and performance dissemination.

Appendix F: Questionnaire "Lean Production contributions for company's sustainability" (in Portuguese)

Contribuições da Produção "Lean" para a Sustentabilidade das Empresas

Universidade do Minho

No âmbito de uma tese de doutoramento de Engenharia Industrial e de Sistemas, que está a ser desenvolvida na Universidade do Minho, elaborou-se um questionário, que pretende investigar se as metodologias de Produção Lean e Sustentável (Green) são conhecidas e/ou estão implementadas nas empresas Portuguesas e em que medida a sua implementação contribui para a produtividade e a sustentabilidade da empresa.

A tese tem o tema: "Contribuições do Lean-Green para a Sustentabilidade das empresas" e o objetivo é desenvolver um modelo concetual que explore as sinergias da Produção Lean e da Eco-eficiência dos Sistemas.

O preenchimento deste questionário não tomará mais do que 10 minutos do seu tempo e solicitamos o seu preenchimento, preferencialmente, até ao dia 30 de Abril. Informamos, ainda, que as respostas serão tratadas com estrita confidencialidade, vindo a ser do conhecimento público apenas os resultados agregados do tratamento da informação de todos os questionários. Este questionário tem 20 perguntas.

Existem 22 perguntas neste inquérito

I - Dados da pessoa responsável pelo preenchimento do questionário

1 [1.]Nome: *

Por favor, escreva aqui a sua resposta:

2 [2.]Contato:

Por favor, escreva aqui a sua resposta:

3 [3.]Cargo: *

Por favor, escreva aqui a sua resposta:

4 [4.]Há quantos anos trabalha nesta empresa? *

Por favor, escreva aqui a sua resposta:

II - Identificação/Caraterização da empresa

5 [5.]Nome da empresa: *

Por favor, escreva aqui a sua resposta:

6 [6.]Cidade: *

Por favor, escreva aqui a sua resposta:

7 [7.]Quantos colaboradores trabalham na empresa? *

Por favor, selecione **apenas uma** das seguintes opções:

- ○ Microempresa (menos de 10)
- ○ Pequena Empresa (entre 10 a 49)
- ○ Média Empresa (entre 50 e 249)
- ○ Grande Empresa (250 ou mais)
- ○ Não sabe / Não responde

8 [8.]Qual o setor de atividade? *

Por favor, selecione **todas** as que se aplicam:

- ☐ Agricultura, Produção Animal, Caça, Floresta e Pesca
- ☐ Indústrias Extrativas
- ☐ Indústrias Transformadoras (alimentares, bebidas, têxteis, vestuário, madeira, mobiliário e outros)
- ☐ Eletricidade, Gás, Vapor, Água Quente e Fria e Ar Frio
- ☐ Captação, Tratamento e Distribuição de Água; Saneamento, Gestão de Resíduos e Despoluição
- ☐ Construção
- ☐ Comércio por grosso e a Retalho; Reparação de Veículos Automóveis e Motociclos
- ☐ Transportes e Armazenagem
- ☐ Alojamento, Restauração e Similares
- ☐ Atividades de Informação e Comunicação (inclui edição, telecomunicações, serviços informáticos e outros)
- ☐ Atividades Financeira e de Seguros
- ☐ Atividades Imobiliárias
- ☐ Atividades de Consultoria, Cientificas, Técnicas e Similares
- ☐ Atividades Administrativas e dos Serviços de Apoio
- ☐ Outro: ____________

9 [9.]Qual o(s) produtos(s)/serviço(s) principal(ais) fornecido(s) pela empresa? *

Por favor, escreva aqui a sua resposta:

10 [10.]Há quantos anos começou a empresa a funcionar? *

Por favor, selecione **apenas uma** das seguintes opções:

- ○ Menos de 10 anos
- ○ De 10 a 30 anos
- ○ Mais de 30 anos

11 [11.]Qual o seu principal mercado? *

Por favor, selecione **todas** as que se aplicam:

- ☐ Nacional
- ☐ Espanha
- ☐ Resto da Europa
- ☐ Outro: ____________

III - Caraterização do sistema de gestão e do modelo de produção

12 [12.]O sistema de gestão da empresa encontra-se certificado? *

Por favor, selecione **apenas uma** das seguintes opções:

○ Sim
○ Não

13 [12.1]Está certificado de acordo com: *

Responda a esta pergunta apenas se as seguintes condições são verdadeiras:
° Resposta era Y'Sim' na pergunta '12 [12.]' (O sistema de gestão da empresa encontra-se certificado?)

Por favor, selecione **todas** as que se aplicam:

☐ Qualidade (ISO 9001)
☐ Ambiente (ISO 14001)
☐ Higiene e Segurança (OHSAS 18001/NP 4397)
☐ Responsabilidade Social (ISO 26000)
☐ Outro: ______

14 [13.]Dos vários modelos de produção existentes, indique aquele(es) que considera mais próximo dos adotados pela empresa: *

Por favor, selecione **todas** as que se aplicam:

☐ Sistema "Taylorista/Fordista" ou Produção em massa
☐ Sistema de produção da Toyota ("Toyota Production System")
☐ Sistema socio-técnico
☐ Produção "Lean" ("Lean Production", "Lean Manufacturing", "Lean Management")
☐ Produção Just-in-Time (JIT)
☐ Produção sem stocks
☐ Produção ligeira ou magra
☐ Produção ágil
☐ Sistema Kaizen
☐ Sistema Kanban
☐ Outro: ______

Um modelo de produção define como as empresas organizam e gerem o sistema de produção, desde o abastecimento de materias à organização das pessoas, dos equipamentos, do fluxo de materiais e de informação.

15 [14.]Considera que o modelo de produção da empresa contribui para uma maior preocupação com: *

Por favor, selecione **todas** as que se aplicam:

☐ O ambiente
☐ As pessoas
☐ A responsabilidade social
☐ Os desperdícios
☐ Os custos
☐ A produtividade
☐ Outro: ______

Desperdício é toda a atividade que não acrescenta valor do ponto de vista do cliente, como por exemplo, o transporte de materiais, esperas, a sobreprodução, as movimentações/deslocações de funcionários, o sobreprocessamento, os defeitos e a existência de stocks.

