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STÉFANO CIANNELLA

THE INFLUENCE OF LEAN PRACTICES ON EMPLOYEE SOCIAL SUSTAINABILITY: AN EXPLORATORY STUDY

JOÃO PESSOA

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Research advisor: Luciano Costa Santos, D.Sc.

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This dissertation was evaluated and approved in its present version as the final requirement for the degree of Master of Production Engineering at the Federal University of Paraíba, Brazil.

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To the reader.

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Believe me, remembering is the least evil. No one should trust present happiness, there's a drop of Cain's drivel in it.

Machado de Assis

RESUMO

A sustentabilidade corporativa e a manufatura enxuta (*lean*) têm sido extensivamente associadas visando à prospecção e o desenvolvimento de ganhos de natureza ambiental. Os aspectos teóricos da dimensão social da sustentabilidade, assim como sua operacionalidade, apresentam-se pouco desenvolvidos nos estudos relacionados ao *lean* sustentável. Sustentabilidade social no chão-de-fábrica em ambientes produtivos pode ser traduzida como sustentabilidade social de trabalhadores (SST), que é um tópico emergente devido à sua capacidade de se apresentar como uma alavanca para o desenvolvimento de sustentabilidade corporativa em níveis hierárquicos de base. Ainda assim, aspectos operacionais da SST são invulgarmente estudados. Nesse contexto, esta dissertação aborda e investiga a influência de práticas de manufatura *lean* em dimensões de sustentabilidade social de trabalhadores. Dado o estado ainda inaugural da discussão *lean*-SST, um estudo exploratório foi delineado, pautado em duas etapas: na primeira, buscaram-se evidências de tal relação por meio da aplicação de procedimentos de revisão sistemática da literatura e, no segundo momento, realizou-se a aplicação do processo hierárquico analítico (AHP) para relacionar SST às práticas *lean* com base na opinião de especialistas. A revisão da literatura gerou vinte e três conexões entre oito práticas *lean* e quatro dimensões de SST, o que permitiu a construção de um modelo AHP para o cálculo adequado de prioridades entre práticas *lean* e dimensões sociais. A dimensão "saúde e segurança" foi considerada como a mais crítica para o estabelecimento de SST no chão-de-fábrica, e o 5S como a prática com maior influência geral nas dimensões consideradas. Este estudo contribuiu para incorporar a noção de práticas *lean* como facilitadoras da SST, em particular, para oferecer uma noção de quais práticas devem ser priorizadas ao longo de um processo de implementação do *lean* com benefícios sociais aos trabalhadores. Complementarmente, através da aplicação do AHP, identificaram-se conexões *lean*-SST não abordadas na literatura, oferecendo uma base para futuras investigações.

Palavras-chave: manufatura *lean*; sustentabilidade corporativa; sustentabilidade social de trabalhadores; trabalhadores; processo hierárquico analítico.

ABSTRACT

Corporate sustainability and lean manufacturing have been linked in late research with a major interest in environmental benefits, leaving the theoretical insights and the practicality of the social sphere of sustainability considerably underdeveloped. Social sustainability on the shop floor of productive systems can be translated to employee social sustainability (ESS), which is an emerging topic given its potential to leverage corporate sustainability at the bottom line. However, procedural aspects of ESS are still ill-explored. Addressing this gap, this dissertation investigates the influence of lean manufacturing practices on dimensions of employee social sustainability, which enabled the identification of the most critical practices. Given the incipient stage of the present disclosure, an exploratory study was conducted in two phases: first, seeking evidence in the literature through means of a systematic literature review, and second, applying the analytic hierarchy process (AHP) to connect ESS to lean practices based on expert opinion. From the systematic review, 23 links were found bridging the gap between eight lean practices and four dimensions of employee social sustainability. Based on these pieces of evidence, an AHP model was designed to calculate priorities among lean practices and social dimensions. Relying on expert opinion, "health and safety" was assessed as the most critical social dimension, and 5S was rated the most influential lean practice on ESS overall. This study contributed to introducing the perspective of lean practices as enablers of ESS. Particularly, it pointed which specific practices should be prioritized in the lean implementation process with social sustainability purposes. Additionally, it identified unreported connections in the literature, thus building a basis for further investigation.

Keywords: Lean manufacturing; corporate sustainability; employee social sustainability; employee social sustainability; employee; analytic hierarchy process.

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LIST OF ABBREVIATIONS

AHP	*Analytic hierarchy process*
AHP-GDM	*Analytic hierarchy process-Group decision making*
AIP	*Aggregation of individual priorities*
AIJ	*Aggregation of individual judgements*
ANP	*Analytic network process*
CI	*Consistency index*
CR	*Consistency ratio*
DEMATEL	*Decision-making trial and evaluation laboratory*
ESS	*Employee social sustainability*
GTA	*Graph-theoretic approach*
HRM	*Human resources management*
LP	*Lean practice*
MCDA	*Multiple-criteria decision analysis*
RI	*Random consistency index*
SLR	*Systematic literature review*
TBL	*Triple bottom line*
TPM	*Total productive maintenance*
TPS	*Toyota production system*
VSM	*Value stream mapping*
WCED	*World Commission on Environment and Development*

LIST OF SYMBOLS

m	*Number of judges*
n	*Number of alternatives*
β_k	*Weight of the judge*
$w_i^{[k]}$	*Vector of individual priorities*
$w^{[G]}$	*Vector of group priorities*
λ_{MAX}	*Maximum value in the priorities vector*
W	*Kendall's coefficient of concordance*
S	*Squared deviation of the sum of judgements*
R	*Sum of judgements*
$\bar{R}$	*Mean of sum of judgements*
T	*Correction factor of* W *for tied judgements*
t	*Number of tied judgements*
χ^2	*Chi-squared probability distribution*
α	*Significance level*

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INTRODUCTION

1.1 Research theme and scope

Sustainable lean manufacturing is recently undergoing enthusiastic discussion due to the interest that corporations have in adopting the sustainability strategy into manufacturing (CHERRAFI *et al.*, 2016; BEN RUBEN; VINODH; ASOKAN, 2019; HENAO; SARACHE; GÓMEZ, 2019). Usually, business sustainability is approached following the triple bottom line (TBL) model, which encapsulates three larger dimensions: environmental, economic, and social (ELKINGTON, 1999). The idea of a sustainable lean system has been progressively developed through the basic premise of waste reduction for economic (SHAH; WARD, 2003) and environmental benefits (FARIAS *et al.*, 2019b), along with health and safety issues, and employee empowerment as instances of sources of social improvements (CAMUFFO; DE STEFANO; PAOLINO, 2017).

Social sustainability can be approached from a corporate sustainability perspective of a multi-stakeholder scenario, which is then formed by internal and external entities (GALUPPO *et al.*, 2014). In broader terms, corporate sustainability alludes to organisational efforts that include social and environmental issues aligned with business management and connections with stakeholders. The social dimension of corporate sustainability values collective well-being as the prime concern for organisations (AL MARZOUQI; KHAN; HUSSAIN, 2020), which can be extended to the scope of work in the form of employee social sustainability (ESS). Earlier, Spreitzer and Porath (2012) stated that ESS is defined as the sustaining of a sound and satisfactory workplace through the implementation of sustainable human-resources practices focused on promoting employees' job satisfaction, engagement, and commitment.

The debate on sustainable lean manufacturing as a leverage to achieve sustainable performance has been focused on environmental benefits in considerable research (FLORIDA, 1996; KLEINDORFER; SINGHAL; VAN WASSENHOVE, 2005; CHIARINI, 2014). The linkages between lean manufacturing and the environmental pillar of sustainability have been extensively explored in the literature, given the shared goals of lean and green manufacturing towards eliminating waste (FARIAS *et al.*, 2019b). In contrast, studies investigating the relationship between lean manufacturing and social sustainability are still scarce, despite being considered a fertile field of study by recent research (BHATTACHARYA; NAND; CASTKA, 2019; HENAO; SARACHE; GÓMEZ, 2019) and having workers pointed as a crucial component for improvements in a lean environment (WONG; WONG, 2014).

Exploring the synergies, misalignments and trade-offs between lean practices and sustainable outcomes has not been broadly discussed from an integrated sustainable perspective

(MARTÍNEZ-LEÓN; CALVO-AMODIO, 2017; BEN RUBEN; VINODH; ASOKAN, 2019), as the social dimension is the least explored by researchers (CHERRAFI *et al.*, 2016; CICCULLO *et al.*, 2018). Moreover, a rather limited number of papers investigate the influence of lean manufacturing practices on ESS (CHERRAFI *et al.*, 2016; BHATTACHARYA; NAND; CASTKA, 2019), leaving literature with a still narrow, and often controversial, body of knowledge regarding how these practices affect employee social outcomes (CAMUFFO; DE STEFANO; PAOLINO, 2017; SALENTIJN; BEIJER; ANTONY, 2021).

Addressing the lean-ESS gap, this dissertation aggregates a set of lean practices (LPs) commonly used on the shop floor as enablers of ESS given their reported linkages in the literature. Since this topic is still in a rather inaugural stage, an exploratory study was conducted following two phases: first, seeking evidence in the literature, and secondly, applying the analytic hierarchy process (AHP) to connect ESS to lean practices and build rankings of relative importance based on expert opinion

1.2 Research questions and path of investigation

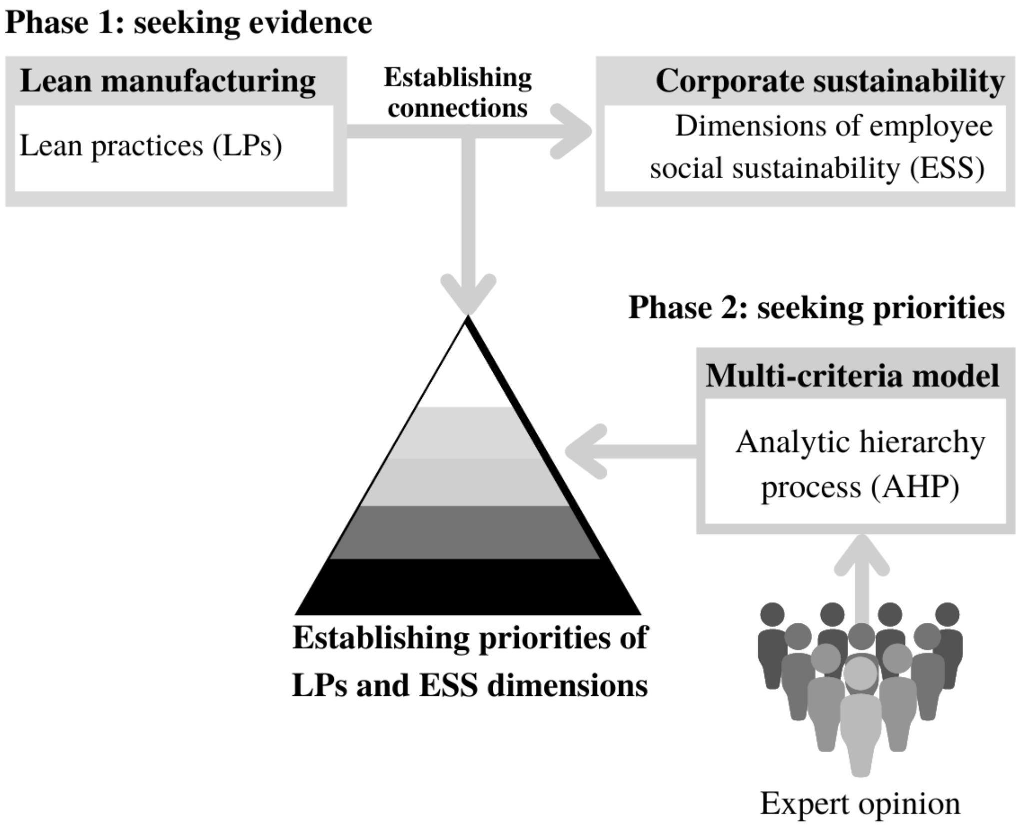
Based on the existing gap in the lean-ESS literature and the low level of awareness on the influence of LPs on ESS dimensions, this study addresses two main research questions:

***RQ*1: What are the connections bridging employee social sustainability dimensions and lean practices that can be found on the shop floor?**

***RQ*2: What is the relative importance among employee social sustainability dimensions and lean practices?**

Figure 1 illustrates the two complementary segments of this dissertation: the first was focused on systematically identifying and extracting lean practices and ESS dimensions, as well as their connections. Then, the second portion aimed at applying a hierarchical model to build rankings of importance of LPs and ESS dimensions based on expert opinion.

Figure 1. Research design



1.3 Research objectives

1.3.1 Main

To investigate, in an exploratory fashion, the influence of lean practices on dimensions of employee social sustainability in terms of quantified priorities organised in a ranking, as a means to better elucidate their role on the social sustainability of a lean-based manufacturing organisation.

1.3.2 Specific

(1) To identify dimensions of employee social sustainability dimensions and lean practices, along with their relationships through a synthesis of lean-ESS literature to date;
(2) To design and apply a multi-criteria decision analysis model for the evaluation of priorities of dimensions of employee social sustainability and lean practices;
(3) To establish priorities of dimensions of employee social sustainability and lean practices using expert opinion.

1.4 Dissertation structure

This dissertation is partitioned into six chapters (Figure 2). Chapter 1 introduces the research theme and scope, and the objectives related to the research questions.

Chapter 2 provides the necessary theoretical background for a decent comprehension of this document, encompassing basic ideas on lean manufacturing and sustainability science, followed by a brief introduction to the concept of employee social sustainability (ESS).

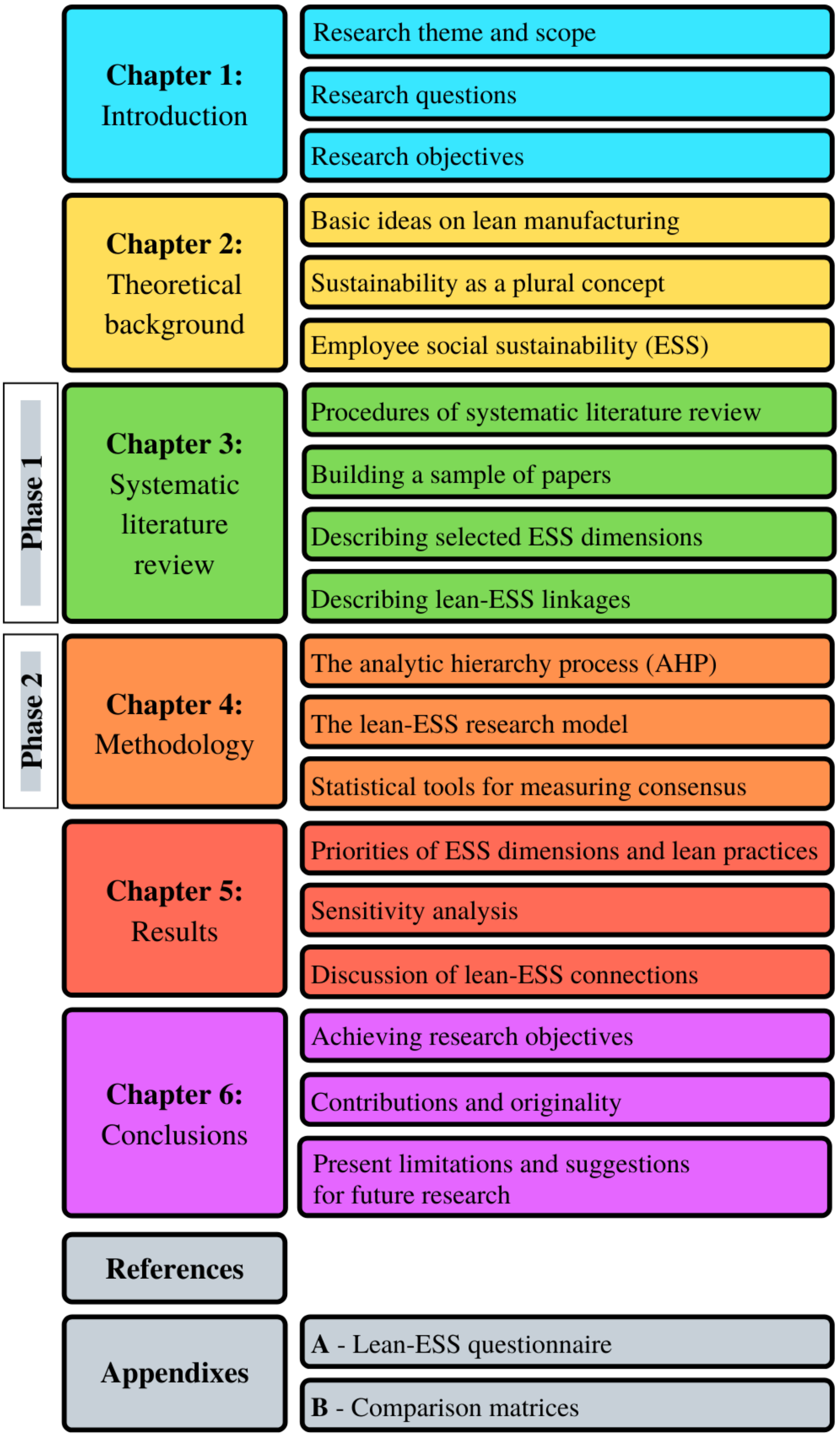
Chapter 3 concerns methodological procedures of the systematic literature review, which characterises Phase 1 of this research, and describes selected ESS dimensions and their connections with lean practices.

Next, Chapter 4 elucidates the design of the lean-ESS research model based on review results (delineating Phase 2), added to the description of a statistical tool used for measuring group consensus.

Chapter 5 presents a thorough presentation and discussion of ESS dimensions and lean practices priorities originated from the application of the research model.

Finally, Chapter 6 recollects the objectives of the study and discusses their accomplishment, main contributions, present limitations, and an agenda for future research.

Figure 2. Chapters and respective main sections



2

THEORETICAL BACKGROUND

2.1 The nuts and bolts of lean manufacturing

The *fons et origo* of lean manufacturing can be traced back to the shop floors of Japanese manufacturers in the first two decades of the post-World War II period, particularly the Toyota Motor Corporation. Moyano-Fuentes and Sacristán-Díaz (2012, p. 551) stated that ‘lean manufacturing first appeared in the Toyota automotive company during the 1950s to tackle smaller markets with a greater variety of vehicles, which required greater production flexibility’. Thus, lean manufacturing is essentially related to the Toyota Production System (TPS), which emerged as a solution for gaining competitiveness through the total elimination of waste (SALENTIJN; BEIJER; ANTONY, 2021).

Along with mitigating waste and creating product flow, the TPS innovated as a management system by levelling production, conceptualising just-in-time deliveries and autonomation, promoting product flow, introducing mistake-proof devices, and improving human resources through the principle of respect-for-people (SUGIMORI *et al.*, 1977).

These elements represented an alternative model to the current production mode based on large batch sizes and inventory maintenance that were commonly employed in North American factories (HINES; HOLWE; RICH, 2004). In Japan, the motivation for this shift was instigated by the negative effects of Fordism on shop-floor employees, namely the alienation of work resulted from monotonous and repetitive tasks, low wages, long working hours, and an intense labour routine (GOTTESMAN, 2016).

Ohno (1988) formulated the purpose of lean as the pursuit of the delivery of a product with the minimum usage of resources that will meet customers' expectations. In the same year, the term ‘lean’ was first used in academic research by John F. Krafcik[1], despite its recognition as a noteworthy solution for improving financial performance since the late 1970s (MOYANO-FUENTES; SACRISTÁN-DÍAZ, 2012; INMAN; GREEN, 2018). Still, there is a considerable debate over a proper definition for lean manufacturing (SHAH; WARD, 2003; PETTERSEN, 2009).

Defining lean is important for introducing its practices and implementing the lean system itself (MARODIN; SAURIN, 2013), with several authors having tackled this issue. De Treville *et al.* (2006) defined it as a complex system whose purpose is to maximise labour utilisation (both human and machine) whilst reducing the process and product variability. In

[1]Krafcik, J.F. (1988), “Triumph of the Lean Production System”, *Sloan Management Review*, Vol. 30 No. 1, pp. 41–52.

line with variability reduction, Shah and Ward (2007, p. 791) extended the concept to 'an integrated socio-technical system whose main objective is to eliminate waste by concurrently reducing or minimising supplier, customer, and internal variability'. Moreover, it is argued that lean is imbued with an efficient value creation process (MOYANO-FUENTES; SACRISTÁN-DÍAZ, 2012). This point of view stems from Ohno (1988) considerations on efficiency, which are explicitly related to value-adding and non-value adding activities.

Kumar, Mathiyazhagan and Mathivathanan (2020) brought a simpler concept for lean that focuses on increasing production by reducing associated costs, namely raw material, utilities and operational costs. The reduction of associated costs is an usual premise for lean manufacturing, which is also emphasised by Yusup *et al.* (2015):

> [Lean manufacturing] has a great influence in controlling and reducing the usage of material and resources in product development, **reducing the operation cost**, controlling the inventory level and requirement, maximise the use of available space, and increase the utilisation of labour. (YUSUP *et al.*, 2015, p. 117, our emphasis).

Martínez-León and Calvo-Amodio (2017) proposed that lean can be distinguished into two different goals: the first is aimed at reducing waste throughout the system, while the second is more concerned with maximising customer value. As for waste, it is simply any system input that is not converted just-in-time to an output valued by customers (THÜRER; TOMAŠEVIĆ; STEVENSON, 2017). These inputs may take the form of human or machine activity and capital investment, for instance.

Despite such an effort to approach lean, the knowledge on lean manufacturing still lacks a general agreement on its definition (PETTERSEN, 2009). One reason for the variety of perspectives on lean stems from its dependence on business dynamics. Attempts to provide a static definition for lean have failed in recognising that production systems are constantly changing their relations with the local environment, economics, politics, advances in technology, and social conditions.

Still, the lean literature has helped to identify activities that are coherent with its philosophy, which promotes waste and buffer minimisation that ultimately leads to a reduction of associated costs.

2.2 First ideas on sustainability

The paradigm of modern sustainability encapsulates a complex trait of intricacy on the pursuit of a generalist concept, which has evolved from an initial issue of timber exploration in the second half of the 16th century, to a progressive global agenda in present days. The idea of 'sustaining' was coined in 1560 from the concern towards the rational use of forests, so that they could be able to self-regenerate and be permanently maintained. In such a context, the German word *Nachhaltigkeit* came out as a verbal translation for such an idea, which means 'lastingness' (DU PISANI, 2006; BOFF, 2012). However, it was only in 1713 with the publication of the book *Sylvicultura Oeconomica oder Anweisung zur wilden Baumzucht,* by Hans Carl von Carlowitz that the term 'sustainability' was given a strategic notion, suggesting alternatives for efficient consumption and reforestation as well.

In 1984, a distinguishing conference was organised as the World Commission on Environment and Development (WCED) whose motto was "A global agenda for change". The discussions and endeavours of this commission concluded in 1987, with its chairman, the Prime Minister of Norway, Gro Harlem Brundtland, having had outlined their insights for the goals of following decades in the report *Our Common Future* (WCED, 1987, p. 41), which contains the distinguished guideline for sustainability as the basis for the 'development that meets the needs of the present without compromising the ability of future generations to meet their own needs and aspirations'.

Despite considerable efforts since the 1980s, there is still an ongoing issue in the sustainability science, and consequently affecting sustainability research, that is the dearth of clarification about the very concept of sustainability, for there are many definitions that are open to interpretation, thus giving sustainability a flexible feature (FEIL; SCHREIBER, 2017).

Lima and Partidario (2020) provide a short commentary on the evolution of the total number of definitions for sustainability in the modern era, amounting from 60 definitions until 1989 to a number close to one hundred in 1997. Table 1 illustrates the plurality of the concept of sustainability by listing twenty definitions in chronologic order of publication since 1987.

Table 1. Definitions of sustainability

Authorship	**Year**	**Definition**
WCED	1987	'development that meets the needs of the present without compromising the ability of future generations to meet their own needs.'
Brown *et al.*	1987	'the persistence of all components of the biosphere, even those with no apparent benefit to humanity.'
Costanza and Patten	1995	'[sustainability] (*i*) means avoiding extinction and living to survive and reproduce, and (*ii*) means avoiding major

Authorship	Year	Definition
		disruptions and collapses, hedging against instabilities and discontinuities.'
Viederman	1995	'a vision of the future that provides us with a road map and helps us focus our attention on a set of values and ethical and moral principles by which to guide our actions.'
Goodland	1995	'[sustainability] seeks to improve human welfare by protecting the sources of raw materials used for human needs and ensuring that the sinks for human wastes are not exceeded, to prevent harm to humans.'
Hart	1997	'to develop a sustainable global economy: an economy that the planet is capable of supporting indefinitely.'
Fricker	1998	'sustainability is presently seen as a delicate balance between the economic, environmental and social health of a community, nation and of course the Earth.'
Caldwell	1998	'physical preservation of human societies and their cultures, institutions, social orders and regimes.'
Elkington	1999	'the principle of ensuring that our actions today do not limit the range of economic, social and environmental options open to future generations.'
US Environmental Protection Agency	2003	'sustainability [is a system that] creates and maintains the 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.'
Du Pisani	2006	'sustainability refers to the necessary reconciliation between the demand for well-being that is associated with the idea of development and the conservation of natural support systems.'
US National Research Council	2011	'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.'
Vadari and Parandker	2011	'refers to the organisation's ability to address current business needs and to have the agility and strategic

Authorship	Year	Definition
		management to prepare successfully for future business, market, and operating environment.’
Baines *et al.*	2012	‘the application of environmentally and socially sensitive practices to reduce the negative impact of manufacturing activities while, at the same time, harmonising the pursuit of economic benefits.’
Boff	2012	‘sustainability is a way of life which demands proper alignment of human practices, restricted potentialities of each biome and the needs of present and future generations.’ (our translation)
Martínez-Jurado and Moyano-Fuentes	2014	‘Meeting a firm’s and stakeholders’ needs without compromising the ability to meet their future needs.’
Longoni and Cagliano	2015	‘at the shop-floor level, sustainability means the creation of more efficient and less costly processes in terms of power and resources usage, which can be translated to environmental sustainability, and keeping decent and adequate working conditions as a means to provide worker well-being (social sustainability).’
Martínez-León and Calvo-Amodio	2017	‘the purpose of sustainability – expected effect – is to meet the needs and aspirations of the present without compromising – or affecting – the ability of future generations to meet their needs; that is, to maintain a state of dynamic equilibrium between the needs and aspirations at present and future states.’
Feil and Schreiber	2017	‘is a process that measures the degree or quality level of the complex human-environmental system in order to evaluate its distance from the sustainable.’
Salas-Zapata and Ortiz-Muñoz	2019	‘(*i*) a set of social-ecological criteria that guide human action, (*ii*) a vision of humankind that is realized through the convergence of the social and ecological objectives of a particular reference system, (*iii*) an object, thing or phenomenon that happens in certain social-ecological systems, and (*iv*) an approach that entails the incorporation of social and ecological variables into the study of an activity, process or human product.’

Sustainability is indeed a wide sphere that encompasses a large number of concepts, and the majority of researchers agree on the idea that there is a lack of consensus on what sustainability means and how to integrate into a production system effectively, thus being a rather pluralist definition which has conceptualizations from ecology, economy, politics and sociology, for instance (BOLIS; MORIOKA; SZNELWAR, 2014).

Lima and Partidario (2020, p. 2) stress its ‘openness and plasticity to every context’, which then leads to a larger perception of how vague and ambiguous the term is. In this sense, sustainability assumes a mutable aspect. Notwithstanding, it is considered common knowledge that sustainability is directly related to an everlasting conception of, or at least long-termed, human and Nature coexistence, and that economy should favour the odds for both sides in a win-win type of relationship. Still, there is much debate amongst researchers regarding to what extent can sustainability assume an epistemological definition (BOLIS; MORIOKA; SZNELWAR, 2014).

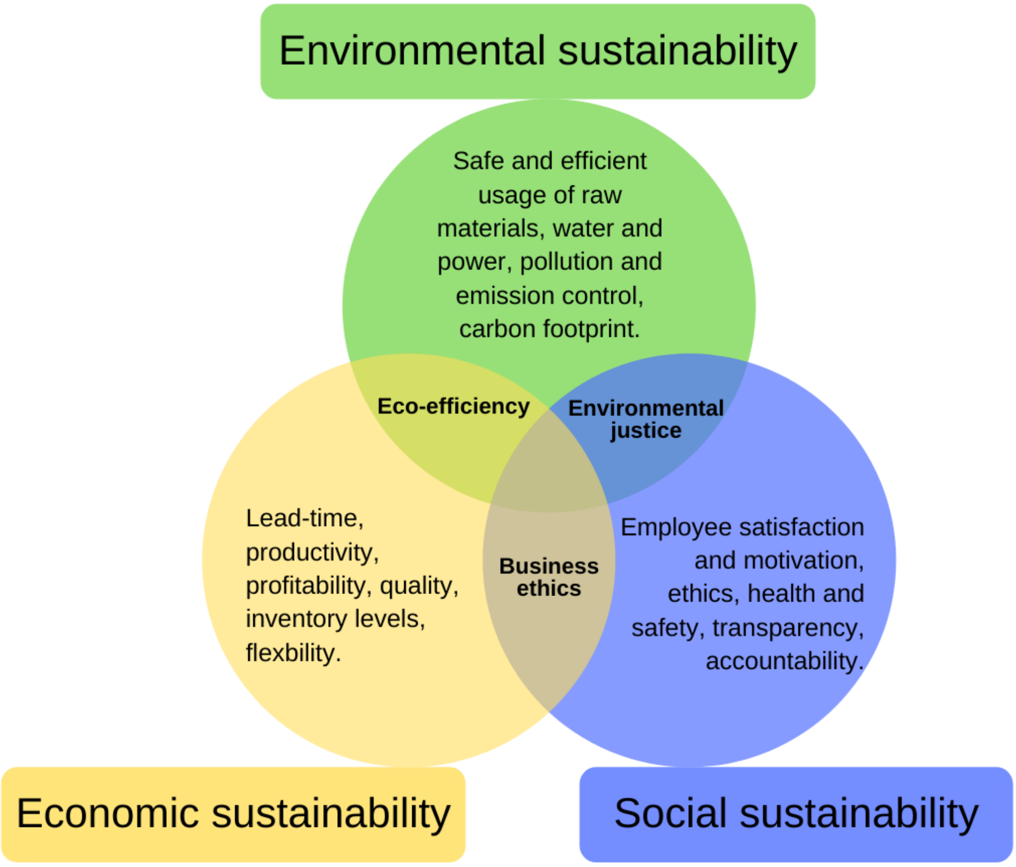
From the aforementioned, it is possible to state that sustainability is surely a polysemous term, with a broad range of definitions thought to fit and answer questions that arise from the ultra-dynamic trait of the socioecological order of Neo-Capitalism (BOFF, 2012). That being considered, interesting queries may arise from the actual debate on sustainability definition: (*i*) to what extent can we define sustainability given that human organisations are daily-based mutable, with corporative actions being moderated by a frequently chaotic and divergent mix of different stakeholders’ demands and needs, and (*ii*) how can one or a group define a term that is based on human-Nature interactions and needs while considering that they are non-steady? Such dynamism of the postmodern society builds up to a high level of complexity for questions related to a healthy human-Nature interaction in present days.

2.2.1 The triple bottom line for sustainable business

The conceptualisation of the triple bottom line model for business sustainability is commonly associated with Elkington (1999), who provided a far-reaching presentation and discussion of the bases on which modern organisations must develop to endure and sustain their businesses in the 21st century. He argued that the methods by which companies measure value should include not only a financial bottom line (profit or loss) but a social and environmental one as well.

Following this premise, Elkington provided an extensive discussion on environmental, economic and social pillars of sustainability, and introduces their ‘shear zones’ that are theoretical overlapping regions between each pillar, namely eco-efficiency (economic and environmental), environmental justice (environmental and social), and business ethics (social and economic). The concept has evolved into one that is often described as three overlapping circles, as depicted in Figure 3.

Figure 3. Triple bottom line model for sustainable business



Source: Adapted from Bhattacharya, Nand and Castka (2019)

The three bottom lines for sustainability are fluid, movable and adaptable, with each bottom line having different levels of importance amongst late capitalism organisations. In fact, ‘the three bottom lines are not stable; they are in constant flux, due to social, political, economic and environmental pressures, cycles and conflicts’ (ELKINGTON, 1999, p. 73).

The TBL model for sustainability can be translated into the threefold goal of keeping its dimensions balanced in a production system: the social dimension (the quality of life and wealth of employees, customers and community as a whole), the environmental dimension (the consideration of carrying capacity of the ecosystem the company is inserted in), and the economic dimension (achieving competitive marks and returns over the assets and inputs that were invested). However, that is not usually the case, for, in the operation of a production system, trade-offs between the three dimensions of sustainability may emerge from influential relationships that specific manufacturing practices might have on each sustainability dimension (FLORIDA, 1996; KLEINDORFER; SINGHAL; VAN WASSENHOVE, 2005; BAUMER-CARDOSO *et al.*, 2020).

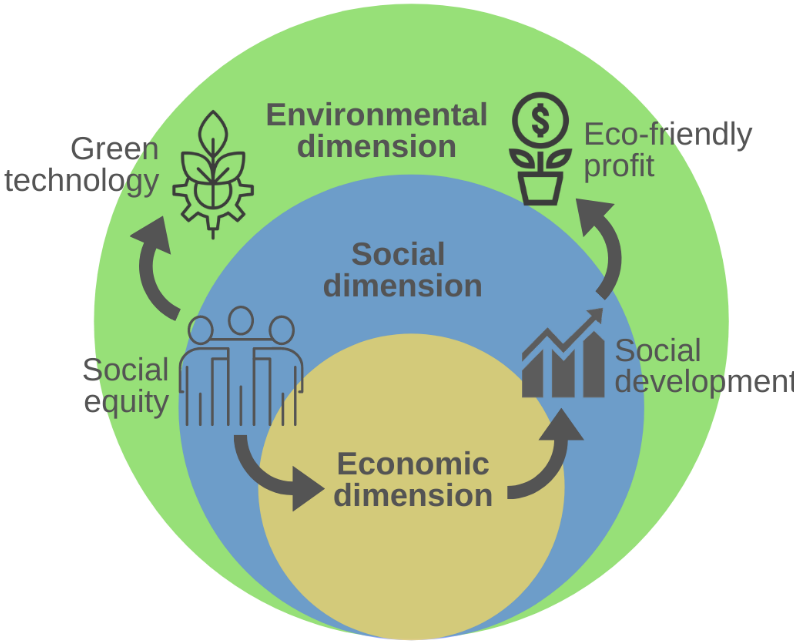
Elkington's work is considered a benchmark in the sustainable business management field. According to Lima and Partidario (2020), the main contribution of the TBL from a practical sense was providing a simplified concept that is feasible and useful for multiple contexts, which solidified a basis for applied sustainability and research. Yet, the novelty surrounding the TBL model is overrated.

Two years before the publication of Elkington's *Cannibal with Forks: the triple bottom line of 21st-century business*, Goodland (1995) had already considered the economic and social aspects of environmental sustainability and described them as small portions of a holistic paradigm that is sustainability. In the words of Goodland (1995):

> The environment has now become a major constraint on human progress. Fundamentally important though social sustainability is, environmental sustainability or maintenance of life-support systems is a prerequisite for social sustainability. […] poverty reduction is the primary goal of sustainable development, even before environmental quality can be fully addressed. […] Poverty reduction has to come from qualitative development, from redistribution and sharing, from population stability, and from community sodality, rather than from throughput growth. (GOODLAND, 1995, p. 1).

Another perspective on the TBL model can be taken upon considering that environment – or planet – as the original structure on which life on its many forms can be supported. This is the level on which everything else depends on everything that comes from Nature. Human society, which is related to the social sustainability dimension, exists within the environment, thus an agent for the development of both environment and the economy. Finally, since the economy emerged from basic societal relationships, it must be under control to build a solid basis for social development and the construction of juster societies. Following this logic, the three overlapping circles in Figure 3 now shape shift into three nested circles as depicted in Figure 4, where the economy is a wholly-owned supplement of the environment (ROSEN, 2018).

Figure 4. Nested relations of sustainability dimensions



Source: Adapted from Rosen (2018)

The concept of sustainability in Engineering is focused on factors that are necessary to be included in the move towards sustainability engineering, which has a considerable impact on environmental development, individual satisfaction, societal well-being, and standards for quality of life (ROSEN, 2018).

Nowadays, the TBL is well disseminated and accepted amongst the academic community and corporations alike, with an increasing number of studies and reports asserting the importance of aligning the three bottom lines for a sustainable business. One conclusion from Bhattacharya, Nand and Castka (2019) is that not enough to measure only the financial, and upper management must consider the societal component of their business through integration with society and fomenting benefits for employees and the community. For the authors, it is expected that a combination of the three dimensions of sustainability positively impacts the development of cleaner modes of production.

2.3 Employee social sustainability in lean

The social dimension of sustainability emerged from an ecological viewpoint of global economic issues faced by many communities. A classic definition for societal sustainability is given by Brown *et al.* (1987) in the same year the Brundtland Commission was being held. The authors' definition is related to maintaining the satisfaction of human needs, such as clear access for basic (food, water, and shelter) and cultural needs (freedom, safety, leisure, and education).

Clearly, it assumed the individual aspect rather than a larger social context. Satisfying essential needs as a benchmark for social sustainability is harmonically associated with Maslow's hierarchy of human needs published in the decade of 1970 and with the work of economist Manfred Max-Neef and his associates (MAX-NEEF; HOPENHAYN; HAMRELL, 1992).

Two main approaches exist to conduct studies on corporate sustainability from a multi-stakeholder premise: the internal and the external domains (GALUPPO *et al.*, 2014). For Pfeffer (2010) the internal domain concerns the human factor within organisational boundaries, which may include employees and the upper management, while the external domain aggregates components from outside the organisation (*e.g.*, suppliers, customers, shareholders, and local community). Metrics of social performance in the internal domain were defined by Henao *et al.* (2021) as "baseline metrics", which include labour practices, working conditions, and worker well-being and development. Upon establishing social metrics in the baseline, the level of employee social sustainability (ESS) can be assessed on the shop floor of an organisation.

The construct of social sustainability, according to Venugopal and Saleeshya (2019), is based on the presumption that decision-making processes and projects must be directed towards the improvement of social conditions. Given this perspective, Wong and Wong (2014) treated employees as valuable assets that must be well managed to achieve sustainable lean production. For the authors, workers are the main actors of changes towards improvement. Recently, Varela *et al.* (2019) asserted that the human input is valuable for any lean-based organisation that is driven toward its growth and reputation as a competitive business, considering that a lean system is a socio-technical production system (SUGIMORI *et al.*, 1977; OHNO, 1988).

Despite the recognised importance of workers in lean, the employee viewpoint on corporate social sustainability has been to a great extent overlooked in the literature to date. Notwithstanding, a few initiatives toward this path have arisen, especially connected with performance dimensions of ESS (STANIŠKIENĖ; STANKEVIČIŪTĖ, 2018). In any case, other than investigating the social outcomes, Boström (2012) pointed to tending to the procedural aspects concerning social sustainability, *i.e.*, the way to accomplish these results.

Lean practices are distinguished into soft practices, which concerns people, their inner development and relationships at work, and hard practices, which are more consistent with overall performance and the organisation of the physical work environment (SALENTIJN; BEIJER; ANTONY, 2021). Still, there is limited and often clashing information about the mediating effect of the implementation of LPs on social outcomes, particularly when it comes to shop-floor employees (CAMUFFO; DE STEFANO; PAOLINO, 2017).

Cherrafi *et al.* (2016) found that several societal dimensions in a lean shop floor, namely employee health and safety, job stress, staff morale, and workforce development, are practically not investigated. According to the authors, it is imperative to investigate people and their perception of a sustainable workplace in a lean system, as well as to build a cohesive and robust measurement system to assess social performance in sustainable lean manufacturing.

Furthermore, Ciccullo *et al.* (2018) pointed to the need for a more in-depth analysis of the effects of including the social dimension when considering the integration between lean and sustainability. Notwithstanding, the social aspects of such integration remain largely unexplored. Gupta, Narayanamurthy and Acharya (2018) suggested that sustainable manufacturing research should henceforth address the advances on the "lean-social" endeavour, specifically the impact of these paradigms on employees.

In the next year, Bocquet, Dubouloz and Chakor (2019) found that a growing portion of the literature is concerned with the development of environmental outcomes from LPs, *i.e.* the lean-green paradigm (FARIAS *et al.*, 2019b), leaving the social discussion with little room.