16 [15.]Considera que o modelo de produção da empresa promove a sustentabilidade da empresa? *

Por favor, selecione **apenas uma** das seguintes opções:

○ Sim
○ Não
○ Não sei

17 [16.]Dos benefícios que se seguem, indique os que considera alcançados pela empresa? *

Por favor, selecione **todas** as que se aplicam:

- ☐ Redução do tempo de entrega ao cliente
- ☐ Redução dos desperdícios
- ☐ Melhoria da satisfação do cliente
- ☐ Melhoria da qualidade dos produtos
- ☐ Aumento dos lucros
- ☐ Aumento da produtividade
- ☐ Aumento da satisfação dos colaboradores
- ☐ Redução de stocks
- ☐ Redução dos custos de produção
- ☐ Redução do consumo de água
- ☐ Redução do consumo de energia
- ☐ Redução do consumo de matérias primas
- ☐ Redução do consumo de substâncias poluentes
- ☐ Redução de lixos tóxicos
- ☐ Desenvolvimento de novos produtos em menos tempo
- ☐ Aumento da flexibilidade para produzir produtos diferentes
- ☐ Outro: ________

18 [17.]Das várias abordagens para apoiar o processo de melhoria do desempenho ambiental nas empresas (processos e/ou produtos), assinale as que considera já adotadas pela empresa: *

Por favor, selecione **todas** as que se aplicam:

- ☐ Gestão do Ciclo de Vida (Life-Cycle Management)
- ☐ Avaliação do Ciclo de vida (Life-Cycle Assessment)
- ☐ Eco-Design (Design for Environment)
- ☐ Rotulagem ecológica (Eco-Labelling)
- ☐ Produção Limpa (Clean Production)/Prevenção de Poluição
- ☐ Seleção de fornecedores de matérias-primas mais sustentáveis (Green Procurement)
- ☐ Sistema de Gestão Ambiental (Environmental Management System)
- ☐ Gestão ambiental da cadeia logística (Environmental Supply Chain Management)
- ☐ Nenhuma abordagem adotada
- ☐ Outro: ________

19 [18.]Dos vários indicadores de gestão da empresa, refira os indicadores de sustentabilidade usados na sua empresa: *

Por favor, selecione **todas** as que se aplicam:

- ☐ Consumo de energia (consumo direto e indireto de energia, discriminado por fonte de energia primária)
- ☐ Consumo de materiais (inclui matérias-primas, outros materiais do processo como catalisadores e solventes, bem como, produtos e peças semi-produzidos)
- ☐ Consumo de água (de rede pública ou obtida por fonte superficial ou subterrânea)
- ☐ Emissões de gases de efeito de estufa
- ☐ Emissões de substâncias que destroem o Ozono (ODS) e outras emissões atmosféricas
- ☐ Produção de resíduos sólidos e líquidos
- ☐ Custo associado ao tratamento e deposição de resíduos
- ☐ Custo associado à emissão de gases
- ☐ Intensidade energética e material
- ☐ Outro: ________

20 [19.]Produção "Lean" é um modelo de produção, focado no cliente, que procura a eliminação dos desperdícios (atividades que não acrescentam valor do ponto de vista do cliente) e a entrega atempada de produtos de qualidade, a baixo custo, respeitando as pessoas e o ambiente. Considera que a empresa implementa este modelo de produção? *

Por favor, selecione **apenas uma** das seguintes opções:

- ○ Sim
- ○ Não

21 [19.1.]
Justifique por favor a resposta anterior:
*

Responda a esta pergunta apenas se as seguintes condições são verdadeiras:
° Resposta era N'Não' na pergunta '20 [19.]' (Produção "Lean" é um modelo de produção, focado no cliente, que procura a eliminação dos desperdícios (atividades que não acrescentam valor do ponto de vista do cliente) e a entrega atempada de produtos de qualidade, a baixo custo, respeitando as pessoas e o ambiente. Considera que a empresa implementa este modelo de produção?)

Por favor, escreva aqui a sua resposta:

22 [20.]Tem algum comentário ou sugestão que gostasse de fazer? De seguida click, por favor, no botão SUBMETER para concluir. Obrigado!

Por favor, escreva aqui a sua resposta:

Appendix G: Characterization of key indicators

Table 66 - Characterization of Economic Performance (Eco 1)

Economic Performance (Eco 1)	
Eco 1.1	**Net profit margin (Npm)**
Description	Percentage of net profit measures the proportion of the total amount of net profit relative to the total amount of revenues (in €).
Equation	$Npm = \frac{Total\ amount\ of\ Net\ Profit}{Total\ amount\ of\ Revenues} x100$
Range/Ranking	< 1% 60% >1% to 5% 80% >5% 100%
Trend	The higher, the better
Justification	In order to define reasonable ranking for companies net profit margins, this author relied in a list, from the New York University Stern School of Business, presenting this indicator by activity sector (NYU Stern, 2019). The values encountered were a Npm = 1.82% for the Auto & Truck and a Npm = 4.92% for the Auto Parts.
Eco 1.2	**Research, Development and Innovation (RDI)**
Description	Percentage of research, development and innovation measures the proportion of the amount on research, development and innovation relative to the total amount of revenues (in €).
Equation	$RDI = \frac{Total\ amount\ of\ RDI}{Total\ amount\ of\ Revenues}\ x\ 100$
Range/Ranking	0% to 1% 60% >1% to 3% 80% >3% 100%
Trend	The higher, the better
Justification	The Eurostat site (Eurostat, 2019b) showed that, in 2018, the value for research and development expenditure by sectors of performance (as a % of GDP) in Portugal was 1.35%. And for the European Union (considering 28 countries) the value was 2.12%. The countries with the highest values of research and development were the Sweden with 3.31%, then the Austria with 3.17%, followed by the Germany with 3.13%. In the Europe 2020 indicators, the target for 2020 for the EU gross domestic expenditure on R&D, as a percentage of GDP, is 3% of GDP (Eurostat,

Table 67 - Characterization of Market Presence (Eco 2)

Market Presence (Eco 2)	
Eco 2.1	**Standard entry level wage (Selw)**
Description	Percentage of standard entry level wage measures the proportion of the entry level wage relatively to local minimum wage (in €).
Equation	$Selw = \frac{Entry\ level\ wage}{Local\ minimum\ wage}\ x\ 100$
Range/Ranking	100% to 110% 60% >110% to 120% 80% >120% 100%
Trend	The higher, the better
Justification	For this indicator, this author was based on the fact that a company must comply with the minimum wage values established by law. The minimum wage in Portugal in 2017 was 557 € and in 2018 was 580 € (Guerreiro, 2019).
Eco 2.2	**Local senior management (Lsm)**
Description	Percentage of senior management hired locally, measures the proportion of the number of top managers hired from the local community relative to the total number of top managers.
Equation	$Lsm = \frac{Number\ of\ top\ managers\ from\ local\ community}{Number\ of\ top\ managers}\ x\ 100$
Range/Ranking	0% to 40% 60% >40% to 80% 80% >80% 100%
Trend	The higher, the better
Justification	This indicator was defined based on experience and the assumption that each company should engage and develop the community within which it operates.

Table 68 - Characterization of Procurement (Eco 3)

Procurement (Eco 3)	
Eco 3.1	**Spending on local suppliers (Sls)**
Description	Percentage of spending on local suppliers measures the proportion of the total costs with local suppliers relative to the total suppliers' costs (in €).
Equation	$Sls = \frac{Spending\ on\ local\ suppliers}{Global\ spending\ on\ suppliers}\ x\ 100$
Range/Ranking	0% to 35% 60% >35% to 70% 80% >70% 100%
Trend	The higher, the better
Justification	This indicator has been defined based on experience and on the assumption that given the specificity of the sector, sometimes a company has to comply with the group buying policies.