Despite the dearth of conclusive studies on the field of lean and employee social performance, the few existing pieces of information presented in the lean-ESS literature are, in fact, inconclusive and divergent. For example, on the one hand, there has been supporting evidence that lean practices can reduce stress and promote worker's intrinsic motivation (CONTI *et al.*, 2006) in the long run (GAIARDELLI; RESTA; DOTTI, 2019), while on other hand studies have shown that an ill-carried lean operation may result in higher levels of stress (DE TREVILLE; ANTONAKIS, 2006). Also, some common practices like pull production and continuous improvement were found to harm worker's health (BROWN; O'ROURKE, 2007; STIMEC; GRIMA, 2019). Therefore, research on the impacts of LPs on ESS dimensions is necessary to elucidate conflicting results and bring new theoretical and managerial insights.

3
SYSTEMATIC LITERATURE REVIEW

3.1 Procedures of the systematic literature review

This chapter provides a thorough description of procedures of systematic literature review (SLR) used in a specific sample of papers on lean manufacturing and sustainability, from its conception and design to the analysis of the final sample of selected papers. The purpose of this chapter is to answer the first research question of this study that is: **what are the connections bridging lean practices and employee social sustainability dimensions that can be found on the shop floor?**

The SLR described in this chapter encompassed the following procedures:

- Extracting two separate groups of variables of lean practices and employee social sustainability dimensions in the manufacturing sector;
- Bridging the gap between LPs and ESS dimensions by relying on pieces of evidence found in the literature;
- Summarising the set of reported linkages.

The SLR procedures used in this dissertation are a combination of the guidelines given by Tranfield, Denyer and Smart (2003) and Garza-Reyes (2015). Figure 5 outlines the designed phases of the systematic review.

Figure 5. Phases of the systematic literature review

SRL PHASES	OBJECTIVES	PROCEDURES	TOOLS AND CRITERIA
Pre-plan the review	Become acquainted to the research theme, main problematics, methodologies, trends and references	Pre-selection of studies	Non-structured search
		Skimming for relevant information related to the research theme	Google Scholar, digital libraries, academic databases.
Plan the review	State and justify the need for the review.	Define the scope of the review and research questions	
	Stablish a set of search strings for Boolean search and databases.		
	Define a time range.		1997 – 2020
	Define paper exclusion criteria.		Book chapters, conference proceedings, unpublished working papers, theses.
	Define standards for journal quality.		Journals with impact factor (JCR) higher than 1.000.
	Define type of data for extraction.	Stablish categories of variables that are related to the research questions.	Lean practices and social dimensions, linkages between lean and social variables.
Build sample of papers	Locate and select papers.	Apply search strings in selected databases.	ISI Web of Science and Scopus.
	Assess journal quality.	Consult JCR database.	
Analysis and synthesis	Extract and analyse data	Collect variables and fit into predefined categories	Microsoft Excel spreadsheet
Report results	Report consensus, similarities, disparities, convergence or divergence of papers' insights	Perform a qualitative analysis of the sample of papers	Microsoft Excel spreadsheet

3.2 Pre-planning the review

A primary search for relevant papers on the subjects of lean and sustainability was conducted in a non-structured fashion using Google Scholar, Research Gate and ISI Web of Science database. Also, brainstorming sessions were conducted with contributors and the research advisor to build know-how about the research theme.

A variety of keywords were selected from these sessions, which included ‘lean manufact*’, ‘sustainab*’, ‘green’, ‘environmental*’, ‘soci*’, ‘economic*’ and ‘social performance’. These keywords were used as search strings, followed by a screening of titles and abstracts. At this moment no time range was specified for this whole primary ‘gathering’ is about building up an initial body of information. An important outcome from these procedures was the identification of relevant publications and major gaps in the sustainable lean literature.

3.3 Planning the review

In this phase, the triple bottom line model was adopted as a reference for sustainable business. The reason for choosing the TBL model was due to the unavailability of papers that tackled lean and social sustainability only. Thus, decoupling the social pillar from a broader perspective on sustainability was found rather infeasible. For this reason, it was decided to use search strings related to a wider sustainability approach, for it was found that a major portion of the literature discusses all three sustainability spheres conjunctly, except for the case of lean and green, or environmental sustainability, which was still dominant in the sustainable manufacturing field.

3.3.1 Search strings

Throughout the following steps of the review, Scopus (www.scopus.com) from Elsevier, and ISI Web of Science (www.wokinfo.com) from Thomson-Reuters were used as databases. The search strings used for sample collection are presented in Table 2.

Table 2. Search strings for Boolean search

Group	Boolean logic	Search strings	Category
Lean manufacturing	**N/A**	*'lean manufact*' OR 'lean management' OR 'lean system*' OR 'lean approach' OR 'lean process*' OR 'lean practice*' OR 'lean thinking' OR 'Toyota Production System' OR TPS*	**Topic**
Sustainability (TBL)	***AND***	*sustainab* OR 'sustainable performance' OR 'sustainable production' OR 'triple bottom line' OR 'triple bottom-line' OR 'triple-bottom line' OR TBL OR 3BL*	**Topic**
Dimensions of sustainability	***AND***	*green OR environment* OR 'environmental sustainability' OR economic* OR 'economic* sustainability' OR 'social sustainability' OR 'social performance' OR 'social responsibility' OR 'social impact'*	**Topic**

3.3.2 Exclusion criteria

The first exclusion criterion (or filter) was the time interval, which was defined to include papers from 1997 – when J. Elkington's *Cannibal With Forks* had its first edition published – to March 2020.

The second filter consisted of the selection of suitable categories related to lean manufacturing and sustainability. For the ISI Web of Science, the categories applied as a filter were 'Environmental Sciences', 'Green Sustainable Science Technology', 'Engineering Environmental', 'Engineering Industrial', 'Engineering Manufacturing', 'Management', 'Operations Research Management Science', 'Environmental Studies', 'Business', 'Sociology' and 'Anthropology'. As for the Scopus database, related categories were 'Engineering', 'Environmental Science', 'Business, Management and Accounting', and 'Social Sciences'

As a third filter, the type of document was defined as peer-reviewed original articles and reviews. For the fourth filter, only papers written in the English language were considered.

The fifth filter consisted of screening for suitable titles and abstracts. As a final exclusion procedure, the sample was screened for duplicates and journal quality (JCR > 1.000).

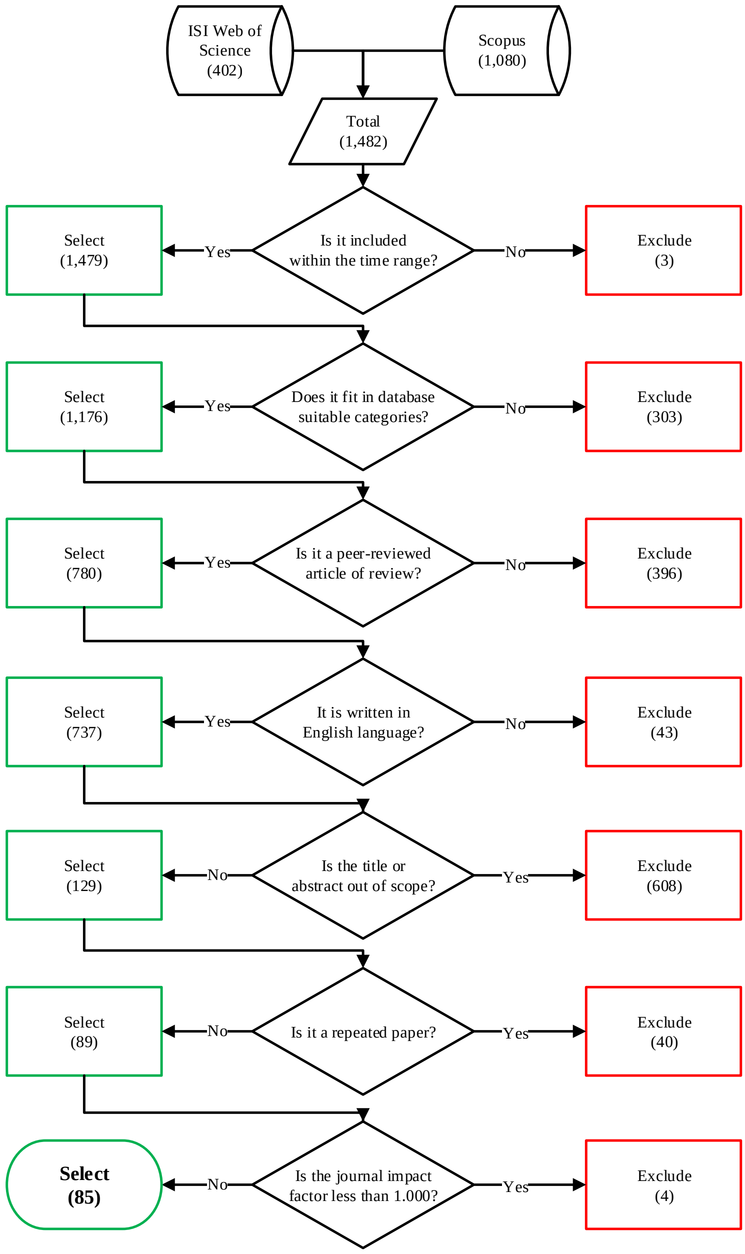
3.3.3 Type of data to extract

Given that the review was designed to uncover relationships between lean practices and social dimensions on the shop floor, two groups of qualitative variables were designated as lean manufacturing practices and, as pointed by Al-Marzouqi, Khan and Hussain (2020), dimensions of employee social sustainability. Once these two groups were filled with suitable variables, the extraction of relationships reported in the literature started to be conducted.

3.4 Building a sample of papers

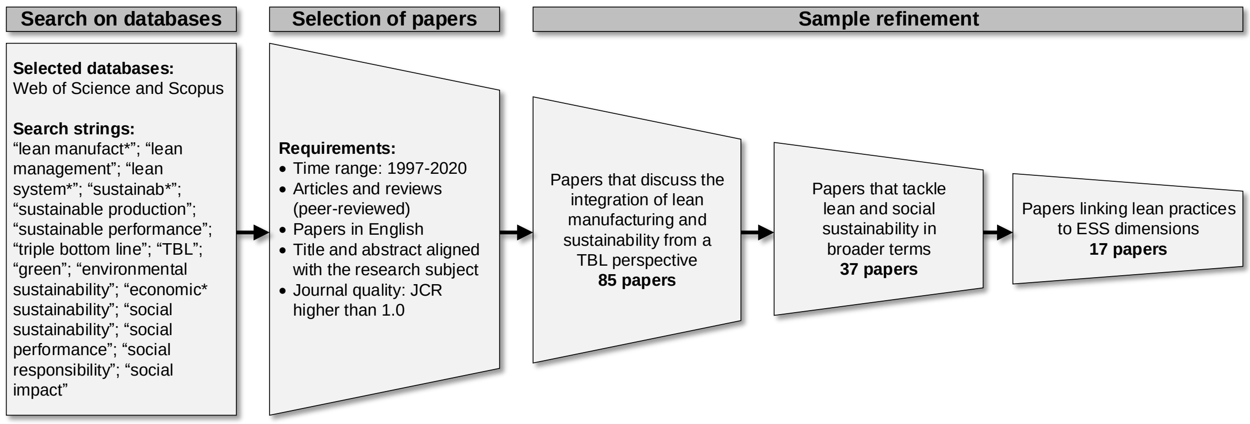
To gather an initial set of papers, the search strings outlined in Table 2 were used in the two aforementioned databases, thus returning 1,482 papers in total, with most of them unfit to the review purpose. Then, exclusion criteria were applied consecutively with each filter reducing the initial set towards a more suitable sample as illustrated in Figure 6.

Figure 6. Application of exclusion criteria



Sequentially, a sample refinement similar to the one conducted by Farias *et al.* (2019b) was executed to build a final sample of papers that explicitly addresses relationships between LPs and dimensions of ESS. Figure 7 depicts this refinement starting from the planning phase.

Figure 7. Sample refinement



Papers that do not report or discuss linkages between lean manufacturing and social sustainability in general terms were excluded from the sample of 85 papers, resulting in a second sample of 37 papers. Following, another reduction was done as a means to further refine the sample. From this point, an even smaller number of papers that approach social sustainability from the perspective of the employee were selected, resulting in a final sample of 17 papers, which are listed in Table 3.

Table 3. Refined lean-ESS sample of papers

	Author	Year	Title
1	Bergenwall, Chen and White	2012	TPS's process design in American automotive plants and its effects on the triple bottom line and sustainability
2	Chiarini	2014	Sustainable manufacturing-greening processes using specific lean production tools: An empirical observation from European motorcycle component manufacturers
3	Pagell *et al.*	2014	Is an efficacious operation a safe operation: the role of operational practices in worker safety outcomes
4	Wong and Wong	2014	Synergizing an ecosphere of lean for sustainable operations
5	Longoni and Cagliano	2015	Cross-functional executive involvement and worker involvement in lean manufacturing and sustainability alignment

	Author	Year	Title
6	Piercy and Rich	2015	The relationship between lean operations and sustainable operations
7	Vicente *et al.*	2015	Business sustainability through employees involvement: a case study
8	Yusup *et al.*	2015	Review the influence of lean tools and its performance against the index of manufacturing sustainability
9	Cherrafi *et al.*	2016	The integration of lean manufacturing, six sigma and sustainability: A literature review and future research directions for developing a specific model
10	Verrier, Rose and Caillaud	2016	Lean and green strategy: the lean and green house and maturity deployment model
11	Camuffo, De Stefano and Paolino	2017	Safety reloaded: lean operations and high involvement work practices for sustainable workplaces
12	Martínez-León and Calvo-Amodio	2017	Towards lean for sustainability: understanding the interrelationships between lean and sustainability from a systems thinking perspective
13	Sajan *et al.*	2017	Lean manufacturing practices in Indian manufacturing SMEs and their effect on sustainability performance
14	Bocquet, Dubouloz and Chakor	2019	Lean manufacturing, human resource management and worker health: are there smart bundles of practices along the adoption process?
15	Henao, Sarache and Gómez	2019	Lean manufacturing and sustainable performance: Trends and future challenges
16	Huo, Gu and Wang	2019	Green or lean? A supply chain approach to sustainable performance
17	Iranmanesh *et al.*	2019	Impact of lean manufacturing practices on firms' sustainable performance: lean culture as a moderator

3.5 Analysis and synthesis

3.5.1 Describing ESS dimensions

The ESS dimensions identified in the final sample are aligned with the ones already mentioned in the literature, especially with those related to employee well-being (ABID *et al.*,

2020; AL MARZOUQI; KHAN; HUSSAIN, 2020). Next, Table 4 describes each social dimension found in the selected literature.

Table 4. Description of ESS dimensions

Dimension of ESS	**Description**
Employee autonomy and empowerment	Dimension related to the development of employees' creative capacity, proactiveness and sense of worthiness towards their careers and importance for sustaining the organisation. It concerns the involvement of employees toward the generation and implementation of ideas for continuous improvement, decentralisation of decision-making, task enrichment, and a greater appreciation of insights generated on their work routine.
Employee health and safety	Occupational health is commonly studied in conjunction with safety from the point of view of different organisational policies, which may include occupational risk assessment, accident reduction programs, safety management, internal pollution control, and safety education.
Job stress reduction	Job stress has been defined in broad terms as the employees' physiological and psychological reaction to pressure demand against their perception of their ability to cope with it. Job stress on the shop floor has a direct impact on employee well-being and productivity. It may impair employee's social and problem-solving skills, resulting in absenteeism and higher turnover. Although being part of the health discussion, stress was found to be discussed solely in several publications.
Enhanced workplace	Enhanced workplaces are workflow-driven manufacturing environments that are continuously modified and improved to facilitate the execution of tasks, whilst ensuring a clean, safe and ergonomic workstation. This dimension tackles the aggregation of physical factors that altogether drive the employee towards comfort and productivity.

Bocquet, Dubouloz and Chakor (2019, p. 120) discussed employee empowerment considering that this social dimension is mainly characterised by '[…] sharing power and promoting employee's autonomy through task enrichment and work organisation'. The term autonomy is recurrent in the social sustainability research (CAMUFFO; DE STEFANO; PAOLINO, 2017; IRANMANESH *et al.*, 2019), being often combined with other factors of self-performance and morale, such as participation and engagement (LONGONI; CAGLIANO, 2015).

Employee health was explored conjointly with safety through as the culmination of a series of organisational policies, such as occupational risk and safety management (VINODH; ARVIND; SOMANAATHAN, 2011; CAMUFFO; DE STEFANO; PAOLINO, 2017), cleanness and pollution (SAJAN *et al.*, 2017; DAS, 2018), occupational illness and injury rates (FAULKNER; BADURDEEN, 2014; PAGELL *et al.*, 2014), handling and proper storage of hazardous materials (CHERRAFI *et al.*, 2016), and safety education (VICENTE *et al.*, 2015). From the review, it can be inferred that the current literature indicates that implementing lean manufacturing may promote occupational health and safety (CAMUFFO; DE STEFANO; PAOLINO, 2017).

Job stress has been defined in broad terms as the employees' physiological and psychological reaction to pressure demand against their perception of their ability to cope with it (CRANWELL-WARD; ABBEY, 2005). The job stress dimension was separated from health and safety because it was found to be discussed solely in several publications (CONTI *et al.*, 2006; BROWN; O'ROURKE, 2007; STIMEC; GRIMA, 2019), and majorly stems from pressure for high standards of quality and just-in-time deliveries (LONGONI; CAGLIANO, 2015).

Job stress on the shop floor has a direct impact on employee well-being and productivity, for, at high levels, it is capable of impairing employee's social and problem-solving skills, as well as causing absenteeism and higher turnover (CONTI *et al.*, 2006; CULLINANE *et al.*, 2013). Although any organisational change may be seen as a source of stress (DAHL, 2011), Conti *et al.* (2006) found that lean manufacturing is not inherently stressful and job stress is more significantly related to other variables. Indeed, despite the stress intensification due to the pressure for change in the lean implementation start-up, evidence has been found that lean manufacturing may lead to stress reduction as the lean system evolves (GAIARDELLI; RESTA; DOTTI, 2019).

An enhanced workplace is a workflow-driven manufacturing environment capable of easing the execution of tasks in clean, safe, and ergonomic workstations (PIERCY; RICH, 2015; VICENTE *et al.*, 2015; GAIARDELLI; RESTA; DOTTI, 2019). An often reported benefit from lean implementation is its impact on the physical place where work is carried out

(VINODH; ARVIND; SOMANAATHAN, 2011; DAS; VENKATADRI; PANDEY, 2014; GAO; SUI PHENG; TAY, 2020).

3.5.2 Linkages between ESS dimensions and lean practices

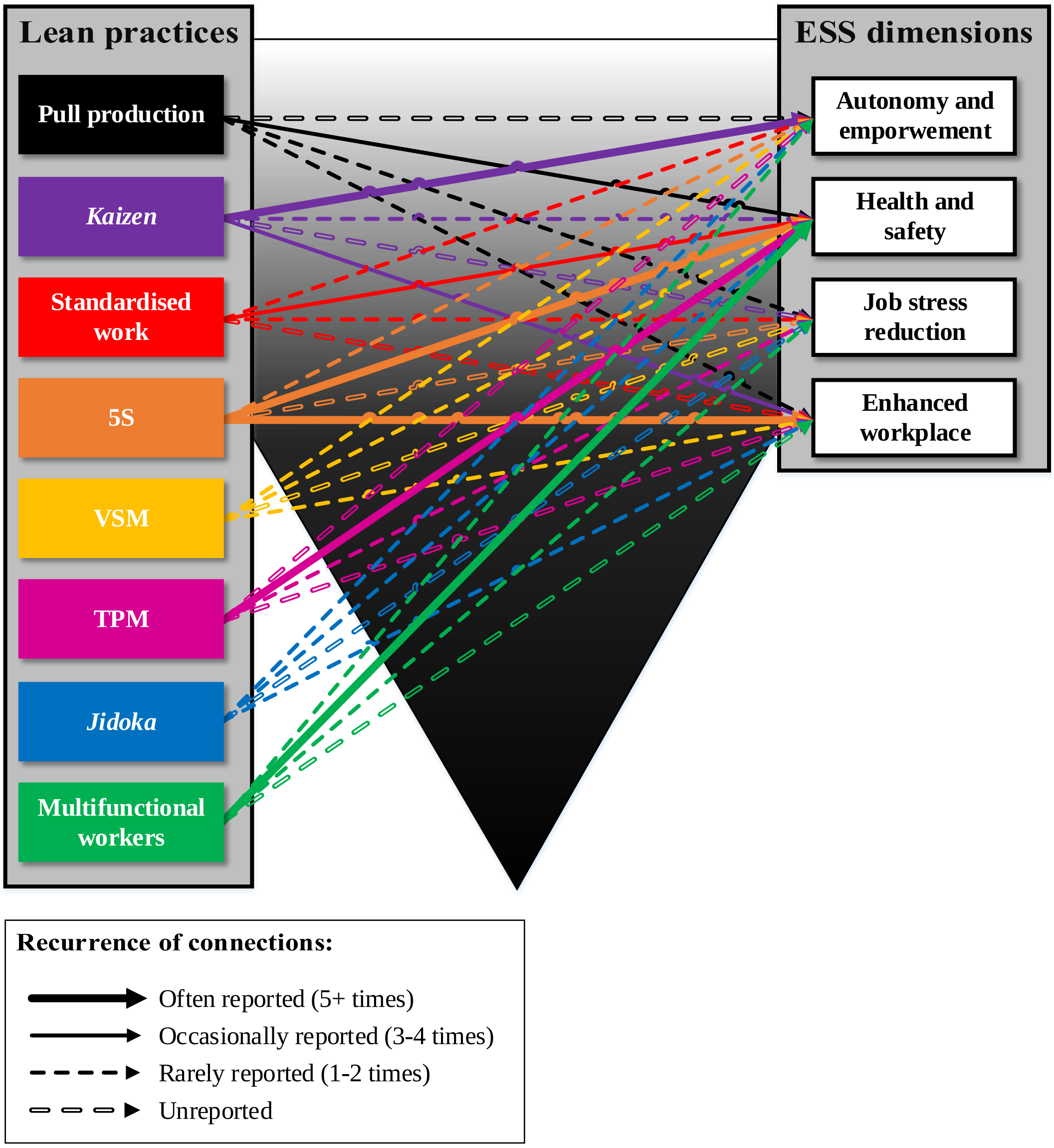
Reported linkages were found between eight lean practices (pull production, *kaizen*, standardised work, 5S, value stream mapping, total productive maintenance, *jidoka*, and multifunctional workers) and four ESS dimensions (autonomy and empowerment, health and safety, job stress reduction, and enhanced workplace). Table 5 summarises the collected connections.

Table 5. Linkages between lean practices and ESS dimensions

	ESS dimensions			
Lean manufacturing practices	**Autonomy and empowerment**	**Health and safety**	**Job stress reduction**	**Enhanced workplace**
Pull production (production control method in which downstream activities signal their material demands for upstream activities)		[6,9,11]	[9]	[9,17]
Kaizen (continuous improvement) (ongoing and incremental improvement, conducted both in routine activities and improvement events, to solve problems throughout the organisation)	[4,13,14,15,16]	[4,13]		[4,13,15]
Standardised work (establishment and documentation of standards for the execution of tasks in a manufacturing environment)	[3]	[2,3,5,12]	[13]	
5S (housekeeping practice that follows five principles: utilization, organisation, cleanliness, standardization, and discipline)	[4]	[3,4,5,8,10,12,13,14,16]		[8,12,13,15,17]
Value stream mapping (VSM) (support tool that maps material and information flows, helping the identification of activities that do not add value)	[4]	[4,9]		[4,10]
Total productive maintenance (TPM) (maintenance approach that requires full employee participation to promote the overall equipment effectiveness)		[3,4,5,9,13]	[9]	
Jidoka (autonomation) (providing operators and machines with the ability to detect problems and stop the production process immediately when abnormalities occur)	[1]	[1]		[8]
Multifunctional workers (workers trained to perform different tasks, allowing system flexibility to keep the production flow stable)	[3,7]	[1,2,3,7,8,12]	[9]	

Several linkages could not be identified in the sample and remained unchecked, thence designated as a potential connection. Figure 8 shows all connections along with their recurrence in the selected literature.

Figure 8. Summary of lean-ESS connections and their recurrence up until March 2020



3.6 Reporting results

3.6.1 Major insights

According to Martínez-Jurado and Moyano-Fuentes (2014), a prominent aspect of the lean-for-employee recent debate concerns the development of blue-collar workers' abilities in performing and improving their tasks, as well as occupational health and safety issues. The authors also claimed that motivation, communication, problem-solving skills, and teamwork are essential for the successful operation of a sustainable lean system.

Vicente *et al.* (2015) pointed out that previous research had a substantial focus on the technical and operational aspects of lean production, or hard practices, putting aside social aspects and the impacts the lean manufacturing practices may have on employees. The authors found that a lean environment is prone to affect people with stress in the forms and anxiety and psychological strain, mainly due to the operational goal of reducing lead-time, cycle times, and the underlying basic demand for continuous improvement.

One downside associated with lean production is that the implementation and conduction of LPs usually tend to overlook social outcomes associated with health, safety, and stress (VARELA *et al.*, 2019). This remark stems from an intense focus on waste minimisation derived from the seven key sources of waste: transportation, inventory, motion, waiting, over-processing, over-production, and defects.

It is also argued that customer satisfaction as a strategic objective can serve as leverage for social performance (HUO; GU; WANG, 2019). This observation is supported by the argument that to deliver high-quality products while engaging in pull production, shop-floor employees must have a high degree of multifunctionality and positive motivations. For such a purpose, an organisation must provide sufficient and cooperative training, increasing employee autonomy, satisfaction, and well-being.

In sum, lean can be perceived as a program where social improvement is possible, considering its role in empowering employees by valuing their ideas and inputs, as well as allowing them to engage in the implementation of new initiatives (CALDERA; DESHA; DAWES, 2017).

3.6.2 The ambivalent nature of lean-ESS connections

The analysis of the selected lean-ESS literature provided mixed and still inconclusive results of outcomes from the implementation of lean manufacturing practices on dimensions on employee social sustainability (CAMUFFO; DE STEFANO; PAOLINO, 2017; SALENTIJN; BEIJER; ANTONY, 2021), with several authors having identified beneficial and detrimental social outcomes (LONGONI; CAGLIANO, 2015; CAMUFFO; DE STEFANO; PAOLINO, 2017; SAJAN *et al.*, 2017).

Nevertheless, the amount of reported positive outcomes from the lean-ESS relation surpasses its negative counterpart (MARTÍNEZ-LEÓN; CALVO-AMODIO, 2017) the same way in Table 6, which is a result of the analysis of the reviewed lean-ESS literature (Table 3).

Table 6. Classification of the selected literature in terms of types of effect lean practices on ESS dimensions

	Autonomy and empowerment		**Health and safety**		**Job stress reduction**		**Enhanced workplace**	
*Type of effect**	P	N	P	N	P	N	P	N
Pull production	×	×	×	[3,5,15]	×	[5]	[5]	×
Kaizen	[4,7,9,13]	×	[9,13]	×	×	×	[7,9,13]	×
Standardised work	[11]	×	[2,6,11]	[14]	×	[13]	×	×
5S	[9]	×	[2,4,6,9,10,11 12,13,17]	×	×	×	[6,7,8,9, 13,17]	×
VSM	[9]	×	[5,9]	×	×	×	[9,12]	×
TPM	×	×	[2,5,9,11,13]	×	[5]	×	×	×
Jidoka	×	[1]	[1]	×	×	×	[8,17]	×
Multifunc. workers	[11,16]	×	[1,6,11,16]	[1,14,17]	[5]	[14]	×	×

Notes: P (positive), N (negative)

The problem-solving approach of lean was discussed as a beneficial trait for employees by having a positive impact on motivation, commitment, and job satisfaction (VINODH; ARVIND; SOMANAATHAN, 2011). Lean practices were discussed as fruitful for employees as they might reduce stress through teamwork, employee participation, and top management support, as well as on boosting employee's inner motivation by basing a more pleasant perception of their working life (DE TREVILLE; ANTONAKIS, 2006; WONG; WONG, 2014).

Vicente *et al.* (2015) obtained constructive results regarding employee satisfaction, involvement and participation in continuous improvement actions. By promoting regular meetings with the upper management, assembling visual management boards, organising *kaizen* events, and teaching the importance of 5S, a percentage of 85% of the employees agreed that the opportunity to identify problems and share them with superior management 'was an "excellent" idea' (p. 6). Hence, the authors argue that HRM efforts and lean practices can be supportive of basic human needs at work, such as understanding, participation, creation, and identity, which can impact the long-term sustainability of the company.

Chiarini (2014) demonstrated that lean practices, particularly 5S, can significantly improve health and safety conditions in the working environment, as well as reducing injury rates. As far as health and safety in the work environment is concerned, an examination of the literature suggests that there is a consensus on lean being able to afford the ability to design workstations under ergonomic standards (VINODH; ARVIND; SOMANAATHAN, 2011).

Longoni and Cagliano (2015) outlined points of divergence in the lean-ESS relation. As an example, job rotation, as an organisational policy to promote a multifunctional workforce, may increase employee well-being by diminishing dull and repetitive tasks, whilst it also may increase the risk of injury and physical stress and affect worker health and safety due to the execution of new activities without previous competence development (BERGENWALL; CHEN; WHITE, 2012; BOCQUET; DUBOULOZ; CHAKOR, 2019). To overcome this duality, proper training must be provided and well-conducted.

Camuffo, De Stefano and Paolino (2017) encountered an inconsistent relation between how lean is perceived and its social outcomes. While lean is treated as a human-centred, socio-technical production system that encompasses the improvement of the working environment quality, having been acknowledged for providing safer workplaces employing a high-committed and sustainable workforce, it was observed to cause an intense pressure for high-quality standards and fast delivery. These two basic premises of the lean system were pointed as the main cause for worker health deterioration, as well as physical and psychic stress.

Other authors collected a wide range of negative side-effects such as loss of autonomy associated with work standardisation, mitigation on well-being, and high stress due to high-quality demands (MARTÍNEZ-JURADO; MOYANO-FUENTES, 2014; SAJAN *et al.*, 2017).

Bocquet, Duboulouz and Chakor (2019) provided a careful examination of the dual nature of social outcomes caused by LPs. Although linked with physiological and psychological tensions in employees (*e.g.* job depression, anxiety, distress, physical pain, hypertension, and cardiovascular disease), lean practices also have been associated with social benefits in the form of increased job satisfaction, collaboration, and employee involvement through teamwork, multiskilling, work cognition, and organisational citizenship. Some lean practices considered on this matter are standardisation of work, multifunctional workers, quality management and pull production. Still, based on evidence collected from three case studies of French manufacturing organisations, the authors affirmed that ‘lean is inherently stressful and worker well-being deterministic’ (p. 118).

This statement counterpoints Conti *et al.*(2006), who found through testing an extensive set of hypotheses that lean is not inherently stressful, and job stress majorly stems from operational and design aspects of lean systems.

Based on these pieces of evidence, it can be inferred that lean practices play a dual role in employee social sustainability outcomes. Albeit such an intricate relationship, the ESS dimensions and LPs considered in this study were streamlined as beneficial elements to corporate social sustainability, so that the respondents could have a clear perspective upon giving their judgements in the AHP questionnaire. The next chapter elaborates on including this restriction in the research methodology, as well as the derivation of the lean-ESS hierarchical model and its theoretical basis.

4
METHODOLOGY

4.1 Choosing a method

Throughout Chapter 3, the SLR procedures were comprehensively described, which served as a means to scrutinise the current lean-ESS literature, as well as to identify and link lean practices and ESS dimensions. Their connections were built on collected evidence (Table 4, subsection 3.5.1) and presented in graphical form (Figure 8, section 3.5.2).

This study incorporates an exploratory premise. Although the survey methodology is a suitable option for the solidification of collected relationships, as in Pagell *et al.* (2014) and Sajan *et al.* (2017), the current scenario of the lean-ESS discussion in the manufacturing sector presented mixed results as discussed in sub-section 3.6.2, which hampers the establishment of a group of hypotheses to be tested.

Moreover, there is a considerable number of social dimensions related to both internal and external stakeholder's metrics (HENAO; SARACHE; GOMEZ, 2021), which are currently uncertain how they relate to corporate sustainability. Hence, to build an initial outlook of employee social sustainability on the shop floor, an exploratory study is aligned to point and address the few evidenced lean-ESS interactions.

For this study, it was necessary to choose a research method with the following procedural aspects:

- Aimed at building a hierarchy of alternatives based on a common goal;
- Mathematically accurate;
- Accountable for one-way interactions (*i.e.* LPs affecting ESS dimensions);
- Able to synthesise results in the form of a group response;
- Adaptable to a digital instrumental of data collection;
- Software-based;
- Capable of performing sensitivity analysis.

Given the main objective of prioritisation of multiple alternatives grouped in two sets of interconnected variables, the multi-criteria decision analysis (MCDA) approach is appropriate for calculating numerical values of priorities of different criteria and alternatives. There is a variety of MCDA methods with specific applications. In this case, the AHP (SAATY; VARGAS, 2012) is a suitable option since it is compatible with model limitations and the type of result this study intends to provide.

The Analytic Hierarchy Process (AHP) method was chosen in the face of other options such as the Analytic Network Process (ANP), Graph-Theoretic Approach (GTA), and Decision-

Making Trial and Evaluation Laboratory (DEMATEL). The AHP meets the criteria of accounting for a group response: according to Forman and Peniwati (1998, p. 1), '[the] AHP is often used in group settings where group members either engage in discussion to achieve a consensus or express their preferences'. Considering that this study used a sample of experts acting as independent judges, their judgements had to be combined into a single group response with some level of consensus associated. How to perform such synthesis and assess group consensus is clarified throughout this chapter in section 4.5.

A modest number of internal linkages (ESS dimensions interacting with one another) have been found in a handful of studies, yet they were not modelled in this research due to the formulation of the AHP itself. All the other mentioned MCDA models conjugate more complex networks of inter and inner relations, which can be drawn from theoretical studies, empirical evidence or a combination of both sources, yet providing different outcomes useful to design performance criteria for specific assessment applications, such as in Azevedo *et al.*(2012) and Farias *et al.* (2019a).

Next, the AHP method is described through its premise of decision analysis, comparison rationale, application, and representative formulae.

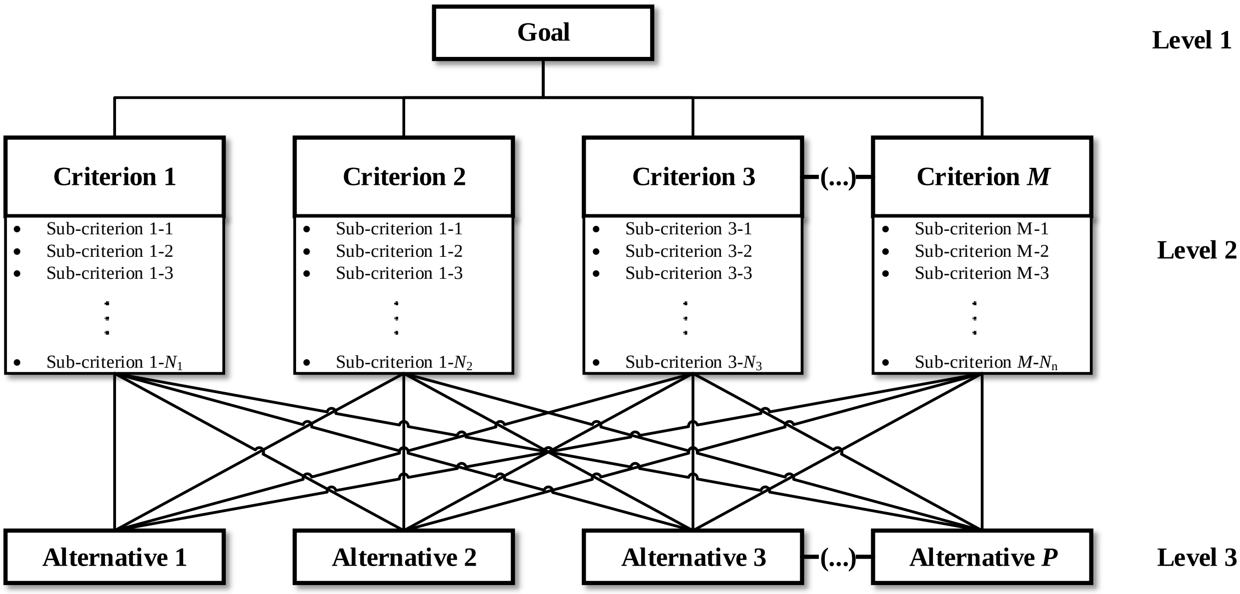
4.2 The AHP approach

The AHP (SAATY, 1990) and the ANP (SAATY, 1999, 2004) are two related MCDA methods that are commonly found in quantitative studies of lean within a wide range of different applications (CIL; TURKAN, 2013; WONG; IGNATIUS; SOH, 2014; THOMAS; SALEESHYA; HARIKUMAR, 2017; FARIAS *et al.*, 2019a). Both techniques converge on the point of using subjective pairwise comparisons of variables, however with different purposes. While the AHP is aimed at building rankings of criteria and alternatives assuming a unidirectional relationship between those (YADAV *et al.*, 2019), the ANP was formulated to more complex networks of interdependent relations amongst its components (AGARWAL; SHANKAR; TIWARI, 2006; FARIAS *et al.*, 2019a).

The formulation of the AHP assumes the evaluation of the consistency of given judgements. This feature is an important remark of the technique since it allows the model to be progressively refined as it can be constantly adjusted and reviewed, thus providing a more accurate comprehension of the problem (SAATY, 1990).

In a generic hierarchy structure, several components are used to define a decision analysis problem. These components are usually allocated in three levels, which are (*i*) a goal, (*ii*) a set of criteria and respective sub-criteria, and (*iii*) the available alternatives linked to the criteria (BUSHAN; RAI, 2004). Figure 9 is a representation of such a hierarchy structure. The sub-criteria are generally found in more complex situations.

Figure 9. A three-level general hierarchy model



Source: Adapted from Bushan and Rai (2004)

Building an AHP model follows the very same layout and consists of designing a hierarchy structure to define the problem and establish relations within the hierarchical model (SAATY; VARGAS, 2012). The AHP methodology is generally conducted through four main phases (ESCOBAR; MORENO-JIMÉNEZ, 2007), namely:

1. Modelling — The problem is first structured according to a hierarchy of goals, criteria, sub-criteria, and alternatives. Here, the criteria are the ESS dimensions, which can then be considered determinants of social performance. The alternatives, or enablers of ESS, are the lean practices;

2. Valuation — Model variables are hierarchically set and data are collected through a questionnaire involving pairwise comparisons, first between criteria and then between alternatives using Saaty’s fundamental scale (Table 7);

Table 7. Saaty's fundamental scale for pairwise comparisons

Intensity of importance	**Definition**	**Explanation**
1	Equal importance	Two criteria/alternatives contribute equally to the objective
3	Moderate importance of one activity over another	Judgment marginally favour one over another
5	Essential or strong importance	Judgment strongly favour one over another
7	Very strong importance	A criterion/alternative is strongly favoured and its dominance is demonstrated in practice
9	Extreme importance	The highest possible order of dominance
2, 4, 6, 8	Intermediate values	Suitable when a certain level of compromise is needed

Source: SAATY (1990)

3. Prioritisation — For the calculation of priorities, three types of weights must be calculated: (*i*) criteria weights (relative importance of each criterion to the goal), (*ii*) local alternatives weights (relative importance of one alternative to a specific criterion), and (*iii*) global alternatives weights (relative importance of all alternatives to the goal). Eigenvalue calculations are applied for the quantification of these weights;

4. Synthesis — In this step, the consistency index (CI) is calculated through $CI = \frac{\lambda_{MAX} - n}{n-1}$, where λ_{MAX} is the highest value among the priorities vector and n is the order of the comparison matrix. The CI is a quantification of the inconsistency in judgement. Then, the consistency ratio (CR) is calculated using $CR = CI/RI$, where RI is the random consistency index (Table 8) and depends on n. A general rule-of-thumb states that CR values under 10% are acceptable, but should never go above 20% (SAATY; KEARNS, 1985, p. 34). Should the consistency

index fails to meet this threshold, the judgements for the pairwise comparisons must be re-evaluated (DI ZIO; MARETTI, 2014).