Table 69 - Characterization of Materials (Env 1)

Materials (Env 1)	
Env 1.1	**Materials used (Mu)**
Description	Percentage of materials used measures the proportion of the total materials incorporated in the final product, relatively to the total input materials purchased by the company (in Ton).
Equation	$Mu = \frac{Total\ materials\ incorporated\ in\ final\ product}{Total\ input\ materials}\ x\ 100$
Range/Ranking	Min: 0% Max: 100%
Trend	The higher, the better
Justification	Total input materials include the following material types: raw materials, associated process materials (needed for the manufacturing process but are not part of the final product (ex: lubricants), semi-manufactured goods or parts (components) and materials for packaging (paper, cardboard and plastics) (GRI, 2016, p. 6). Percentage obtained by direct calculation. This percentage will be high, as most input materials will be incorporated into the final product.
Env 1.2	**Recycled input materials used (Rim)**
Description	Percentage of recycled input materials measures the proportion of the total recycled input materials used, relatively to the total input materials purchased by the organization (in Ton).
Equation	$Rim = \frac{Total\ recycled\ input\ materials\ used}{Total\ input\ materials}\ x\ 100$
Range/Ranking	0% to 25% 60% >25% to 50% 80% >50% 100%
Trend	The higher, the better
Justification	This percentage gives insight about the total recycled materials incorporated in the final product. So as to define a reasonable ranking for Rim, this author searched for information concerning this subject. Eurostat reported that recycling rates in EU are "steadily growing" (Eurostat, 2019b). In 2016, EU recycling was around 55% of all waste.

Table 70 - Characterization of Energy (Env 2)

Energy (Env 2)	
Env 2.1	**Useful energy (Ue)**
Description	Percentage of useful energy measures the proportion of energy consumption in the factory, relative to the total energy consumption by the company (in GJ).
Equation	$Ue = \frac{Energy\ consumption\ in\ the\ factory}{Total\ energy\ consumption}\ x\ 100$
Range/Ranking	Min: 0% Max: 100%
Trend	The higher, the better
Justification	Percentage obtained by direct calculation. The largest share of energy consumed in this sector (automotive) will be given by the production area. This author searched for information concerning this subject. The 2019 Environmental Status Report, from APA (Portuguese Environment Agency) stated that the energy imports in 2017 increased by 8.1% over the previous year, while domestic production decreased by 12.7%. In 2017, final energy consumption increased by 1.2% and primary energy consumption increased by 3.7%, due to the increase in natural gas and coal consumption. Energy dependency has also increased over the past year, standing at 79.7% in 2017 (APA, 2019, p. 33).
Env 2.2	**Renewable energy (Re)**
Description	Percentage of renewable energy measures the proportion of renewable energy used relative to the total energy consumption by the company (in GJ).
Equation	$Re = \frac{Renewable\ \ Energy\ used}{Total\ energy\ consumption}\ x\ 100$
Range/Ranking	0% to 25% 60% >25% to 50% 80% >50% 100%
Trend	The higher, the better
Justification	This percentage gives insight about the total recycled energy incorporated in the final product. In order to define reasonable ranking for companies Re, this author searched for information concerning this subject. The Eurostat Statistics Illustrated showed that, the share of renewable energy in gross final energy production increased from 11% in 2008 to 16% in 2014. In 2017, Portugal had a share of 28.1% and the EU (28) a share of 17.5% (Eurostat, 2019a). Also, the 2019 Environmental Status Report, from APA (Portuguese Environment Agency) stated that the incorporation of renewable energy sources into gross final energy consumption was 28.1% (APA, 2019).

Table 71 - Characterization of Water (Env 3)

Water (Env 3)	
Env 3.1	**Water used (Wu)**
Description	Percentage of water used measures the proportion of water consumption in the factory, relatively to the total water consumption by thecompany (in m3).
Equation	$Wu = \frac{Water\ consumption\ in\ the\ factory}{Total\ water\ consumption}\ x\ 100$
Range/Ranking	0% to 25% 60% >25% to 50% 80% >50% 100%
Trend	The higher, the better
Justification	This percentage gives insight about the total water consumption in the factory. The largest share of water consumed in this sector (automotive) should be given by the production area. The total volume of water consumption provides an indication of the company's relative size and importance as a user of water.
Env 3.2	**Recycled and reused water (Rrw)**
Description	Percentage of recycled and reused water measures the proportion of total volume of water recycled and reused, relatively to the total water consumption (in m3).
Equation	$Rrw = \frac{Total\ recycled\ and\ reused\ water}{Total\ water\ consumption}\ x\ 100$
Range/Ranking	0% to 25% 60% >25% to 50% 80% >50% 100%
Trend	The higher, the better
Justification	This percentages gives insight about the total recycled and reused water incorporated in the final product. This percentage is a measure of efficiency and demonstrates the success of a company in reducing total water withdrawals and discharges. Increased reuse and recycling can reduce water consumption, treatment, and disposal costs.
Env 3.3	**Net water needs reduction (Nwnr)**
Description	Percentage of net water needs reduction measures the evolution of the current year water consumption relative to the previous year water consumption (in m3). The previous year water consumption is the total water consumption in the previous year and the current year water consumption is the total water consumption in the year of reporting.
Equation	$Nwnr = \frac{Previous\ year\ water\ consumption - Current\ year\ water\ consumption}{Previous\ year\ water\ consumption}\ x\ 100$
Range/Ranking	<1% 60% >1% to 3% 80% >3% 100%
Trend	The higher, the better
Justification	This percentages gives insight about net water needs evolution in the company. The total water consumption is equal to the total water withdrawal minus the total water discharge.

Table 72 - Characterization of Biodiversity (Env 4)

Biodiversity (Env 4)	
Env 4.1	**Biodiversity investment (Bi)**
Description	Percentage of biodiversity investment measures the proportion of total amount invested in biodiversity relative to the total amount of revenues (in €).
Equation	$Bi = \frac{Total\ amount\ invested\ on\ biodiversity}{Total\ amount\ of\ Revenues}\ x\ 100$
Range/Ranking	0% to 0.02% 60% >0.02% to 0.05% 80% >0.05% 100%
Trend	The higher, the better
Justification	In an attempt to define rational rankings for Bi, this thesis author searched for information concerning this subject. The European Environment Agency (EEA) stated that, in 2006, the EU expenditure on the Life project represented 0.066 % of the total EU budget (EEA, 2019). The 2019 Environmental Status Report, from APA (Portuguese Environment Agency) did not reported any data related to investment in biodiversity (APA, 2019).