Table 8. Random consistency index values

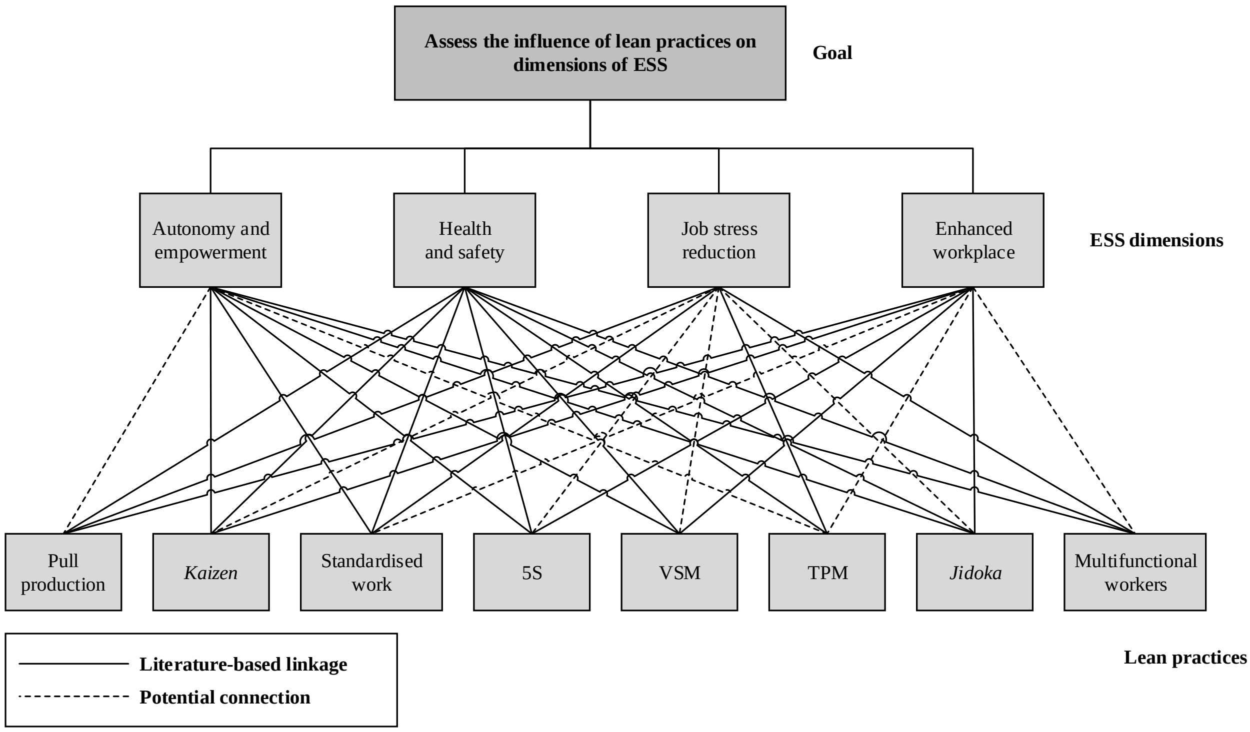
n	1	2	3	4	5	6	7	8	9	10
RI	0.0	0.0	0.52	0.89	1.11	1.25	1.35	1.40	1.45	1.49

Source: SAATY; VARGAS (2012, p. 9)

4.3 The lean-ESS research model

The lean-ESS model of Figure 10 assumed a hierarchical structure to establish priorities of ESS dimensions and lean practices. Besides the connections found in the literature review (Table 4, area 3.5), potential associations, *i.e*. unreported, were included

Figure 10. The lean-ESS research model



The proposed lean-ESS model contains twenty-three literature-based (solid lines) and nine potential linkages (dashed lines). The aggregation of the potential connections is supported by (*i*) the previously mentioned exploratory trait of this research, given the inaugural stage of the lean-ESS investigation, and (*ii*) the evidence that both hard and soft lean practices may impact social results (GAIARDELLI; RESTA; DOTTI, 2019; SALENTIJN; BEIJER; ANTONY, 2021).

4.3.1 The case of multiple judges in AHP

For the case of multiple judges, it is necessary to synthesise their judgements into a single group response. This situation characterises an AHP–Group Decision Making (AHP-GDM) problem (ESCOBAR; MORENO-JIMÉNEZ, 2007; ABDEL-BASSET; MOHAMED; SANGAIAH, 2018). Mainly, there are two approaches to compute individual judgements into a single representative judgement: the aggregation of individual judgements (AIJ) and the aggregation of individual priorities (AIP).

The rationale of each method is thoroughly explained by Forman and Peniwati (1998). In sum, the AIP is preferable when judges act as separately, having no group interaction, whereas the AIJ is more suitable when there is a group acting as a single unit. This basic distinction is established as follows: 'The AIJ […] is a synergistic aggregation of individuals judgements when individuals are willing to, or must out of necessity, relinquish their own preferences for the good of the organisation.' (FORMAN AND PENIWATI, 1998, p. 167).

These representative traits of each method are distinguished through the way individual judgements are aggregated. In the AIP, the priorities of each judge are calculated first-hand based on individual judgements, and then a final group priority vector is synthesised using either arithmetic or geometric means. In turn, the AIJ first combines the judgements of each judge to finally calculate group priorities (DI ZIO; MARETTI, 2014), however only through a geometric mean (FORMAN; PENIWATI, 1998). Although very similar and serving the same purpose, these two approaches have a disparity in their methodology based on how the group of judges is operationalised.

As mentioned, both weighted arithmetic or geometric averages can be used in the AIP. Notwithstanding, each type of average provide different results when applied on Saaty's fundamental scale (Table 7), for the arithmetic mean assumes the progression between two given elements in terms of equivalent intervals, while the geometric mean deals with the same progression in terms of equal ratios (FORMAN; PENIWATI, 1998).

That being considered, the formulation of the AHP is more aligned with the geometric approach since the underlying logic of judgements towards a ranking is based on ratios, *i.e.*, how many times an alternative is more important than the other (FORMAN; PENIWATI, 1998). Also, using the arithmetic mean can sometimes result in the same outcome for two completely different situations when working with a group of judges (DI ZIO; MARETTI, 2014), as exemplified by a larger group judging an alternative in a single direction, and the same group now partitioned into two sub-groups of equal size providing opposite judgements to one another. If smaller and smaller sub-groups are consistently formed, then it will reach the point when any *m* number of previous members of the group providing independent judgements, which justifies the use of AIP.

Given that the sample of experts in this study worked as independent judges of the relative importance of ESS dimensions and lean practices, and the geometric mean is presented in the literature as a more compatible option to use in combination with the AHP, this study assumed the AIP as its method for computing a single group response, which is described in the following lines.

Assuming that there are n alternatives and m judges whose weight β_k ($k = 1, 2, \ldots, m$) is considered when calculating the group response, following the conditions:

$$\beta_k \geq 0 \qquad (1) \qquad \text{and,}$$

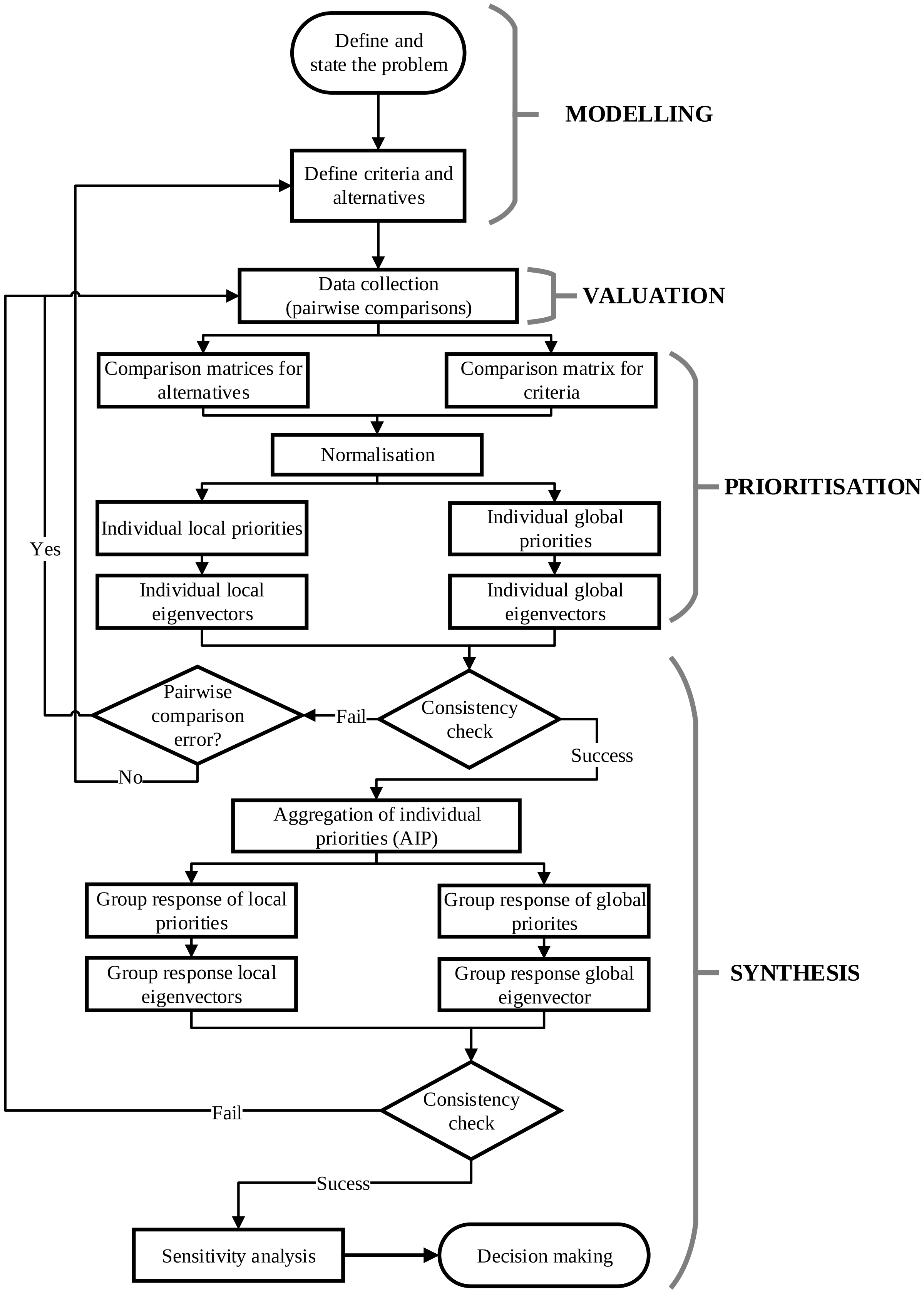
$$\sum_{k=1}^{m} \beta_k = 1 \qquad (2)$$

Then the aggregation of vectors of individual priorities $w_i^{[k]}$, with $k = 1, 2, \ldots, m$, results in the vector of group priorities $w^{[G]}$ as the weighted geometric average (ESCOBAR; MORENO-JIMÉNEZ, 2007, p. 289):

$$w^{[G]} = \prod_{k=1}^{m} \left(w_i^{[k]} \right)^{\beta_k}, \quad i = 1, 2, \ldots, n \qquad (3)$$

A flowchart comprising the basic steps for an AHP-GDM problem is showed in Figure 11 following a four-phased implementation guideline. The use of suitable software was essential to ease the process of data analysis and application of the AHP technique. The software *Expert Choice 2000* was used to compute all comparison matrices, as well as calculate individual and group eigenvalues and priority vectors, and finally to perform a sensitivity analysis.

Figure 11. Flowchart of application of AHP with multiple judges



Source: Adapted from Forman and Peniwati (1998) and Escobar and Moreno-Jiménzez (2007)

4.4 Data collection and sample of experts

To collect trustworthy input data for the lean-ESS research model, expert opinion was gathered from a group of national and international experts in the fields of lean manufacturing and corporate sustainability. The instrument of data collection consisted of a digital questionnaire sent through e-mail, which features two main sections: section one contains questions about personal information, namely contact information, country of residence, current job position, and work experience. Section two contains questions about the level of importance (weights) of ESS dimensions (global priorities) and LPs (local priorities) for each ESS dimension. The number of pairwise comparisons amounted to 118. Table 9 provides information on the number of delivered questionnaires, as well as the demographics of experts who accepted the invitation to participate.

Table 9. Questionnaire data and respondents' demographics

Respondent	Current occupation	Expertise	Experience	Locale
P_1	Professor/researcher	Environmental Management	1-5 years	Brazil
P_2	Professor/researcher	Operations Management	5-10 years	India
P_3	Consultant	Operations Management	+10 years	Brazil
P_4	Manager	Operations Management	+10 years	Colombia
P_5	Professor/researcher	Operations Management	+10 years	India
P_6	Engineer	Continous Improvement	1-5 years	Brazil
P_7	Professor/researcher	Operations Management	5-10 years	Brazil

Questionnaires sent	44 nationally	
	35 internationally	**Notes:** questionnaires were sent to experts residents in Italy, France, Portugal, United Kingdom, Spain, China, India, Mexico, and Colombia.
Questionnaires replied	4 nationally	
	3 internationally	

Invitations to participate were electronically mailed first by October 18th, 2020, to a larger group of 79 carefully selected experts. Throughout the following five weeks, friendly reminders were sent every start of the week. Despite the effort, only seven questionnaires were returned, with the last one received on November 23rd, 2020, which gives a response rate of 8.97%, with around one questionnaire replied per week. A low response rate is common in studies involving expert opinion, especially ones employing a digital instrument. As pointed by Walliman (2011), a downside of using online data collection tools is the unpredictability of the response rate, despite its low cost and high feasibility.

4.5 Estimating group consensus

The seven experts provided individual responses for pairwise comparisons between LPs and ESS dimensions. They were asked to fill the AHP questionnaire (Appendix A) based on their knowledge and experience in the manufacturing sector and matters of corporate sustainability, acting as independent agents, *i.e.* there was no interaction between the respondents. This restriction is determinant to eliminate the risk of one being affected by interpersonal biases relying on authority, reputation and personality, confrontation or even embarrassment.

The AIP allows a single group response based on the individual priorities given by judges, however, it is unable to account for the level of agreement amongst group members for a given set of group priorities (DI ZIO; MARETTI, 2014). Given that the respondents acted independently, it is necessary to estimate the level of consensus achieved for each set of comparisons. Consensus can be statistically computed through Kendall's coefficient of concordance (KENDALL; SMITH, 1939, p. 276), or simply Kendall's *W*.

4.5.1 Calculating consensus through Kendall's coefficient of concordance

Assuming an m number of individual rankings for n alternatives, Kendall's W is mathematically represented by:

$$W = \frac{12S}{m^2\left(n^3 - n\right)} \qquad (4)$$

with S as the squared deviation of the sum of judgements R_i and $\bar{R}$ as its mean for each alternative (SIEGEL, 1956, p. 231):

$$S = \sum_{i=1}^{n}\left(R_i - \frac{\sum R_i}{N}\right)^2 = \sum_{i=1}^{n}\left(R_i - \bar{R}\right)^2 \qquad (5)$$

Kendall's *W* can be corrected for tied judgements through the inclusion of a factor *T* (LEGENDRE, 2005, p. 229):

$$W = \frac{12S}{m^2\left(n^3 - n\right) - mT} \qquad (6)$$

which depends on the number of tied judgements t_k of *m* judges (SIEGEL, 1956, p. 234):

$$T = \sum_{k=1}^{m}\left(t_k^3 - t_k\right) \qquad (7)$$

The coefficient of concordance *W* ranges from a value of zero (no agreement amongst judges) and a positive one (complete agreement) (AZEVEDO *et al.*, 2012). Categorical levels of group consensus are suggested as low, moderate, and strong agreement with values of 0.10, 0.30, and 0.50, respectively (KRASKA-MILLER, 2013).

Along with Kendall's *W*, the *p*-value is estimated for statistical significance. To calculate the *p*-value in this case, the right-tailed probability of the chi-squared χ^2 distribution for a given *W* can be estimated using the following formula given by Friedman (1940, p. 87):

$$W = \frac{\chi^2}{m\left(n-1\right)} \qquad (8)$$

which gives the explicit form in χ^2,

$$\chi^2 = m\left(n-1\right)W \qquad (9)$$

The number χ^2 is used to a hypothesis test for the null hypothesis H_0, which assumes that no relationship exists amongst the judgements within a 95% level of confidence (α = 0.05). The *MegaStat* add-in for Microsoft Excel was used for the calculation of Kendall's *W* and its associated *p*-value. Should the *p*-value fall above 0.05, then the null hypothesis H_0 is confirmed and it is possible to statistically infer that there is no significant agreement amongst judges in the group response, which is clearly not a desirable outcome and hence should be avoided.

5
RESULTS

5.1 Results from the lean-ESS research model

5.1.1 Priorities of ESS dimensions

The relative importance of ESS dimensions to corporate social sustainability was estimated using a comparison matrix (Table 10). Since four dimensions were considered, this comparison matrix has four rows and four columns. Respondents were able to provide judgements using Saaty's fundamental scale (Table 7), and a single vector of ESS priorities (E-vector) was calculated through the method discussed in section 4.3. It is worth noting that decimal values are present due to internal calculations of group judgement synthesis employed by the *Expert Choice 2000* software.

All comparisons matrices are composed of a grey diagonal that represents in-between comparisons of the same variable, which assumes a value of 1.000 since they are equally important when compared to themselves. The elements in the yellow portion represent pairwise comparisons included in the AHP questionnaire, and the elements in the white portion of the matrix being the symmetrical comparisons. All comparisons follow the structure [*element in the row*] compared to [*element in the column*]. Should the row have more importance, then the scale is applied directly. For the opposite case, the scale is applied as its reciprocal (1/scale). Consequently, only the comparisons in the yellow blocks must be completed, with the white blocks as their reciprocal.

Table 10. ESS dimensions pairwise comparison matrix (group response)

	Autonomy and empowerment	Health and safety	Job stress reduction	Enhanced workplace	**E-vector**
Autonomy and empowerment	1.000	1/1.879	1.715	1.907	**0.257**
Health and safety	1.879	1.000	2.365	3.379	**0.439**
Job stress reduction	1/1.715	1/2.365	1.000	1.740	**0.181**
Enhanced workplace	1/1.907	1/3.379	1/1.740	1.000	**0.122**

Notes: CR = 0.0008 (< 0.10 = acceptable), W_{ESS} = 0.377, *p*-value = 0.0470 (< 0.05 = significant correlation)

Employee "health and safety" dimension was ranked the first position with a priority of 0.439, and "enhanced workplace" (0.122) was ranked the least important ESS dimension for the group of respondents. Employee "autonomy and empowerment" (0.257) was pointed second place in the group ranking of ESS dimensions, which, together with “health and safety”, accounted for nearly 70% of the total priority assigned by respondents. The CR value of 0.008 (< 0.10) indicates acceptable judgements. Commentaries by respondents in this section are listed in Table 11.

Table 11. Commentaries by respondents on ESS dimensions

Respondent	Commentary
P_3	‘Every improvement and autonomy action must be first assessed by the Work Safety board, due to the risk of failing to meet some security criterion. There are many instances of this case in the industry, which led to disastrous results.’
P_4	‘I believe that some dimensions may be a consequence of others, for example, if you don’t have safety it is very likely that you won’t feel comfortable on your job or task, and you will find it stressful.’

Concerning group consensus, concordance level calculations used rankings instead of priorities values, as demonstrated by Kendall and Smith (1939). Hence, individual rankings of ESS dimensions were organised to estimate the level of agreement amongst respondents. Individual and group rankings of ESS dimensions are listed in Table 12. In the case of ESS dimensions, a moderate level of agreement was achieved ($0.300 < W < 0.500$) with a respective *p*-value of 0.0470, which statistically validates the existence of significant agreement amongst respondents.

Table 12. Individual and group rankings of ESS dimensions

	Autonomy and empowerment	Health and safety	Job Stress Reduction	Enhanced Workplace	CR
P_1	2	1	4	3	0.170
P_2	3 (Tied)	1	2	3 (Tied)	0.003
P_3	3	1	4	2	0.120
P_4	2	1	3	4	0.010
P_5	1	2	3	4	0.060
P_6	1	2	3	4	0.080
P_7	1 (Tied)	2 (Tied)	1 (Tied)	2 (Tied)	0.000
Group	**2**	**1**	**3**	**4**	**0.008**

5.1.2 Priorities of LPs for employee autonomy and empowerment

The LPs under the employee "autonomy and empowerment" dimension resulted in the priorities organised in Table 13. "Standardised work" had the highest value in the E-vector across all LPs considered, with a priority value of 0.169. Next, 5S (0.153) is in second place, followed by TPM, *kaizen*, and "multifunctional workers", with values of 0.148, 0.137, and 0.137, respectively. The least important LP for employee "autonomy and empowerment" was "pull production", with a priority value of 0.049.