Table 73 - Characterization of Emissions (Env 5)

Emissions (Env 5)	
Env 5.1	**GHG emissions intensity (GHGei)**
Description	Percentage of GHG emissions intensity measures the total GHG emissions (in Kg CO2e), relative to the total amount of revenues (in €).
Equation	$GHGei = \frac{Total\ GHG\ emissions}{Total\ amount\ of\ Revenues}$
Range/Ranking	0 Kg/€ to 0.2 Kg/€ 100% >0.2 Kg/€ to 0.4 Kg/€ 80% >0.4 Kg/€ 60%
Trend	The lower, the better
Justification	In an attempt to define reasonable rankings for GHGei, this thesis author searched for information concerning this subject. The 2019 Environmental Status Report, from APA (Portuguese Environment Agency), reported that, in 2016, the carbon intensity emitted by Portugal was 0.39kg (or 390g) CO2eq. per euro of GDP at 2010 prices. This value was 4.4% less than the previous year (APA, 2019, p. 35).
Env 5.2	**GHG emissions reduction (GHGer)**
Description	Percentage of reduction of GHG emissions measures the evolution of the current emissions year relative to the previous year emissions (in t CO2 e).
Equation	$GHGer = \frac{Previous\ year\ emissions - Current\ year\ emissions}{Previous\ year\ emissions}\ x\ 100$
Range/Ranking	< 1% 60% >1% to 5% 80% >5% 100%
Trend	The higher, the better
Justification	So as to define reasonable rankings for GHGer, this thesis author searched for information concerning this subject. In the Europe 2020 Strategy was set as target that GHG emissions should be 20% lower than 1990 levels (Eurostat, 2019b). Therefore, a 20% reduction over 30 years (2020-1990) means that this reduction was on average less than 1% annually. In the 2019 Environmental Status Report, from APA (Portuguese Environment Agency), it was reported that the target for 2020/2030, relatively to 2005, is to guarantee a trajectory of reduction of national GHG emissions, in order to reach goals of -18% to -23% in 2020 (68 to 72 Mt CO2 eq.) (APA, 2019, p. 36).

Table 74 - Characterization of Effluents and Waste (Env 6)

Effluents and Waste (Env 6)	
Env 6.1	**Spills (Sp)**
Description	Percentage of spills measures the proportion of total volume of spills relative to the total effluents discharged (in m3).
Equation	$Sp = \frac{Total\ volume\ of\ spills}{Total\ effluents\ discharged}\ x\ 100$
Range/Ranking	0% 100% >0% to 0.1% 80% >0.1% 60%
Trend	The lower, the better
Justification	Spill is an accidental release of a hazardous substance that can affect human health, land, vegetation, water bodies, and ground water. Material of spill, can be: oil spills (soil or water surfaces), fuel spills (soil or water surfaces), spills of wastes (soil or water surfaces), spills of chemicals (mostly soil or water surfaces), and other (to be specified by the company) (GRI, 2016). Total effluents discharged are the sum of water discharged without need for treatment plus treated water plus washings plus spills plus effluent discharged into the natural environment. In an attempt to define a reasonable ranking for Sp, this indicator was established grounded on the fact that each company should reduce its impact within the community in which it operates. In the investigation made, the data found only reported the number of spills and their volumes.
Env 6.2	**Hazardous industrial residues (Hir)**
Description	Percentage of hazardous industrial residues (waste) measures the proportion of total hazardous residues (waste) weight relative to the total waste weight produced by the company (in Ton).
Equation	$Hir = \frac{Total\ Hazardous\ Industrial\ Residues}{Total\ residues}\ x\ 100$
Range/Ranking	0% to 2% 100% >2% to 10% 80% >10% 60%
Trend	The lower, the better
Justification	This percentage gives insight about the total hazardous industrial residues (waste) produced by the organization. Total residues are the sum of non-hazardous residues plus hazardous residues plus any other type of residue. With the purpose of defining a reasonable ranking for Hir, this indicator was grounded on the fact that each company should reduce its impact in the community in which operates and on sustainability reports. Data obtained: Navigator (2017) had 0.15% of Hir (Navigator, 2017); EDP (2018) had 0.94% (EDP, 2018); Lameirinho (2018) had 1.4% (Lameirinho, 2018) and Sonae (2018) had 2.53% (Sonae, 2018). The 2017 Environment Statistics, from INE, reported that the manufacturing industry, in 2017, was the main waste generating industry, contributing with 29.9% of the total waste generated (INE, 2018).
Env 6.3	**Recycled residues (Rr)**
Description	Percentage of recycled residues (waste) measures the total of recycled residues (waste) relative to the total residues (waste) weight produced by the company (in Ton).
Equation	$Rr = \frac{Recycled\ residues}{Total\ residues}\ x\ 100$
Range/Ranking	0% to 60% 60% >60% to 85% 80% >85% 100%
Trend	The higher, the better
Justification	This percentage gives insight about the recycled residues (waste) in comparison with the total residues (waste) produced by the company. This indicator accounts for the percentage of waste that is sent for recycling or other destinations. So as to define a reasonable ranking for Rr, this author searched for information concerning this subject. In "Car production and Sustainability", VDA reported that 80% of production waste of German automakers was recycled (VDA, n.d.). Also, data was searched in sustainability reports. In 2017, the percentage of recycled residues in Navigator was 84% (Navigator, 2017).

Table 75 - Characterization of Environmental Compliance (Env 7)

Environmental Compliance (Env 7)	
Env 7.1	**Environmental compliance (Ec)**
Description	Environmental compliance measures the number of environmental non-compliance cases (nc), in a year.
Equation	$Ec = Number\ of\ environmental\ non-compliance\ cases$
Range/Ranking	0 to 2 environmental nc 100% >2 to 5 environmental nc 80% >5 environmental nc 60%
Trend	The lower, the better
Justification	Environmental compliance includes the non-compliance cases with laws and regulations in the environmental area. It considers the significant fines and non-monetary sanctions, as well as, the cases brought through dispute resolution mechanisms (GRI, 2016, p. 6). With the purpose of defining a reasonable ranking for Ec, this indicator was established based on the fact that each company purpose is to have a good image in the market, as a transparent and reputable company. Also, taken in consideration was the fact that a company should reduce its impact in the community in which operates.

Table 76 - Characterization of Employment (Soc 1)

Employment (Soc 1)	
Soc 1.1	**Effective contracted employees (Ece)**
Description	Percentage of effective contracted employees measures the number of employees with an effective contract relative to the total number of employees.
Equation	$Ece = \frac{Number\ of\ effective\ contracted\ employees}{Total\ number\ of\ employees}\ x\ 100$
Range/Ranking	Min: 0% Max: 100%
Trend	The higher, the better
Justification	Percentage obtained by direct calculation.
Soc 1.2	**Female employees (Fe)**
Description	Percentage of female employees measures the number of female employees relative to the total number of employees.
Equation	$Fe = \frac{Number\ of\ female\ employees}{Total\ number\ of\ employees}\ x\ 100$
Range/Ranking	0% to 25% 60% >25% to 50% 80% >50% 100%
Trend	The higher, the better
Justification	In order to define a reasonable ranking for female employees percentage, this author searched for it in reference companies . EDP had 24% of female employees (in its sustainability report) (EDP, 2017, p. 43)
Soc 1.3	**Women in management (Wim)**
Description	Percentage of women in management measures the number of women in management relative to the total number of employees in management.
Equation	$Wim = \frac{Number\ of\ women\ in\ management}{Total\ number\ of\ employees\ in\ managment}\ x\ 100$
Range/Ranking	0% to 25% 60% >25% to 50% 80% >50% 100%
Trend	The higher, the better
Justification	So as to define a rational ranking for women in management, this author searched for data. The 2019 INE report, of "Sustainable Development Goals - Indicators for Portugal – Agenda 2030" depicted that the proportion of women in managerial positions compared to men in the same situation, in 2018, for "Top managers of first degree" was 39% (INE, 2019a, p. 130). For this indicator, and for 2016, it was also found for EDP company a percentage of 25% of women in management (EDP, 2016, p. 37).
Soc 1.4	**Employee turnover (Et)**
Description	Percentage of employee turnover measures the proportion of employees who left the organization relative to the total number of employees.
Equation	$Et = 1 - \frac{Number\ of\ employees\ who\ left\ the\ organization}{Total\ number\ of\ employees}\ x\ 100$
Range/Ranking	Min: 0% Max: 100%
Trend	The higher, the better
Justification	This percentage will present low values, as shown in 2018 social report from attorney general's office (prosecutor's office): the turnover rate was 14.02% (MP, 2018). Therefore, the relative Et is inversely related to the Et (1-Et).