Table 13. LPs pairwise comparison matrix for autonomy and empowerment (group response)

	Pull production	*Kaizen*	Standard. work	5S	VSM	TPM	*Jidoka*	Multifunc. workers	**E-vector**
Pull production	1.000	1/2.494	1/4.633	1/2.959	1/3.408	1/2.945	1/1.390	1/2.462	**0.049**
Kaizen	2.494	1.000	1/1.240	1.461	1.200	1/1.086	1.179	1/1.222	**0.137**
Standard. work	4.633	1.240	1.000	1.195	1.823	1.023	1.416	1.000	**0.169**
5S	2.959	1/1.461	1/1.195	1.000	1.525	1/1.031	2.013	1.543	**0.153**
VSM	3.408	1/1.200	1/1.823	1/1.525	1.000	1/1.162	1.000	1/1.014	**0.116**
TPM	2.945	1.086	1/1.023	1.031	1.162	1.000	1.755	1.096	**0.148**
Jidoka	1.390	1/1.179	1/1.416	1/2.013	1/1.000	1/1.755	1.000	1/1.888	**0.091**
Multifunc. workers	2.462	1.222	1/1.000	1/1.543	1.014	1/1.096	1.888	1.000	**0.137**

Notes: CR = 0.020 (< 0.10 = acceptable), $W_{A\&E}$ = 0.255, *p*-value = 0.0449 (< 0.05 = significant correlation)

Individual and group rankings of LPs under the autonomy and empowerment dimension are listed in Table 14. A nearly moderate level of agreement was achieved amongst respondents (0.100 < W < 0.300) with a *p*-value of 0.0449.

Table 14. Individual and group rankings of LPs for autonomy and empowerment

	Pull production	*Kaizen*	Standardised work	5S	VSM	TPM	*Jidoka*	Multifunctional workers	CR
P_1	5	4	3	8	2	1	7	6	0.170
P_2	8	3	1	4	6	5	2	7	0.090
P_3	8	7	6	1	3	2	4	5	0.150
P_4	6	8	2	1	5	4	7	3	0.190
P_5	8	1	6	2	5	7	4	3	0.120
P_6	8	4	3	5	7	2	6	1	0.080
P_7	7	1	3	6	4	5	8	2	0.200
Group	**8**	**4**	**1**	**2**	**6**	**3**	**7**	**5**	**0.020**

Respondents' commentaries in this section are listed in Table 15.

Table 15. Commentaries by respondents on employee autonomy and empowerment

Respondent	Commentary
P_3	'5S is the basis for all contexts, and all implemented action will automatically lead to *kaizen*, standardisation and employee autonomy.'
P_4	'Again, I think that some lean "tools" should be applied in a cause-effect sequence, so the question regarding if some tool or principle or more important, can easily become if something is "necessary for". For example, the success of *Kanban* or TPM is highly related to having previously implemented standardised work or 5S'

5.1.3 Priorities of LPs for employee health and safety

The combined judgements of LPs under the employee "health and safety" dimension resulted in the comparison matrix of Table 16. The practice of 5S was assigned with the highest value in the E-vector, with a priority of 0.248. TPM is at second place with a priority of 0.190, followed by "standardised work" and *kaizen* with values of 0.166 and 0.112, respectively.

Table 16. LPs pairwise comparison matrix for employee health and safety (group response)

	Pull production	*Kaizen*	Standard. work	5S	VSM	TPM	*Jidoka*	Multifunc. workers	**E-vector**
Pull production	1.000	1/4.443	1/5.359	1/4.151	1/1.755	1/4.187	1/3.109	1/1.565	**0.040**
Kaizen	4.443	1.000	1/1.326	1/2.473	1.846	1/2.236	1.036	1.162	**0.112**
Standard. work	5.359	1.326	1.000	1/1.795	2.652	1/1.090	1.996	1.819	**0.166**
5S	4.151	2.473	1.795	1.000	3.980	2.029	2.176	2.256	**0.248**
VSM	1.755	1/1.846	1/2.652	1/3.980	1.000	1/2.177	1/1.222	1/1.382	**0.067**
TPM	4.187	2.236	1.090	1/2.029	2.177	1.000	2.542	3.136	**0.190**
Jidoka	3.109	1/1.036	1/1.996	1/2.176	1.222	1/2.542	1.000	1/1.234	**0.091**
Multifunc. workers	1.565	1/1.162	1/1.819	1/2.256	1.382	1/3.136	1.234	1.000	**0.087**

Notes: CR = 0.020 (< 0.10 = acceptable), $W_{H\&S}$ = 0.526, p-value = 0.0006 (< 0.05) = significant correlation)

Table 17. Individual and group rankings of LPs for employee health and safety

	Pull production	*Kaizen*	Standardised work	5S	VSM	TPM	*Jidoka*	Multifunctional workers	CR
P_1	7	6	3	2	8	1	4	5	0.130
P_2	8	5	1	3	7	4	2	6	0.120
P_3	7	5	3	1	8	2	6	4	0.130
P_4	5	8	3	1	7	2	6	4	0.190
P_5	8	2	5	3	1	7	6	4	0.040
P_6	8	4	2	1	5	3	6	7	0.090
P_7	8	2	3	4	7	1	6	5	0.170
Group	**8**	**4**	**3**	**1**	**7**	**2**	**5**	**6**	**0.020**

Individual and group rankings of LPs for "health and safety" are listed in Table 17. A strong level of agreement was present amongst respondents ($W > 0.500$) with a p-value of 0.0006. Linkages between LPs and employee "health and safety" were often discussed by a fair number of publications in the sample of collated papers, which can be a potential reason for the strong level of agreement achieved in a single application of the questionnaire.

5.1.4 Priorities of LPs for job stress reduction

The combined judgements of LPs importance under "job stress reduction" resulted in the comparison matrix and the E-vector comprised in Table 18. It is convenient to restate that only two articles were the only ones to address job stress explicitly, thus fitting this dimension into its sphere of influence.

Table 18. LPs pairwise comparison matrix for job stress reduction (group response)

	Pull production	*Kaizen*	Standard. work	5S	VSM	TPM	*Jidoka*	Multifunc. workers	E-vector
Pull production	1.000	1/3.140	1/3.830	1/4.511	1/1.968	1/2.375	1/2.246	1/2.701	**0.046**
Kaizen	3.140	1.000	1/1.877	1/1.417	1.402	1/1.435	1.222	1.522	**0.127**
Standard. work	3.830	1.187	1.000	1.316	1.654	1/1.052	1.270	1.552	**0.178**
5S	4.511	1.417	1/1.316	1.000	2.666	1.251	1.468	1.897	**0.186**
VSM	1.968	1/1.402	1/1.654	1/2.666	1.000	1/1.573	1/1.081	1/1.222	**0.091**
TPM	2.375	1.435	1.052	1/1.251	1.573	1.000	1.755	1.700	**0.160**
Jidoka	2.246	1/1.222	1/1.270	1/1.468	1.081	1/1.755	1.000	1.352	**0.112**
Multifunc. workers	2.701	1/1.522	1/1.552	1/1.897	1.222	1/1.700	1/1.352	1.000	**0.100**

Notes: CR = 0.010 (< 0.10 = acceptable), W_{JSR} = 0.372, p-value = 0.0109 (< 0.05 = significant correlation)

The highest priority was given by the group to 5S (0.186), followed by "standardised work" (0.178), TPM (0.160) and *kaizen* (0.127). The first three practices presented rather near values for their priorities. “Job stress reduction” was the least explored ESS dimension in the reviewed lean-ESS literature, with only two papers addressing its relation with LPs, specifically “pull production”, “standardised work”, TPM, and “multifunctional workers”. Despite the dearth of information on the effects of LPs on employee job stress, the group seemed to converge, with a moderate level of agreement (W = 0.372) on a single application of the questionnaire, on the point that 5S, “standardised work”, TPM and *kaizen* are the main lean practices for job stress reduction, which altogether account for a priority of 65.1%. Individual and group rankings of LPs for job stress reduction amongst shop-floor employees are listed in Table 19. Commentaries by respondents in this section are presented in Table 20.

Table 19. Individual and group rankings of LPs for job stress reduction

	Pull production	*Kaizen*	Standardised work	5S	VSM	TPM	*Jidoka*	Multifunctional workers	CR
P_1	8	5	2	4	6	1	3	7	0.080
P_2	7	4	1	5	8	6	2	3	0.100
P_3	8	7	1	3	5	2	6	4	0.150
P_4	8	4	1	2	6	3	5	7	0.140
P_5	7	4	5	1	2	8	6	3	0.100
P_6	5	4	2	1	7	3	6	8	0.110
P_7	8	1	7	3	4	5	6	2	0.070
Group	**8**	**4**	**2**	**1**	**7**	**3**	**5**	**6**	**0.010**

Table 20. Commentaries by respondents on job stress reduction

Respondent	**Commentary**
P_3	‘Interesting point. Even though “pull production” has been one of the fundamental principles of lean production, to have an effective implemented just-in-time system demands, above all, a solid relationship with suppliers, as well as good practices of maintenance, standardisation of work, multifunctional teams, *et cetera*. The minimal failure on any of these support systems will jeopardise just-in-time and inflict great stress on manufacturing and the value chain.’

5.1.5 Priorities of LPs for enhanced workplace

The combined judgements of LPs importance under the "enhanced workplace" dimension resulted in the comparison matrix and the E-vector comprised in Table 21.

Table 21. LPs pairwise comparison matrix for enhanced workplace (group response)

	Pull production	*Kaizen*	Standard. work	5S	VSM	TPM	*Jidoka*	Multifunc. workers	**E-vector**
Pull production	1.000	1/3.424	1/2.281	1/4.356	1/2.159	1/2.365	1/2.166	1/2.340	**0.047**
Kaizen	3.424	1.000	1.662	1/1.199	2.984	1.565	3.928	2.652	**0.214**
Standard. work	2.281	1/1.662	1.000	1/3.238	1.454	1.328	1.668	1.609	**0.120**
5S	4.356	1.199	3.238	1.000	3.212	2.033	3.140	2.567	**0.254**
VSM	2.159	1/2.984	1/1.454	1/3.212	1.000	1/1.430	1/1.199	1/1.182	**0.078**
TPM	2.365	1/1.565	1/1.328	1/2.033	1.430	1.000	1.907	2.127	**0.126**
Jidoka	2.166	1/3.928	1/1.668	1/3.140	1.199	1/1.907	1.000	1/1.390	**0.074**
Multifunc. workers	2.340	1/2.652	1/1.609	1/2.567	1.182	1/2.127	1.390	1.000	**0.087**

Note: CR = 0.010 (< 0.10 = acceptable), W_{EW} = 0.568, *p*-value = 0.0002 (< 0.05 = significant correlation)

Individual and group rankings of LPs for "enhanced workplace" are shown in Table 22. A strong level of agreement (0.568) was achieved amongst respondents (W > 0.500) with an associated *p*-value of 0.0002. No commentaries have been drawn by respondents in this section.

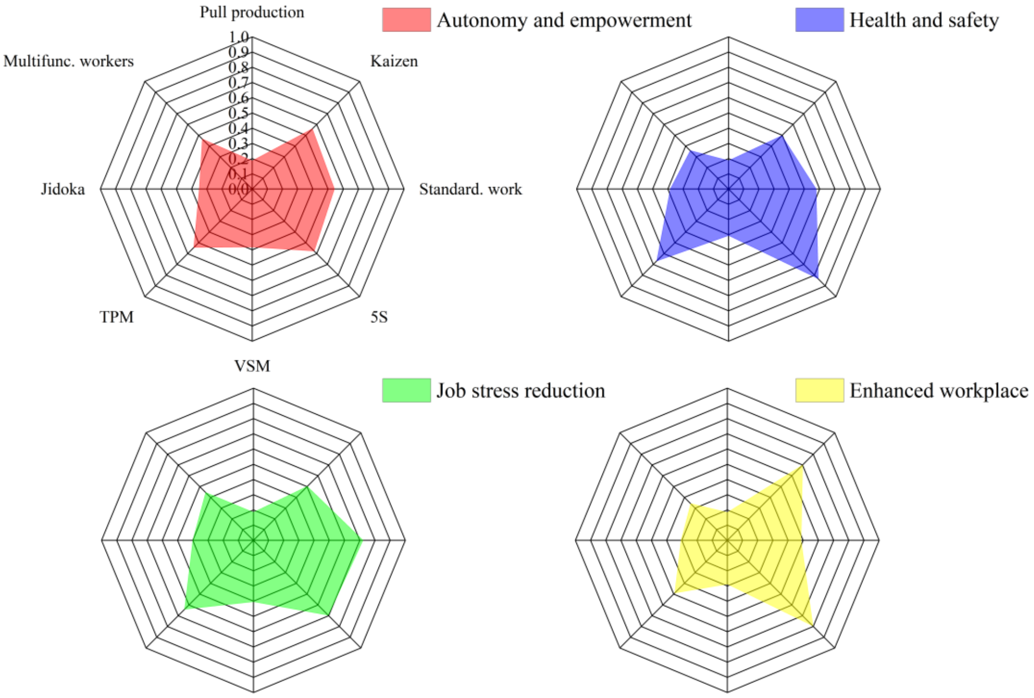
Table 22. Individual and group rankings of LPs for enhanced workplace

	Pull production	*Kaizen*	Standardised work	5S	VSM	TPM	*Jidoka*	Multifunctional workers	CR
P1	8	1	3	2	4	6	7	5	0.100
P2	7	4	2	1	8	3	5	6	0.150
P3	8	2	3	1	6	4	7	5	0.160
P4	8	3	4	2	7	1	5	6	0.110
P5	7	3	6	2	4	8	5	1	0.130
P6	8	3	2	1	5	4	6	6	0.080
P7	6	1	8	3	2	5	7	4	0.140
Group	**8**	**2**	**4**	**1**	**6**	**3**	**7**	**5**	**0.020**

5.2 Summary of group response

The radar graph in Figure 12 puts together the normalised priorities of LPs (varying from zero to one) for each ESS dimension.

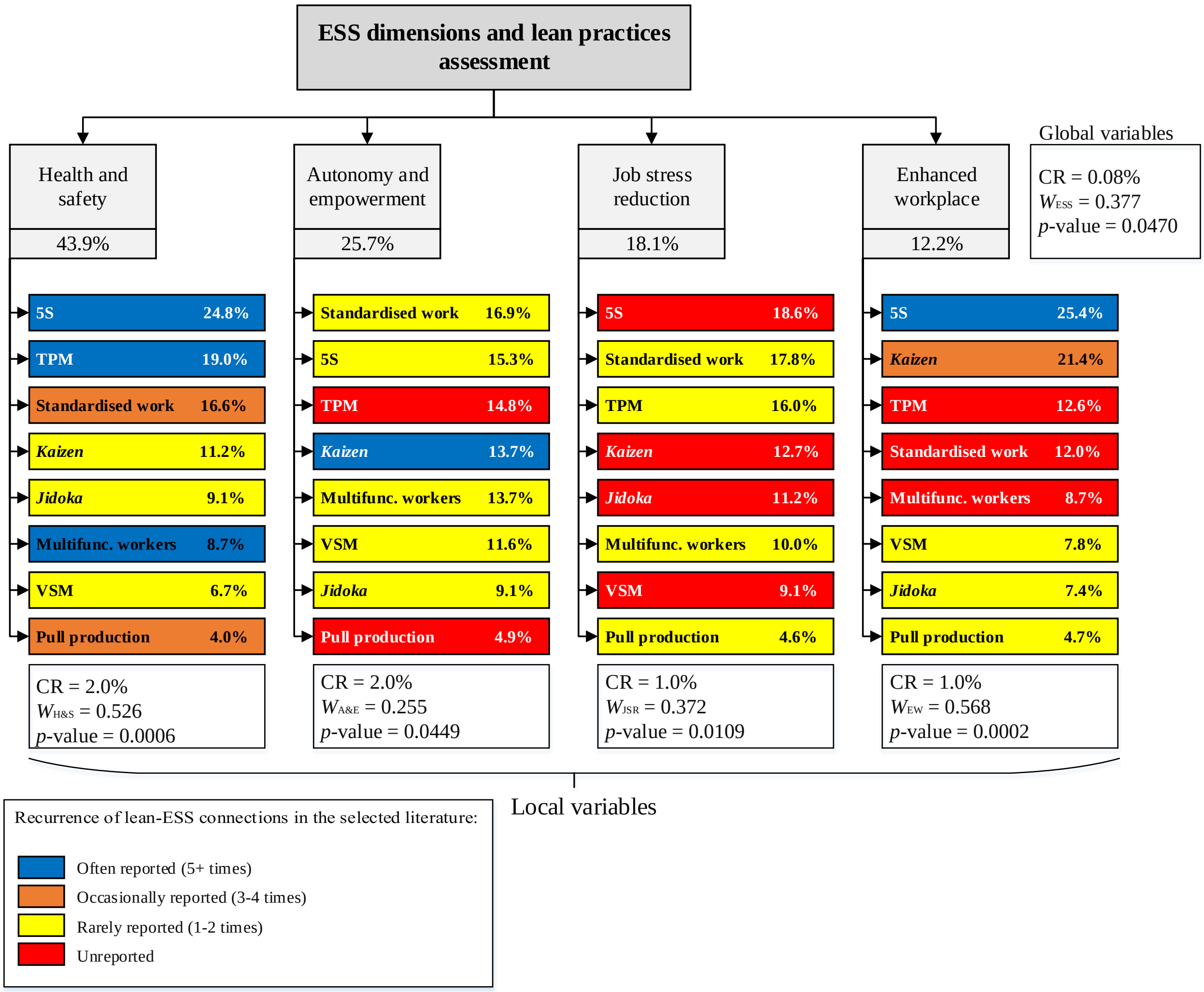
Figure 12. Distribution of normalised priorities of LPs for each ESS dimension



The predominance of 5S over ESS dimensions is noteworthy, except for “job stress reduction” in which “standardised work” was preeminent. In general, operational practices of lean were considered most influential for social outcomes, such as 5S, *kaizen*, and “standardised work”. The least important lean practice for every dimension was “pull production”, which has been discussed in the literature as a significant source of job stress build-up in shop-floor employees (MULLARKEY; JACKSON; PARKER, 1995; CONTI *et al.*, 2006; LONGONI; CAGLIANO, 2015).

The lean-ESS research model is now shown in Figure 13 featuring descendent priorities and the recurrence of each LP-ESS relation in the reviewed literature indicated by different colours, accounting for both positive and negative outcomes.

Figure 13. Priorities and recurrence of connections in the lean-ESS research model

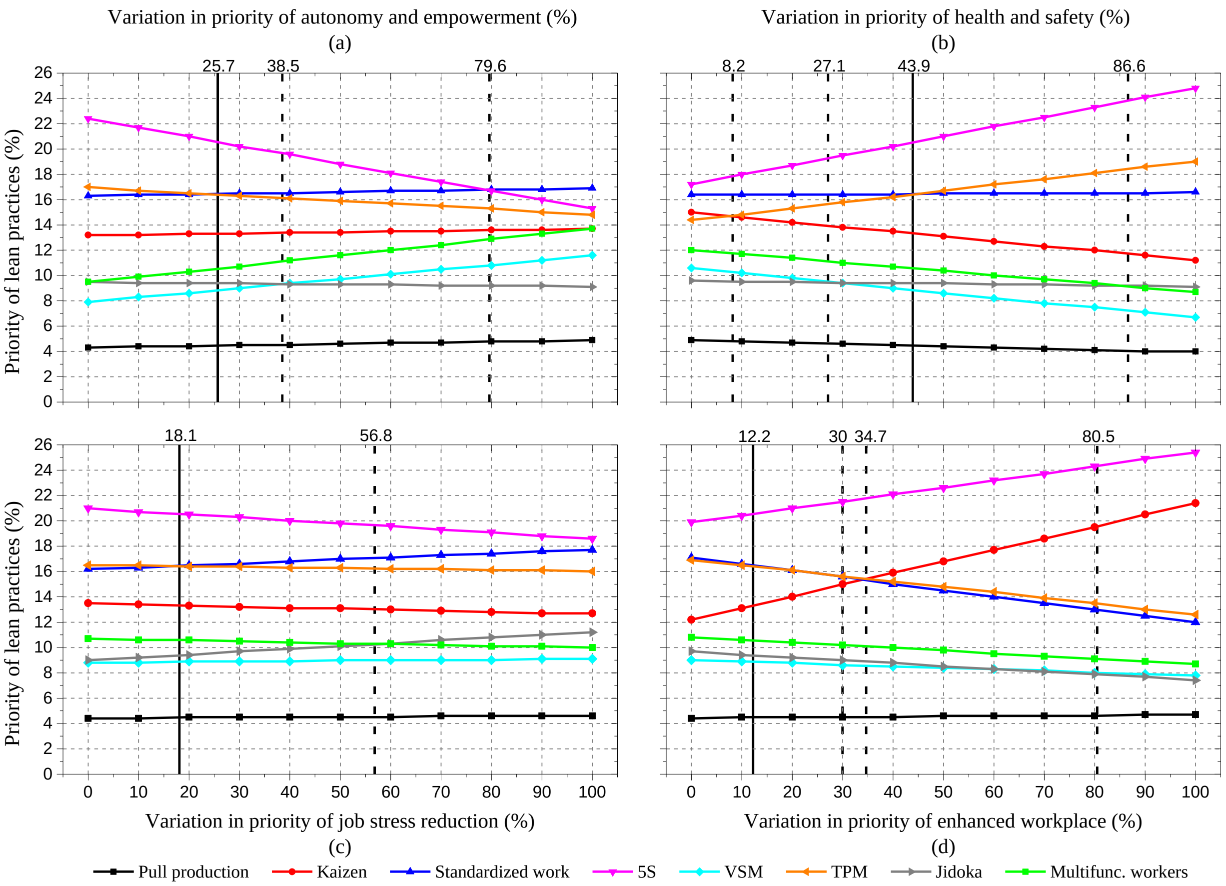


5.3 Sensitivity analysis

The overall rankings of LPs in Figure 13 are unique for a specified set of ESS priorities given by expert opinion. Scenarios with different ESS priorities can be assessed through a sensitivity analysis on their numerical values, which will differentiate cases that prioritise other dimensions with new rankings of LPs. It can be illustrated, for example, in the case of an organisation that decides to assume a larger priority on employee health and safety due to high injury rates, or in the case of high turnover which will demand a prioritisation of "job stress reduction". Also, a sensitivity analysis is convenient for the visualisation of the behaviour of the priorities of each lean practice in the face of changes in ESS priorities.

A sensitivity analysis was performed for each one of the four ESS dimensions. The data presented in the following graphs were acquired in *Expert Choice 2000* software. Figure 14 contains four graphs depicting the linear behaviour of lean practices, whose solid vertical lines indicate the scenario of Figure 13 (current state), and the dashed lines indicate the percentages in which lean practices switch positions in the ranking.

Figure 14. Sensitivity analysis: (a) autonomy and empowerment, (b) health and safety, (c) job stress reduction, and (d) enhanced workplace



Looking at Figure 14-a, for example, gives that 5S is the top priority when “autonomy and empowerment” is set at 25.7% (current weight). When this dimension is enhanced over 79.6%, standardised work assumes the top priority, and 5S drops to second place in the ranking. In contrast, 5S is the top priority regardless of changes in the “health and safety” weight (Figure 14-b), and shifts across the ranking occur regarding the pairs of *kaizen*-TPM, “VSM-*jidoka*”, and “multifunctional workers-*jidoka*”, for lesser and higher values of this dimension.

This type of analysis is essential for a dynamic assessment of practices to prioritise when changes in business strategies take place in an organisation, allowing managers to better act towards improving the ESS dimensions. Moreover, it can help to predict the potential effects of future decisions concerning ESS dimensions and how they will affect lean practices.

5.4 Discussion

5.4.1 ESS dimensions

The emphasis given by expert opinion on the well-being of employees, along with the perception of work safety and the development of a sense of sharing knowledge and freedom to improve their tasks, corroborates the need to recognise the importance and value of employees and their contributions toward the improvement of their work perception and routine. This observation is congruent with Wong and Wong (2014, p. 53): ‘In the lean environment, people are the main theme that drives changes and improvements’.

The dimension of “health and safety” as it was praised by expert opinion was also found to be consistently discussed in the literature. This dimension has the largest number of connections with all lean practices considered in this study, which points to a major interest in establishing employee well-being as the bottom line for a socially sustainable operation of a lean manufacturing system. Practising 5S was considered of the highest importance upon prioritising “health and safety”, probably due to its *seiso* (shine) component that emphasises cleanliness associated with safety (GUPTA; CHANDNA, 2020).

Albeit found marginally explored both in its concept and practicality, the dimension of “autonomy and empowerment” was ranked second place in the ESS ranking. This is an interesting observation when considering empowerment as a relatively recent theoretical conception (PERKINS; ZIMMERMAN, 1995; ZIMMERMAN, 2000) with little information published regarding its functionality in a manufacturing environment. Nevertheless, consulted expert opinion prioritised this dimension. When these two facts are considered, the need to raise a major awareness on the very concept of employee empowerment and its operationality becomes evident, for ranking this dimension in a high position in the hierarchy with a minor discussion gives the impression of a brighten initiative with few efforts in practice.

Enhanced workplace assumed the last position in the ranking, which is a dimension that is manifested mostly by operational aspects and commonly influence by hard practices, hence is ultimately related to the physical work environment.

5.4.2 Lean practices

The expert opinion pointed to 5S as the dominant enabler of ESS amongst the dimensions considered in the model. The demonstrated appraisal for 5S by expert opinion is fairly relatable to the current state of research found in the systematic review, except for job stress reduction that is still poorly explored. Next, the role of lean practices is discussed for each ESS dimension.

- *LPs for employee "autonomy and empowerment"*

The lean manufacturing system advocates for full employee participation, in which autonomous employees may be responsible for designing standards for the activities they carry out. ESS in lean manufacturing requires employees to act towards what they consider fruitful for their routine by following their interests within a pre-established level of freedom. Linking LPs and employee "autonomy and empowerment" was rarely discussed in the lean-ESS literature, which reflects the modest level of consensus over the role of LPs in this dimension, probably due to the limited evidence.

Despite having been associated with autonomy and empowerment in only one paper, "standardised work" was pointed by expert opinion as to the most significant lean practice for employee "autonomy and empowerment". The theoretical discussion of this relation presented that, when employees are given the freedom to participate in the creation of new standards of work on the shop floor, their sense of autonomy and empowerment is enhanced (CAMUFFO; DE STEFANO; PAOLINO, 2017; GAIARDELLI; RESTA; DOTTI, 2019).

The practice of standardising work is notable in empowering autonomous employees, which plays an important role in avoiding risks and vulnerabilities through aggregating the idea of building proper standards by autonomous employees. Besides standardising work, implementing and maintaining 5S is imperative in a manufacturing environment, for it was observed to be decisive to workplace quality (CHIARINI, 2014), and can potentially promote employee autonomy by endowing housekeeping habits in the workstation, as well as employee empowerment due to closer control of their workplace (PFEFFER, 2010; ROJANETTE; VAN DYK; VAN DER MERWE, 2019), and a consequent higher sense of worthiness toward their opinions (GAIARDELLI; RESTA; DOTTI, 2019).

It sounds reasonable that TPM was positioned in the top three LPs in the "autonomy and empowerment" ranking, given that such practice allows the participation of employees in equipment effectiveness through autonomous maintenance. This premise is capable of boosting autonomy on tasks of correction and identification of problems, and empowerment through sharing experience in correctional group tasks.

Promoting *kaizen* events can aid training processes as a practice aimed at improving communication and employee participation. The positive effect of *kaizen* events was addressed in several publications, whose social outcomes lie in sharing knowledge through upgrades in information channels (WONG; WONG, 2014), teamwork and shared tasks (VICENTE *et al.*, 2015), and the promotion of a problem-solving culture and creativity towards innovation (CHERRAFI *et al.*, 2016; SAJAN *et al.*, 2017). Employee creativity and capacity for innovation in the workplace are fomented through sharing knowledge, thus leading to social improvement.

- *LPs for employee "health and safety"*

Ranking 5S as the top priority for employee "health and safety" is coherent with the lean-ESS literature to date since nine publications reported positive outcomes obtained from the implementation and maintenance of housekeeping practices on the shop floor, which is the highest number of papers in the sample associating one lean practice to a single ESS dimension. Reported benefits of 5S to employee "health and safety" ranged to, for instance, from a reduction of leakages and hazardous spills (CHIARINI, 2014; WONG; WONG, 2014) and mitigation of health and safety risks through clean work environments (CHERRAFI *et al.*, 2016), to ergonomic advancements (PIERCY; RICH, 2015) and reduction of strain injuries on employees (VERRIER; ROSE; CAILLAUD, 2016).

TPM was cited by five papers as an enabler of "health and safety". According to the lean-ESS literature, establishing a frequency of autonomous maintenance, repairs, and replacement of machine parts resulted in a positive effect on reducing oil leakages and hazardous solid and gas emissions (CHIARINI, 2014). Moreover, TPM performed by employees can avoid accidents and production problems, as well as develop their organisational capability, thus helping to increase worker welfare (LONGONI; CAGLIANO, 2015).

Preventive maintenance is pointed by Cherrafi *et al.* (2016) as critical for smaller equipment failure rates and consequently less chance of accidents and injuries. Camuffo, De Stefano and Paolino (2017) found that TPM is directly related to the reduction of accidents. Considering these pieces of evidence, ranking TPM as the second top priority for health and safety seems reasonable from expert opinion.

It is safe to note that, even though “standardised work” was positioned in the top three highest priorities for employee “health and safety”, the organisation of jobs and tasks must be properly designed so that the standards for different types of activities are safe and failproof. A standard for an operation is as safe as long as it is well designed. Proper documentation of standardised tasks is considered fundamental for safety policies (LONGONI; CAGLIANO, 2015).

- *LPs for“job stress reduction” on employees*

Even though 5S was ranked the first position in the job stress ranking, there is no information about their relationship in the selected sample of articles. Truly, there is a limited discussion on matters of employee job stress, and half of its links to lean practices are potential, which raises a considerable gap in the contemporary social lean discussion. Besides, the priorities of lean practices are equitably distributed throughout the ranking, thus providing an initial research scenario in which they have similar importance towards reducing job stress. Even though this result is statistically consistent with expert opinion and that there is a somewhat limited discussion on lean and job stress, it raises a substantial gap in the contemporary research on the social perspective of lean manufacturing. This statement is also valid for the case of “autonomy and empowerment”, whose priorities values of lean practices were found to be rather similar as well.

The last position is occupied by “pull production”, and there a discussion of this relation that posed this practice with a negative influence on ESS, given that a high workload and peer pressure on blue-collar workers are commonly associated with employing pull production in just-in-time systems (MULLARKEY; JACKSON; PARKER, 1995), which tends to focus on operational aspects such as reducing cycle times and work-in-progress (CONTI *et al.*, 2006; BOCQUET; DUBOULOZ; CHAKOR, 2019). Besides that, high job demands with little control from workers shall ultimately cause an intensification of work and building up job stress (PFEFFER, 2010). At the shop-floor level, these factors can build up stress and psychological strain in workers (LONGONI; CAGLIANO, 2015).

Kaizen events and “multifunctional workers” have been reported to cause a positive outcome on job stress reduction (CONTI *et al.*, 2006; DE TREVILLE; ANTONAKIS, 2006). Considering the premise of collaborative teamwork towards continuous improvement that is embedded in these two practices, they will eventually contribute to job stress reduction in shop-floor employees by acquiring a perspective of a collective and safe workplace based on the development of competencies (BOCQUET; DUBOULOZ; CHAKOR, 2019). In addition, Gaiardelli, Resta and Doti (2019) found that changes in the work environment derived from hard practices may initially provoke higher job stress amongst shop-floor employees, yet it is compensated as the lean system evolves through time

Nevertheless, there is also evidence that these two LPs caused negative outcomes on job stress. Martínez-Jurado and Moyano-Fuentes (2014) and Sajan *et al.* (2017) stated that the high-quality demands of products are likely to cause a detrimental impact on employee job stress. Furthermore, as a way to promote worker multifunctionality, job rotation may increase the rate of injuries if proper training on new tasks is not provided (BERGENWALL; CHEN; WHITE, 2012), which tends to increase worker physical job stress due to the perception of unsafeness and insecurity when performing a task caused by lack of qualification (BOCQUET; DUBOULOZ; CHAKOR, 2019).

- *LPs for an“enhanced workplace”*

Experts assessed 5S and *kaizen* as underlying practices for the enhanced workplace dimension, supporting the linkages found in the literature. However, although these influences were already suggested before, expert opinion adds the intensity notion since these two practices together correspond to 46.8% of the priority weight. The association of LPs and “enhanced workplace” was theoretically conceived with five practices in the set of lean practices considered in this study. The presumption of a safe and clean workflow-driven workstation was conceptually linked to practices of “pull production”, *kaizen*, 5S, VSM, and *jidoka*. A beneficial link between 5S and workplace safety and cleanliness is reported by Gaiardelli, Resta and Doti (2019) from a perspective of layout changes performed by employees according to their perception of comfort in the workplace.

As top priorities, 5S (0.254) and *kaizen* (0.214) combined amounted to almost half of the total priority among all LPs considered (46.8%). This result is aligned with the results from the study conducted by Vicente *et al.* (2015), who advocated for *kaizen* events and 5S as representative tools for achieving higher levels of workplace organisation and serve as a basis for self-improvement by employees. Regarding workplace development through waste elimination, Das (2018) provided results of a literature review showing that 5S was the most cited tool for accomplishing such a goal, which is reasonable when considering the results of Table 22.

Curiously, *jidoka* was positioned in a low rank, which may sound counterintuitive given that this type of device is supposed to improve workplace routines by mitigating machine breakdowns and the risk of accidents. Nonetheless, although a significant influence of this practice is still uncovered, it is recommendable to investigate a potential moderating effect of *jidoka* on the impact of lean manufacturing on the workplace.

In the lowest position of the LPs for “enhanced workplace” ranking is “pull production” (0.047). VSM and *jidoka* occupied the 6th and 7th positions, with similar priorities of 0.078 and 0.074, respectively. Despite having been given low positions in the ranking, these last two practices have been shown as supportive to shop-floor workers in terms of establishing ergonomic standards in the workstation (CHERRAFI *et al.*, 2016; MARTÍNEZ-LEÓN; CALVO-AMODIO, 2017), and boosting productivity through the employment of fool-proof devices (YUSUP *et al.*, 2015; IRANMANESH *et al.*, 2019).

6
CONCLUSIONS

6.1 Accomplishing research objectives

The main objective of this dissertation was to investigate the level of influence (in terms of relative importance) of different lean practices on dimensions of employee social sustainability on the shop floor. This study was carried out by following two main phases: (*i*) to identify and link two separate groups of lean practices and ESS dimensions via analysis and synthesis of selected lean-ESS literature, and (*ii*) to build and apply a hierarchical research model with consulted expert opinion as input data.

Four ESS dimensions and eight lean practices were considered in the research model. The relative importance of the components in these two groups of variables was assessed through a pairwise comparison logic, with their priorities estimated upon relying on the opinion of seven experts (Table 9, section 4.4). A single application of the lean-ESS research model revealed that employee "health and safety" is the most critical social dimension on the shop floor of the manufacturing sector, which was given a priority of 43.9%. Employee "autonomy and empowerment" was addressed as a second priority (25.7%), followed by "job stress reduction" (18.1%) and "enhanced workplace" (12.2%). The first three priorities are people-oriented and directly affect worker well-being.

Next, each of one the minor objectives is recapped.

(1) To identify dimensions of employee social sustainability dimensions and lean practices, along with their relationships through a synthesis of lean-ESS literature to date;

A systematic literature review was designed and performed to analyse selected sustainable lean literature. The application of exclusion criteria throughout the selection of papers resulted in a larger sample of 85 papers, which underwent a data reduction process to refine the sample and build a solid basis for a more focused and careful synthesis of papers that are aligned with up-to-date lean-ESS research. From this procedure, 17 papers were selected (Table 3, section 3.4) and, from this smaller sample, the lean-ESS variables could be extracted and their relationships identified and described, which culminated in the linkages explicated in Table 4 (subsection 3.5.1) and in Figure 8 (subsection 3.5.2).

(2) To design and apply a multi-criteria decision analysis model for the evaluation of priorities of dimensions of employee social sustainability and lean practices;

To properly approach the problem of establishing priorities of ESS dimensions and LPs accordingly, a lean-ESS research model (Figure 10, section 4.3) was conceived based on reported evidence found in the SLR. This model comprised both reported and potential connections between ESS dimensions and LPs, which amounted to 23 and 9 linkages, respectively. The hierarchical arrangement of these two groups of variables was followed by the application of the analytic hierarchy process (AHP), and the usage of a statistical index of consensus (section 4.5) to verify the existence of significant correlation amongst judgements provided by experts.

(3) To establish priorities of dimensions of employee social sustainability and lean practices using expert opinion.

The AHP technique was used to calculate numerical values of global and local priorities of ESS dimensions and lean practices, respectively. The calculations performed in this last portion of the research were aided by the *Expert Choice2000* software and the *MegaStat* add-in for Microsoft Excel. These pieces of software were employed for (*i*) establishing priorities in the lean-ESS model as a group response and build specific and overall rankings of ESS dimensions and LPs (Figure 13, sub-section 5.2.6), (*ii*) performing a sensitivity analysis to understand individual influences of LPs over each one for the four ESS dimensions (Figure 14, section 5.3), and (*iii*) estimating group consensus and statistically validate each set of pairwise comparisons and calculate priorities. By doing so, it was possible to identify, relying on expert opinion, the social dimensions and lean practices that were deemed as most and least influential in the context of employee social sustainability on the shop floor.

6.2 Contributions and originality

The rankings of ESS dimensions and lean practices in Figure 13 are the first consequence of tackling social sustainability from workers' perspective, who are generally more acquainted with these practices. Given that employee social sustainability has been loosely explored in the literature, a fair contribution would consist of providing clues to a more complex systemic problem of social sustainability on the shop floor, that is, to what extent ESS is affected through commonly used lean manufacturing practices. By following this path, this study was able to analyse the relative importance of ESS dimensions and lean practices and provide an initial ground for further research on the field.

By associating an exploratory premise to this study, the research efforts were aimed at raising questions about issues of ESS given the incipient stage of its state of the art. A relevant contribution of the proposed lean-ESS research model was to introduce the idea of prioritising lean manufacturing practices on the shop floor, which was not discussed in late literature, shedding light on the role of these practices in different ESS dimensions and presenting a basic ground for further investigation around the practicality of ESS.

Another contribution was to offer general guidelines to researchers and practitioners who wish to understand and further explore the influence of lean practices in the recently studied scenario of socially sustainable lean environments. Moreover, the focus on employee “health and safety” suggested by expert opinion should lead to higher levels of employee satisfaction, which positively influences productivity and establish a better organisational image and performance. The insights on priorities given in this study can aid the adequate build-up and sequence of dimensions and lean practices that help organisations achieve blue-collar workers social demands.

Furthermore, this study not only supported the established idea in the contemporary lean-ESS literature that issues related to occupational health, safety, employee autonomy and empowerment, participation, satisfaction, and commitment are critical for the general well-being of the workforce, but also served as a kickstart to more complex investigations towards a better understanding of the tangible side of lean and its outcomes on the most important component of a business: the employee.

The findings of this study can potentially inspire researchers and practitioners alike to dedicate more attention and engage in a further inclusion of the social sphere into lean manufacturing advancements. The employee perception of work can be improved with the proper prioritisation of lean practices and ESS dimensions, resulting in a more significant and rewarding experience at the workplace.

The originality of this study relies on the unprecedented analysis of ESS dimensions and lean practices in the social sustainability discussion, which, besides determining the relative importance of each addressed ESS dimension, was aimed to set priorities amongst lean manufacturing practices as enablers of the ESS performance criteria as a step further in the recent discussion surrounding the theme (AL MARZOUQI; KHAN; HUSSAIN, 2020).

6.3 Research limitations

This study is not exempt from limitations, and it is important to point them. First, it was considered lean in the manufacturing sector, disregarding other types of applications such as lean construction, lean office, lean healthcare, among many others. The results presented here cannot be extended for the lean implementation in organisations inserted in the aforementioned areas. Also, the data collected are not generalist, *i.e.* the results and conclusions from this study are based on subjective reasoning constructed by a restricted group of experts. The sample of experts is not large enough to provide general conclusions that are statistically valid for any manufacturing organisation. Still, the insights provided are valid as empirical evidence, yet must be tested in different scenarios of lean manufacturing applications.

Second, the findings of the SLR are limited by its methodology design (Figure 5). Moreover, articles and reviews were collected using specific search terms in two databases (ISI Web of Knowledge and Scopus), which implicated in a restricted collection of results.

Third, other spheres of social influence, although briefly discussed in the literature, are not included in the scope of analysis for the present dissertation, such as suppliers, customers, and, ultimately, the community as a whole.