Table 77 - Characterization of Occupational Health and safety (Soc 2)

Occupational Health and Safety (Soc 2)	
Soc 2.1	**Absenteeism (Ab)**
Description	Percentage of absenteeism measures the proportion of total number of days in absence/ lost of all employees, relative to the total number of workable days. Total number of workable days = Annual number of working days x Total number of employees.
Equation	$Ab = \frac{Total\ number\ of\ days\ in\ absence\ (or\ lost)}{Total\ number\ of\ workable\ days}\ x\ 100$
Range/Ranking	0% to 5% 100% >5% to 10% 80% >10% 60%
Trend	The lower, the better
Justification	So as to define a rational ranking for absenteeism, this author searched for data. The 2018 report of attorney general's office from prosecutor's office depicted an absenteeism rate of 4.86% (MP, 2018). In Portugal, the rate of absenteeism has remained stable, at about 7% between 2003 and 2007 (EUROFOUND, 2010).
Soc 2.2	**Accidents rate (Ac)**
Description	Accidents rate measures the total number of work-related injuries by the working hours of 100 full-time employees (for a small company) or 500 full-time employees (for a big company), in one year, relative to the total number of hours worked by all employees.
Equation	$Ac = \frac{Number\ of\ work-related\ injuries}{Number\ of\ hours\ worked}\ x\ (200.000\ or\ 1.000.000)$
Range/Ranking	0 to 10 100% >10 to 30 80% >30 60%
Trend	The lower, the better
Justification	A rate based on 200.000 hours worked indicates the number of work-related injuries per 100 full-time workers over a one-year timeframe, based on the assumption that one full-time worker works 2.000 hours (20 hours in 50 weeks of work) per year. For example, a rate of 1 means that, on average, there is one work-related injury for every group of 100 full-time workers over a one-year timeframe. A rate based on 1.000.000 hours worked indicates the number of work-related injuries per 500 full-time workers over a one-year timeframe (GRI, 2018). In order to define a reasonable ranking for accidents rate, data was searched in companies' sustainability reports: Navigator (2017): 9.5 accidents per million hours worked (Navigator, 2017); Lameirinho (2018): 10.7 accidents per million hours worked (Lameirinho, 2018).
Soc 2.3	**Fatalities (Fa)**
Description	Percentage of fatalities measures the number of fatalities work related relative to the total number of work-related injuries.
Equation	$Fa = \frac{Number\ of\ work\ related\ fatalities}{Number\ of\ work-related\ injuries}\ x\ 100$
Range/Ranking	0% to 5% 100% >5% to 10% 80% >10% 60%
Trend	The lower, the better
Justification	In order to define a rational ranking for fatalities, data was searched in companies' sustainability reports. Fortunately, most sustainability reports researched did not reported any fatality. The sustainability report from EDP (2015) reported 2.04% (1 fatality in 49 accidents) (EDP, 2015).

Table 78 - Characterization of Training and Development (Soc 3)

Training and Development (Soc 3)	
Soc 3.1	**Budget in training and development (Btd)**
Description	Percentage of budget in training and development measures the proportion of the company investment in training and development relative to the total amount of revenues (in €).
Equation	$Btd = \frac{Investment\ in\ training\ and\ development}{Total\ amount\ of\ Revenus}\ x\ 100$
Range/Ranking	0% to 0.02% 60% >0,02% to 0.5% 80% >0.5% 100%
Trend	The higher, the better
Justification	This percentage shows the company commitment in investing in their employees training and development. With the purpose of defining a rational ranking for Btd, data was searched in sustainability reports. Data obtained: Galp (2018) had invested 0.02% (Galp, 2018); EDP (2018) had invested 0.03% (EDP, 2018) and Bosch (2016) had invested 0.17% (Bosch, 2016).
Soc 3.2	**Training and development hours (Tdh)**
Description	Percentage of training and development hours measures the proportion of total number of training and development hours of employees relative to the total number working hours.
Equation	$Tdh = \frac{Total\ number\ of\ training\ and\ development\ hours}{Total\ number\ of\ working\ hours}\ x\ 100$
Range/Ranking	0% to 2% 60% >2% to 4% 80% >4% 100%
Trend	The higher, the better
Justification	According to Guerreiro (2019a), and the annual hours of training: Workers are entitled to a minimum of 35 hours of continuous training per year (Article 131.º, n.º 1, paragraph b) from work code). 35 hours are equivalent to 1 week in 48 weeks, considering 4 weeks of annual vacation, thus representing 2% of hours per year. With the aim of defining a reasonable ranking for Tdh, data was searched in sustainability reports. Data obtained: Galp (2018): 0.87% (Galp, 2018); EDP (2018): 0.01% (EDP, 2018); Lameirinho (2018): 0.4% (Lameirinho, 2018).
Soc 3.3	**Employees engagement (Ee)**
Description	This value is obtained by a questionnaire (or similar) assessing the employees' satisfaction, motivation and commitment with company's values.
Equation	—
Range/Ranking	Min: 0% Max: 100%
Trend	The higher, the better
Justification	Percentage obtained in the company questionnaire (or similar).

Table 79 - Characterization of Local Communities (Soc 4)

Local Communities (Soc 4)	
Soc 4.1	**Employees engaged in volunteering (Eeiv)**
Description	Percentage employees engaged in volunteering measures the proportion of employees engaged in volunteering relative to the total number of employees in the company.
Equation	$Eeiv = \frac{Number\ of\ employees\ in\ volunteering}{Total\ number\ of\ employees}\ x\ 100$
Range/Ranking	0% to 10% 60% >10% to 25% 80% >25% 100%
Trend	The higher, the better
Justification	This percentage gives insight about the employees' commitment in contributing for the local community. With the aim of defining a reasonable ranking for Eeiv, data was searched in sustainability reports. Data obtained: Galp (2018): 24.92% (Galp, 2018); EDP (2018): 20% (EDP, 2018).
Soc 4.2	**Donations (Do)**
Description	Percentage of donations measures the proportion of total amount of donations relatively to the total amount of revenus (in €).
Equation	$Do = \frac{Total\ donations}{Total\ amount\ of\ Revenues}\ x\ 100$
Range/Ranking	0% to 0.01% 60% >0.01% to 0.2% 80% >0.2% 100%
Trend	The higher, the better
Justification	This percentage shows the company commitment in contributing for its local community. With the aim of defining a reasonable ranking for Do, data was searched in sustainability reports. Data obtained: Galp (2018): 0.01% (Galp, 2018); EDP (2018): 0.17% (EDP, 2018).; Navigator (2017): 0.12% (Navigator, 2017); Lameirinho (2018): 0.2% (Lameirinho, 2018); Sonae (2018): 0.13% (Sonae, 2018).

Table 80 - Characterization of Socioeconomic Compliance (Soc 5)

Socioeconomic Compliance (Soc 5)	
Soc 5.1	**Socioeconomic compliance (Sec)**
Description	Socioeconomic compliance measures the number of socioeconomic non-compliance cases (nc), in a year.
Equation	$Sec = Number\ of\ socioeconomic\ non-compliance\ cases$
Range/Ranking	0 to 2 socioeconomic nc 100% >2 to 5 socioeconomic nc 80% >5 socioeconomic nc 60%
Trend	The lower, the better
Justification	Socioeconomic compliance includes the non-compliance cases with laws and regulations in the social and economic area. It considers the significant fines and non-monetary sanctions, as well as, the cases brought through dispute resolution mechanisms (GRI, 2016, p. 6).

Appendix H: Rankings definition

Table 81 - Rankings defined and corresponding performance intervals

Economic

Npm - Net Profin Margin

Min	Max	Result
0,00%	1,00%	60,00%
1,01%	5,00%	80,00%
5,01%	100,00%	100,00%

RDI - Research, develop. and innov.

Min	Max	Result
0,00%	1,00%	60,00%
1,01%	3,00%	80,00%
3,01%	100,00%	100,00%

Selw - Standard entry level wage

Min	Max	Result
100,00%	110,00%	60,00%
110,01%	120,00%	80,00%
120,01%	200,00%	100,00%

Lsm - Local senior management

Min	Max	Result
0,00%	40,00%	60,00%
40,01%	80,00%	80,00%
80,01%	100,00%	100,00%

Sls - Spending on local suppliers

Min	Max	Result
0,00%	35,00%	60,00%
35,01%	70,00%	80,00%
70,01%	100,00%	100,00%

Social

Fe - Female Employees

Min	Max	Result
0,00%	25,00%	60,00%
25,01%	50,00%	80,00%
50,01%	100,00%	100,00%

Wim - Women in management

Min	Max	Result
0,00%	25,00%	60,00%
25,01%	50,00%	80,00%
50,01%	100,00%	100,00%

Ab - Absenteeism

Min	Max	Result
0,00%	5,00%	100,00%
5,01%	10,00%	80,00%
10,01%	100,00%	60,00%

Ac - Accidents Rate

Min	Max	Result
0,00	10,00	100,00%
10,01	30,00	80,00%
30,01		60,00%

Fa - Fatalities

Min	Max	Result
0,00%	5,00%	100,00%
5,01%	10,00%	80,00%
10,01%	100,00%	60,00%

Btd - Budget in training and development

Min	Max	Result
0,00%	0,02%	60,00%
0,021%	0,50%	80,00%
0,501%	100,00%	100,00%

Tdh - Training and development hours

Min	Max	Result
0,00%	2,00%	60,00%
2,01%	4,00%	80,00%
4,01%	100,00%	100,00%

Eeiv - Employees engaged in volunteering

Min	Max	Result
0,00%	10,00%	60,00%
10,01%	25,00%	80,00%
25,01%	100,00%	100,00%

Do - Donations

Min	Max	Result
0,00%	0,010%	60,00%
0,011%	0,20%	80,00%
0,201%	100,00%	100,00%

Sec - Socioeconomic compliance

Min	Max	Result
0	2	100,00%
3	5	80,00%
6		60,00%

Environmental

Rim - Recycled input materials used

Min	Max	Result
0,00%	25,00%	60,00%
25,01%	50,00%	80,00%
50,01%	100,00%	100,00%

Re - Renewable energy

Min	Max	Result
0,00%	25,00%	60,00%
25,01%	50,00%	80,00%
50,01%	100,00%	100,00%

Wu - Water used

Min	Max	Result
0,00%	25,00%	60,00%
25,01%	50,00%	80,00%
50,01%	100,00%	100,00%

Rrw - Recycled and reused water

Min	Max	Result
0,00%	25,00%	60,00%
25,01%	50,00%	80,00%
50,01%	100,00%	100,00%

Nwnr - Net water needs reduction

Min	Max	Result
-100,00%	1,00%	60,00%
1,01%	3,00%	80,00%
3,01%	100,00%	100,00%

Bi -Biodiversity investment

Min	Max	Result
0,00%	0,02%	60,00%
0,021%	0,05%	80,00%
0,051%	100,00%	100,00%

GHGei - GHG emissions intensity

Min	Max	Result
0,00	0,20	100,00%
0,201	0,40	80,00%
0,401		60,00%

GHGer - GHG emissions reduction

Min	Max	Result
-100,00%	1,00%	60,00%
1,01%	5,00%	80,00%
5,01%	100,00%	100,00%

Sp - Spills

Min	Max	Result
0,00%	0,00%	100,00%
0,01%	0,10%	80,00%
0,11%	100,00%	60,00%

Hir - Hazardous industrial residues

Min	Max	Result
0,00%	2,00%	100,00%
2,01%	10,00%	80,00%
10,01%	100,00%	60,00%

Rr - Recycled residues

Min	Max	Result
0,00%	60,00%	60,00%
60,01%	85,00%	80,00%
85,01%	100,00%	100,00%

Ec - Environmental compliance

Min	Max	Result
0	2	100,00%
3	5	80,00%
6		60,00%

Appendix I: BOPSE tests carried out with performance intervals

Table 82 - BOPSE test considering a low performance

ECONOMIC (5)	60,00%	ENVIRONMENTAL (14)	60,00%	SOCIAL (13)	60,00%
Economic Performance (Eco. 1)	60,00%	**Materials (Env. 1)**	60,00%	**Employment (Soc. 1)**	60,00%
Net Profit (in €)	1500000	Total materials incorporated in final product (Ton)	3000	Number of effective contracted employees	420
Total amount of Revenues (in €)	150000000	Total input materials (Ton)	5000	Total number of employees	700
Net profit margin (Eco 1.1)	60,00%	**Materials used (Env 1.1)**	60,00%	**Effective contracted employees (Soc 1.1)**	60,00%
Total Amount of RDI (in €)	1000000	Total recycled input materials used (Ton)	1250	Number of female employees	175
Total amount of Revenues (in €)	150000000	Total input materials (Ton)	5000	Total number of employees	700
Research, Development and Innovation (RDI) (Eco 1.2)	60,00%	**Recycled input materials used (Env 1.2)**	60,00%	**Female employees (Soc 1.2)**	60,00%
Market Presence (Eco. 2)	60,00%	**Energy (Env. 2)**	60,00%	Number of women in management	2
Entry level wage (in €)	557	Energy consumption in the factory (GJ)	24000	Total number of employees in managment	10
Local minimum wage (in €)	557	Total energy consumption (GJ)	40000	**Women in management (Soc 1.3)**	60,00%
Standard entry level wage (Eco 2.1)	60,00%	**Useful Energy (Env 2.1)**	60,00%	Number employees who left company	280
Number of Top managers from local community	4	Renewable energy used (GJ)	10000	Total number of employees	700
Number of Top managers	10	Total energy consumption (GJ)	40000	**Employee turnover (Soc 1.4)**	60,00%
Local senior management (Eco 2.2)	60,00%	**Renewable energy (Env 2.2)**	60,00%	**Occupational Health and Safety (Soc. 2)**	60,00%
Procurement (Eco. 3)	60,00%	**Water (Env. 3)**	60,00%	Total number of days absence (lost)	21000
Spending on local suppliers (in €)	3500000	Water consumption in the factory (m3)	6200	Total number of workable days	200000
Global spending on suppliers (in €)	10000000	Total water consumption (m3)	25000	**Absenteeism (Soc 2.1)**	60,00%
Spending on local suppliers (Eco 3.1)	60,00%	**Water used (Env 3.1)**	60,00%	Number of work-related injuries	46
		Total recycled and reused water (m3)	6200	Number of hours worked	1500000
Input Data		Total water consumption (m3)	25000	**Accidents rate (Soc 2.2)**	60,00%
Calculated Value		**Recycled and reused water (Env 3.2)**	60,00%	Number of work related fatalities	5
		Current year water consumption (m3)	25000	Number of work-related injuries	46
		Previous year water consumption (m3)	24000	**Fatalities (Soc 2.3)**	60,00%
		Net water needs reduction (Env 3.3)	60,00%	**Training and development (Soc. 3)**	60,00%
		Biodiversity (Env. 4)	60,00%	Investment in training and development (€)	31000
		Total amount invested on biodiversity (in €)	31400	Total amount of Revenues (in €)	150000000
		Total amount of Revenues (in €)	150000000	**Budget in training and development (Soc 3.1)**	60,00%
		Biodiversity Investment (Env 4.1)	60,00%	Total number of training and development hours	30100
		Emissions (Env. 5)	60,00%	Total number of working hours	1500000
		Total GHG Emissions (Kg CO2 e)	60200000	**Training and development (Soc 3.2)**	60,00%
		Total amount of Revenues (in €)	150000000	**Employees engagement (Soc 3.3)**	60,00%
		GHG Emissions intensity (Env 5.1)	60,00%	**Local Communities/Society (Soc. 4)**	60,00%
		Current year emissions (Kg CO2 e)	60200000	Number of employees in volunteering	70
		Previous year emissions (Kg CO2 e)	60000000	Total number of employees	700
		GHG Emissions reduction (Env 5.2)	60,00%	**Employees engaged in volunteering (Soc 4.1)**	60,00%
		Effluents and Waste (Env. 6)	60,00%	Total donations (€)	16499
		Total volume of Spills (m3)	1,1	Total amount of Revenues (in €)	150000000
		Total effluents dischared (m3)	1000	**Donations (Soc 4.2)**	60,00%
		Spills (Env 6.1)	60,00%	**Socioeconomic Compliance (Soc.5)**	60,00%
		Total Hazardous Industrial Residues (Ton)	121	Number of socioeconomic non-compliance cases	6
		Total volume of residues (Ton)	1200	**Socioeconomic Compliance (Soc 5.1)**	60,00%
		Hazardous Industrial Residues (Env 6.2)	60,00%		
		Recycled residues (Ton)	720	**OEE**	**60,01%**
		Total volume of residues (Ton)	1200	Availability	84,35%
		Recycled Residues (Env 6.3)	60,00%	Performance	84,35%
		Environmental Compliance (Env.7)	60,00%	Quality	84,35%
		Number of environmental non-compliance cases	6	**SUSTAINABILITY (Eco*Env*Soc)**	**21,60%**
		Environmental Compliance (Env 7.1)	60,00%	**BOPSE = (Sustainability + OEE)/2**	**40,81%**

Table 83 - BOPSE test considering a medium performance

ECONOMIC (5)	80,00%	ENVIRONMENTAL (14)	80,00%	SOCIAL (13)	80,00%
Economic Performance (Eco. 1)	80,00%	Materials (Env. 1)	80,00%	Employment (Soc. 1)	80,00%
Net Profit (in €)	5600000	Total materials incorporated in final product (Ton)	4000	Number of effective contracted employees	560
Total amount of Revenues (in €)	150000000	Total input materials (Ton)	5000	Total number of employees	700
Net profit margin (Eco 1.1)	80,00%	Materials used (Env 1.1)	80,00%	Effective contracted employees (Soc 1.1)	80,00%
Total Amount of RDI (in €)	4000000	Total recycled input materials used (Ton)	2500	Number of female employees	350
Total amount of Revenues (in €)	150000000	Total input materials (Ton)	5000	Total number of employees	700
Research, Development and Innovation (RDI) (Eco 1.2)	80,00%	Recycled input materials used (Env 1.2)	80,00%	Female employees (Soc 1.2)	80,00%
Market Presence (Eco. 2)	80,00%	Energy (Env. 2)	80,00%	Number of women in management	5
Entry level wage (in €)	613	Energy consumption in the factory (GJ)	32000	Total number of employees in managment	10
Local minimum wage (in €)	557	Total energy consumption (GJ)	40000	Women in management (Soc 1.3)	80,00%
Standard entry level wage (Eco 2.1)	80,00%	Useful Energy (Env 2.1)	80,00%	Number employees who left company	140
Number of Top managers from local community	8	Renewable energy used (GJ)	20000	Total number of employees	700
Number of Top managers	10	Total energy consumption (GJ)	40000	Employee turnover (Soc 1.4)	80,00%
Local senior management (Eco 2.2)	80,00%	Renewable energy (Env 2.2)	80,00%	Occupational Health and Safety (Soc. 2)	80,00%
Procurement (Eco. 3)	80,00%	Water (Env. 3)	80,00%	Total number of days absence (lost)	20000
Spending on local suppliers (in €)	7000000	Water consumption in the factory (m3)	12000	Total number of workable days	200000
Global spending on suppliers (in €)	10000000	Total water consumption (m3)	25000	Absenteeism (Soc 2.1)	80,00%
Spending on local suppliers (Eco 3.1)	80,00%	Water used (Env 3.1)	80,00%	Number of work-related injuries	16
		Total recycled and reused water (m3)	12000	Number of hours worked	1500000
Input Data		Total water consumption (m3)	25000	Accidents rate (Soc 2.2)	80,00%
Calculated Value		Recycled and reused water (Env 3.2)	80,00%	Number of work related fatalities	1
		Current year water consumption (m3)	25000	Number of work-related injuries	16
		Previous year water consumption (m3)	25500	Fatalities (Soc 2.3)	80,00%
		Net water needs reduction (Env 3.3)	80,00%	Training and development (Soc. 3)	80,00%
		Biodiversity (Env. 4)	80,00%	Investment in training and development (€)	500000
		Total amount invested on biodiversity (in €)	76000	Total amount of Revenues (in €)	150000000
		Total amount of Revenues (in €)	150000000	Budget in training and development (Soc 3.1)	80,00%
		Biodiversity Investment (Env 4.1)	80,00%	Total number of training and development hours	50000
		Emissions (Env. 5)	80,00%	Total number of working hours	1500000
		Total GHG Emissions (Kg CO2 e)	35000000	Training and development (Soc 3.2)	80,00%
		Total amount of Revenues (in €)	150000000	Employees engagement (Soc 3.3)	80,00%
		GHG Emissions intensity (Env 5.1)	80,00%	Local Communities/Society (Soc. 4)	80,00%
		Current year emissions (Kg CO2 e)	35000000	Number of employees in volunteering	175
		Previous year emissions (Kg CO2 e)	35500000	Total number of employees	700
		GHG Emissions reduction (Env 5.2)	80,00%	Employees engaged in volunteering (Soc 4.1)	80,00%
		Effluents and Waste (Env. 6)	80,00%	Total donations (€)	202000
		Total volume of Spills (m3)	1	Total amount of Revenues (in €)	150000000
		Total effluents discharded (m3)	1000	Donations (Soc 4.2)	80,00%
		Spills (Env 6.1)	80,00%	Socioeconomic Compliance (Soc.5)	80,00%
		Total Hazardous Industrial Residues (Ton)	25	Number of socioeconomic non-compliance cases	5
		Total volume of residues (Ton)	1200	Socioeconomic Compliance (Soc 5.1)	80,00%
		Hazardous Industrial Residues (Env 6.2)	80,00%		
		Recycled residues (Ton)	1020	OEE	80,00%
		Total volume of residues (Ton)	1200	Availability	92,83%
		Recycled Residues (Env 6.3)	80,00%	Performance	92,83%
		Environmental Compliance (Env.7)	80,00%	Quality	92,83%
		Number of environmental non-compliance cases	3	SUSTAINABILITY (Eco*Env*Soc)	51,20%
		Environmental Compliance (Env 7.1)	80,00%	BOPSE = (Sustainability + OEE)/2	65,60%

Table 84 - BOPSE test considering a high performance

ECONOMIC (5)	**100,00%**	**ENVIRONMENTAL (14)**	**100,00%**	**SOCIAL (13)**	**100,00%**
Economic Performance (Eco. 1)	100,00%	**Materials (Env. 1)**	100,00%	**Employment (Soc. 1)**	100,00%
Net Profit (in €)	10000000	Total materials incorporated in final product (Ton)	5000	Number of effective contracted employees	700
Total amount of Revenues (in €)	150000000	Total input materials (Ton)	5000	Total number of employees	700
Net profit margin (Eco 1.1)	100,00%	**Materials used (Env 1.1)**	100,00%	**Effective contracted employees (Soc 1.1)**	100,00%
Total Amount of RDI (in €)	5000000	Total recycled input materials used (Ton)	5000	Number of female employees	351
Total amount of Revenues (in €)	150000000	Total input materials (Ton)	5000	Total number of employees	700
Research, Development and Innovation (RDI) (Eco 1.2)	100,00%	**Recycled input materials used (Env 1.2)**	100,00%	**Female employees (Soc 1.2)**	100,00%
Market Presence (Eco. 2)	100,00%	**Energy (Env. 2)**	100,00%	Number of women in management	6
Entry level wage (in €)	669	Energy consumption in the factory (GJ)	39999	Total number of employees in managment	10
Local minimum wage (in €)	557	Total energy consumption (GJ)	40000	**Women in management (Soc 1.3)**	100,00%
Standard entry level wage (Eco 2.1)	100,00%	**Useful Energy (Env 2.1)**	100,00%	Number employees who left company	0
Number of Top managers from local community	9	Renewable energy used (GJ)	40000	Total number of employees	700
Number of Top managers	10	Total energy consumption (GJ)	40000	**Employee turnover (Soc 1.4)**	100,00%
Local senior management (Eco 2.2)	100,00%	**Renewable energy (Env 2.2)**	100,00%	**Occupational Health and Safety (Soc. 2)**	100,00%
Procurement (Eco. 3)	100,00%	**Water (Env. 3)**	100,00%	Total number of days absence (lost)	10000
Spending on local suppliers (in €)	7500000	Water consumption in the factory (m3)	24900	Total number of workable days	200000
Global spending on suppliers (in €)	10000000	Total water consumption (m3)	25000	**Absenteeism (Soc 2.1)**	100,00%
Spending on local suppliers (Eco 3.1)	100,00%	**Water used (Env 3.1)**	100,00%	Number of work-related injuries	10
		Total recycled and reused water (m3)	12700	Number of hours worked	1500000
Input Data		Total water consumption (m3)	25000	**Accidents rate (Soc 2.2)**	100,00%
Calculated Value		**Recycled and reused water (Env 3.2)**	100,00%	Number of work related fatalities	0
		Current year water consumption (m3)	25000	Number of work-related injuries	10
		Previous year water consumption (m3)	26000	**Fatalities (Soc 2.3)**	100,00%
		Net water needs reduction (Env 3.3)	100,00%	**Training and development (Soc. 3)**	100,00%
		Biodiversity (Env. 4)	100,00%	Investment in training and development (€)	752000
		Total amount invested on biodiversity (in €)	77000	Total amount of Revenues (in €)	150000000
		Total amount of Revenues (in €)	150000000	**Budget in training and development (Soc 3.1)**	100,00%
		Biodiversity Investment (Env 4.1)	100,00%	Total number of training and development hours	60500
		Emissions (Env. 5)	100,00%	Total number of working hours	1500000
		Total GHG Emissions (Kg CO2 e)	4000000	**Training and development (Soc 3.2)**	100,00%
		Total amount of Revenues (in €)	150000000	**Employees engagement (Soc 3.3)**	100,00%
		GHG Emissions intensity (Env 5.1)	100,00%	**Local Communities/Society (Soc. 4)**	100,00%
		Current year emissions (Kg CO2 e)	4000000	Number of employees in volunteering	176
		Previous year emissions (Kg CO2 e)	4300000	Total number of employees	700
		GHG Emissions reduction (Env 5.2)	100,00%	**Employees engaged in volunteering (Soc 4.1)**	100,00%
		Effluents and Waste (Env. 6)	100,00%	Total donations (€)	302000
		Total volume of Spills (m3)	0,09	Total amount of Revenues (in €)	150000000
		Total effluents discharded (m3)	1000	**Donations (Soc 4.2)**	100,00%
		Spills (Env 6.1)	100,00%	**Socioeconomic Compliance (Soc.5)**	100,00%
		Total Hazardous Industrial Residues (Ton)	24	Number of socioeconomic non-compliance cases	2
		Total volume of residues (Ton)	1200	**Socioeconomic Compliance (Soc 5.1)**	100,00%
		Hazardous Industrial Residues (Env 6.2)	100,00%		
		Recycled residues (Ton)	1025	**OEE**	**100,00%**
		Total volume of residues (Ton)	1200	Availability	100,00%
		Recycled Residues (Env 6.3)	100,00%	Performance	100,00%
		Environmental Compliance (Env.7)	100,00%	Quality	100,00%
		Number of environmental non-compliance cases	1	**SUSTAINABILITY (Eco*Env*Soc)**	**100,00%**
		Environmental Compliance (Env 7.1)	100,00%	**BOPSE = (Sustainability + OEE)/2**	**100,00%**