Fourth, the AHP method only allows judgements determined by comparisons between ESS dimensions and lean practices through a single direct influence. AHP is not inherently capable of evaluating different interdependences. Also,

Fifth, the used AHP-based model only assessed the positive influences of lean practices, whereas potential negative effects were not considered, although there were reports in the literature of positive and negative impacts of lean practices on employee social sustainability.

6.4 Agenda for future research

A research direction can be drawn concerned with (*i*) understanding how and why lean manufacturing practices influence social outcomes that can be driven towards employee social sustainability, and (*ii*) synthesising and developing more extensive frameworks and models to sustain positive social outcomes in a lean manufacturing environment.

Several suggestions for future research are listed below, based on gaps found in the lean-ESS literature and observations made throughout the conduction of the present study:

- To identify and include a larger number of ESS dimensions and expand the application of the questionnaire to shop-floor employees, since their opinions are valuable to build a more solid set of priorities of LPs and ESS dimensions;

- To further develop the concept of autonomy of workers in lean systems since there is little information about this discussion;
- It is recommendable to investigate a potential moderating effect of *jidoka* on the impact of lean manufacturing on the workplace given its low rank in the enhanced workplace dimension;
- To investigate and model the interdependence of lean practices and ESS dimensions to, not only provide more accurate insights but also to avoid conceptual or practical overlaps;
- To extend the premise of this study to a more extensive investigation regarding levels of integration between lean practices and HRM practices as a way to analyse potential synergies between these two groups of variables;
- To study the implementation of organisational policies based on ESS in organisations that use lean manufacturing principles, as a source of information to build new lean-for-employee frameworks, models, and guidelines.

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APPENDIX A – RESEARCH QUESTIONNAIRE

INSTRUCTION FOR FILLING AND SUBMITTING THE QUESTIONNAIRE

To provide answers for the following questions in Sections I and II, click on the space assigned to the answer you think is most appropriate. It is not necessary to print and scan the questionnaire.

When finished, save a copy and send it by e-mail to **sc@academico.ufpb.br** or **stefanociannella1205@gmail.com**. You will receive feedback by the end of the round with information regarding the next one.

A.1 SECTION I – PERSONAL INFORMATION

1. Based on your knowledge and experience in the subjects of this research, do you feel able and confident to participate?

☐ Yes ☐ No ☐ Partially

If you checked "Partially", please state your reason:
Click or tap here to enter text.

If you checked "Yes", please state your name and e-mail address:
Click or tap here to enter text.

Country of residence:
Click or tap here to enter text.

2. Current job position:

☐ Manager ☐ Analyst ☐ Consultant ☐ Professor or researcher

☐Other: Click or tap here to enter text.

3. Main work field or expertise:

☐Operations and production ☐ Human resources management

☐ Quality control ☐ Research and development

☐ Safety management ☐ Maintenance

☐Other: Click or tap here to enter text.

4. Experience with your main work field or expertise:

☐1 year or less ☐ Between 1 and 5 years ☐ Between 5 and 10 years ☐ More than 10 years

A.2 SECTION II – PAIRWISE COMPARISONS

In this section, you are asked to elicit your opinion on several pairwise comparisons between ESS dimensions (Table 1) and lean practices (Table 2). When comparing these variables, please express your judgement about the importance of one option over the other. Use Saaty fundamental scale[2] to assign numerical values for the comparisons.

Table 3. Saaty fundamental scale for pairwise comparisons

Explanation	Numerical values
If Option A and Option B are equally important: Check →	1
If Option A is moderately more important than Option B: Check →	3
If Option A is strongly more important than Option B: Check →	5
If Option A is very strongly more important than Option B: Check →	7
If Option A is extremely more important than Option B: Check →	9
Use even number for intermediate judgements	2,4,6,8

Example

Given Options A and B, judge their relative importance as shown below:

If you judge Autonomy and empowerment in column A ***strongly*** more important than the factor Health and safety in column B, **then click on number 5 on the left side**.

If you judge the Enhanced workplace in column B ***extremely*** more important than factor the Job Stress Reduction in column A, **then click on number 9 on the right side**.

A Options	Extremely		Very strongly		Strongly		Moderately		Equally		Moderately		Strongly		Very strongly		Extremely	B Options
Autonomy and empowerment	☐ 9	☐ 8	☐ 7	☐ 6	☒ 5	☐ 4	☐ 3	☐ 2	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7	☐ 8	☐ 9	Health and safety
Job Stress Reduction	☐ 9	☐ 8	☐ 7	☐ 6	☐ 5	☐ 4	☐ 3	☐ 2	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7	☐ 8	☒ 9	Enhanced Workplace

Only one answer per line (comparison) is allowed. Follow the same instructions when comparing lean practices and their relative importance for each employees' social sustainability factor.

SAATY, T. L. How to make a decision: The analytic hierarchy process. **European Journal of Operational Research**, v. 48, n. 1, p. 9–26, 1990. Available at: https://doi.org/10.1016/0377-2217(90)90057-I

Regarding overall **CORPORATE SOCIAL PERFORMANCE**,
Use Saaty scale from 1 to 9 (where 1 is Equally important and 9 is Extremely important) to compare dimensions of employee social sustainability on the shop floor in the context of improving the overall SOCIAL PERFORMANCE.
Click on the numerical value to state your judgement of the relative importance when comparing
Options A (left side column) and **Options B (right side column)**

A Options	Extremely		Very strongly		Strongly		Moderately		Equally		Moderately		Strongly		Very strongly		Extremely	**B Options**
Autonomy and empowerment	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Health and safety
Autonomy and empowerment	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Job stress reduction
Autonomy and empowerment	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Enhanced workplace
Health and safety	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Job stress reduction
Health and safety	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Enhanced workplace
Job stress reduction	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Enhanced workplace

Commentaries (optional):

Regarding **AUTONOMY AND EMPOWERMENT**,
Use Saaty's scale from 1 to 9 (where 1 is Equally important and 9 is Extremely important) to compare lean practices to promote AUTONOMY AND EMPOWERMENT of shop-floor employees.
Click on the numerical value to state your judgement of the relative importance when comparing
Options A (left side column) and **Options B (right side column)**

A Options	Extremely		Very strongly		Strongly		Moderately		Equally		Moderately		Strongly		Very strongly		Extremely	**B Options**
Pull production	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	*Kaizen*
Pull production	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Standardised work
Pull production	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	5S
Pull production	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Value stream mapping
Pull production	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Total productive maintenance
Pull production	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	*Jidoka*
Pull production	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Multifunctional workers
Kaizen	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Standardised work

Regarding **AUTONOMY AND EMPOWERMENT**, Use Saaty's scale from 1 to 9 (where 1 is Equally important and 9 is Extremely important) to compare lean practices to promote AUTONOMY AND EMPOWERMENT of shop-floor employees. Click on the numerical value to state your judgement of the relative importance when comparing **Options A (left side column)** and **Options B (right side column)**																		
Kaizen	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	5S
Kaizen	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Value stream mapping
Kaizen	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Total productive maintenance
Kaizen	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	*Jidoka*
Kaizen	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Multifunctional workers
Standardised work	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	5S
Standardised work	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Value stream mapping
Standardised work	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Total productive maintenance
Standardised work	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	*Jidoka*
Standardised work	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Multifunctional workers
5S	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Value stream mapping
5S	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Total productive maintenance
5S	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	*Jidoka*
5S	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Multifunctional workers
Value stream mapping	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Total productive maintenance
Value stream mapping	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	*Jidoka*
Value stream mapping	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Multifunctional workers
Total productive maintenance	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	*Jidoka*
Total productive maintenance	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Multifunctional workers
Jidoka	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Multifunctional workers

Commentaries (optional):

Regarding **HEALTH AND SAFETY**
Use Saaty's scale from 1 to 9 (where 1 is Equally important and 9 is Extremely important) to compare lean practices to promote HEALTH AND SAFETY of shop-floor employees.
Click on the numerical value to state your judgement of the relative importance when comparing
Options A (left side column) and **Options B (right side column)**

A Options	Extremely		Very strongly		Strongly		Moderately		Equally		Moderately		Strongly		Very strongly		Extremely	**B Options**
Pull production	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	*Kaizen*
Pull production	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Standardised work
Pull production	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	5S
Pull production	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Value stream mapping
Pull production	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Total productive maintenance
Pull production	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	*Jidoka*
Pull production	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Multifunctional workers
Kaizen	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Standardised work
Kaizen	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	5S
Kaizen	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Value stream mapping
Kaizen	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Total productive maintenance
Kaizen	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	*Jidoka*
Kaizen	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Multifunctional workers
Standardised work	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	5S
Standardised work	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Value stream mapping
Standardised work	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Total productive maintenance
Standardised work	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	*Jidoka*
Standardised work	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Multifunctional workers
5S	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Value stream mapping
5S	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Total productive maintenance
5S	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	*Jidoka*
5S	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Multifunctional workers

Regarding **HEALTH AND SAFETY** Use Saaty's scale from 1 to 9 (where 1 is Equally important and 9 is Extremely important) to compare lean practices to promote HEALTH AND SAFETY of shop-floor employees. Click on the numerical value to state your judgement of the relative importance when comparing **Options A (left side column)** and **Options B (right side column)**																		
Value stream mapping	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Total productive maintenance
Value stream mapping	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	*Jidoka*
Value stream mapping	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Multifunctional workers
Total productive maintenance	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	*Jidoka*
Total productive maintenance	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Multifunctional workers
Jidoka	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Multifunctional workers

Commentaries (optional):

Regarding **JOB STRESS REDUCTION**, Use Saaty's scale from 1 to 9 (where 1 is Equally important and 9 is Extremely important) to compare lean practices to ease JOB STRESS REDUCTION in shop-floor employees. Click on the numerical value to state your judgement of the relative importance when comparing **Options A (left side column)** and **Options B (right side column)**																		
A Options	Extremely		Very strongly		Strongly		Moderately		Equally		Moderately		Strongly		Very strongly		Extremely	**B Options**
Pull production	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	*Kaizen*
Pull production	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Standardised work
Pull production	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	5S
Pull production	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Value stream mapping
Pull production	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Total productive maintenance
Pull production	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	*Jidoka*
Pull production	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Multifunctional workers
Kaizen	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Standardised work
Kaizen	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	5S
Kaizen	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Value stream mapping
Kaizen	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Total productive maintenance

Regarding **JOB STRESS REDUCTION**, Use Saaty's scale from 1 to 9 (where 1 is Equally important and 9 is Extremely important) to compare lean practices to ease JOB STRESS REDUCTION in shop-floor employees. Click on the numerical value to state your judgement of the relative importance when comparing **Options A (left side column)** and **Options B (right side column)**																		
Kaizen	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	*Jidoka*
Kaizen	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Multifunctional workers
Standardised work	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	5S
Standardised work	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Value stream mapping
Standardised work	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Total productive maintenance
Standardised work	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	*Jidoka*
Standardised work	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Multifunctional workers
5S	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Value stream mapping
5S	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Total productive maintenance
5S	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	*Jidoka*
5S	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Multifunctional workers
Value stream mapping	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Total productive maintenance
Value stream mapping	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	*Jidoka*
Value stream mapping	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Multifunctional workers
Total productive maintenance	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	*Jidoka*
Total productive maintenance	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Multifunctional workers
Jidoka	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Multifunctional workers

Commentaries (optional):

Regarding **ENHANCED WORKPLACE**,
Use Saaty's scale from 1 to 9 (where 1 is Equally important and 9 is Extremely important) to compare lean practices to establish an ENHANCED WORKPLACE for shop-floor employees.
Click on the numerical value to state your judgement of the relative importance when comparing
Options A (left side column) and **Options B (right side column)**

A Options	Extremely		Very strongly		Strongly		Moderately		Equally		Moderately		Strongly		Very strongly		Extremely	**B Options**
Pull production	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	*Kaizen*
Pull production	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Standardised work
Pull production	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	5S
Pull production	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Value stream mapping
Pull production	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Total productive maintenance
Pull production	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	*Jidoka*
Pull production	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Multifunctional workers
Kaizen	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Standardised work
Kaizen	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	5S
Kaizen	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Value stream mapping
Kaizen	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Total productive maintenance
Kaizen	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	*Jidoka*
Kaizen	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Multifunctional workers
Standardised work	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	5S
Standardised work	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Value stream mapping
Standardised work	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Total productive maintenance
Standardised work	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	*Jidoka*
Standardised work	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Multifunctional workers
5S	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Value stream mapping
5S	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Total productive maintenance
5S	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	*Jidoka*
5S	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Multifunctional workers

Regarding **ENHANCED WORKPLACE**, Use Saaty's scale from 1 to 9 (where 1 is Equally important and 9 is Extremely important) to compare lean practices to establish an ENHANCED WORKPLACE for shop-floor employees. Click on the numerical value to state your judgement of the relative importance when comparing **Options A (left side column)** and **Options B (right side column)**																		
Value stream mapping	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Total productive maintenance
Value stream mapping	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	*Jidoka*
Value stream mapping	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Multifunctional workers
Total productive maintenance	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	*Jidoka*
Total productive maintenance	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Multifunctional workers
Jidoka	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Multifunctional workers

APPENDIX B – PAIRWISE COMPARISON MATRICES

B.1 RESPONDENT P_1

ESS DIMENSIONS

	Autonomy and empowerment	Health and safety	Job stress reduction	Enhanced workplace	**E-vector**
Autonomy and empowerment	1.000	1/5.000	5.000	5.000	**0.259**
Health and safety	5.000	1.000	7.000	3.000	**0.585**
Job stress reduction	1/5.000	1/7.000	1.000	1.000	**0.065**
Enhanced workplace	1/5.000	1/3.000	1/1.000	1.000	**0.090**

Notes: CR = 0.170 (≤ 0.100 = acceptable, <0.200 tolerable)

Lean practices for **autonomy and empowerment**

	Pull production	*Kaizen*	Standard. work	5S	VSM	TPM	*Jidoka*	Multifunc. workers	**E-vector**
Pull production	1.000	1/5.000	1/3.000	3.000	1.000	1/3.000	3.000	5.000	**0.109**
Kaizen	5.000	1.000	1/5.000	5.000	1/5.000	1/5.000	1.000	1.000	**0.113**
Standard. work	3.000	5.000	1.000	5.000	1.000	1.000	3.000	1.000	**0.198**
5S	1/3.000	1/5.000	1/5.000	1.000	1/3.000	1/3.000	1.000	1.000	**0.040**
VSM	1/1.000	5.000	1/1.000	3.000	1.000	1.000	5.000	5.000	**0.203**
TPM	3.000	5.000	1/1.000	3.000	1/1.000	1.000	5.000	5.000	**0.226**
Jidoka	1/3.000	1/1.000	1/3.000	1/1.000	1/5.000	1/5.000	1.000	1/5.000	**0.042**
Multifunc. workers	1/5.000	1/1.000	1/1.000	1/1.000	1/5.000	1/5.000	5.000	1.000	**0.067**

Notes: CR = 0.017 (≤ 0.100 = acceptable, < 0.200 tolerable)

Lean practices for **health and safety**

	Pull production	*Kaizen*	Standard. work	5S	VSM	TPM	*Jidoka*	Multifunc. workers	**E-vector**
Pull production	1.000	1/5.000	1/5.000	1/5.000	1.000	1/5.000	1/3.000	1/3.000	**0.030**
Kaizen	5.000	1.000	3.000	1/5.000	3.000	1/5.000	1.000	1/3.000	**0.104**
Standard. work	5.000	1/3.000	1.000	1.000	3.000	1/3.000	3.000	1.000	**0.123**
5S	5.000	5.000	1/1.000	1.000	5.000	1.000	1.000	1.000	**0.178**
VSM	1/1.000	1/3.000	1/3.000	1/5.000	1.000	1/5.000	1/5.000	1/5.000	**0.030**
TPM	5.000	5.000	3.000	1/1.000	5.000	1.000	5.000	5.000	**0.304**
Jidoka	3.000	1/1.000	1/3.000	1/1.000	5.000	1/5.000	1.000	3.000	**0.117**
Multifunc. workers	3.000	3.000	1/1.000	1/1.000	5.000	1/5.000	1/3.000	1.000	**0.115**

Notes: CR = 0.013 (≤ 0.100 = acceptable, < 0.200 tolerable)

Lean practices for **job stress reduction**

	Pull production	*Kaizen*	Standard. work	5S	VSM	TPM	*Jidoka*	Multifunc. workers	**E-vector**
Pull production	1.000	1/3.000	1/5.000	1/5.000	1.000	1/3.000	1/3.000	1/3.000	**0.040**
Kaizen	3.000	1.000	1/3.000	1.000	1.000	1/3.000	1.000	3.000	**0.099**
Standard. work	5.000	3.000	1.000	3.000	3.000	1/3.000	1.000	5.000	**0.204**
5S	5.000	1/1.000	1/3.000	1.000	3.000	1.000	1.000	5.000	**0.150**
VSM	1/1.000	1/1.000	1/3.000	1/3.000	1.000	1/5.000	1/3.000	3.000	**0.062**
TPM	3.000	3.000	3.000	1/1.000	5.000	1/1.000	1.000	5.000	**0.239**
Jidoka	3.000	1/1.000	1/1.000	1/1.000	3.000	1/1.000	1.000	7.000	**0.165**
Multifunc. workers	3.000	1/3.000	1/5.000	1/5.000	1/3.000	1/5.000	1/7.000	1.000	**0.041**

Notes: CR = 0.008 (≤ 0.100 = acceptable, < 0.200 tolerable)

Lean practices for **enhanced workplace**

	Pull production	*Kaizen*	Standard. work	5S	VSM	TPM	*Jidoka*	Multifunc. workers	**E-vector**
Pull production	1.000	1/5.000	1/5.000	1/7.000	1/3.000	1.000	1.000	1/3.000	**0.034**
Kaizen	1/5.000	1.000	3.000	3.000	5.000	5.000	3.000	5.000	**0.312**
Standard. work	5.000	1/3.000	1.000	1/3.000	3.000	3.000	5.000	3.000	**0.143**
5S	7.000	1/3.000	3.000	1.000	9.000	7.000	7.000	3.000	**0.282**
VSM	3.000	1/5.000	1/3.000	1/9.000	1.000	1.000	1.000	3.000	**0.066**
TPM	1/1.000	1/5.000	1/3.000	1/7.000	1/1.000	1/1.000	1.000	3.000	**0.059**
Jidoka	1/1.000	1/3.000	1/5.000	1/7.000	1/1.000	1/1.000	1.000	1/3.000	**0.044**
Multifunc. workers	3.000	1/5.000	1/3.000	1/3.000	1/3.000	1/3.000	3.000	1.000	**0.060**

Notes: CR = 0.010 (≤ 0.100 = acceptable, < 0.200 tolerable)

B.2 RESPONDENT P_2

ESS DIMENSIONS

	Autonomy and empowerment	Health and safety	Job stress reduction	Enhanced workplace	**E-vector**
Autonomy and empowerment	1.000	7.000	5.000	5.000	**0.214**
Health and safety	1/7.000	1.000	7.000	5.000	**0.658**
Job stress reduction	1/5.000	1/5.000	1.000	1.000	**0.060**
Enhanced workplace	1/5.000	1/7.000	1/1.000	1.000	**0.068**

Notes: CR = 0.000298 (≤ 0.100 = acceptable, < 0.200 tolerable)

Lean practices for **autonomy and empowerment**

	Pull production	*Kaizen*	Standard. work	5S	VSM	TPM	*Jidoka*	Multifunc. workers	**E-vector**
Pull production	1.000	1/5.000	1/7.000	1/5.000	1/3.000	1/5.000	1/7.000	1/3.000	**0.023**
Kaizen	5.000	1.000	1/3.000	5.000	1.000	3.000	1.000	3.000	**0.167**
Standard. work	7.000	3.000	1.000	5.000	5.000	3.000	3.000	9.000	**0.332**
5S	3.000	1/5.000	1/5.000	1.000	3.000	3.000	1/3.000	5.000	**0.095**
VSM	5.000	1/1.000	1/5.000	1/3.000	1.000	1/2.000	1/5.000	5.000	**0.073**
TPM	5.000	1/3.000	1/3.000	1/3.000	2.000	1/1.000	1/3.000	5.000	**0.086**
Jidoka	7.000	1/1.000	1/3.000	3.000	5.000	3.000	1.000	5.000	**0.191**
Multifunc. workers	3.000	1/3.000	1/9.000	1/5.000	1/5.000	1/5.000	1/5.000	1.000	**0.033**

Notes: CR = 0.009 (≤ 0.100 = acceptable, < 0.200 tolerable)

Lean practices for **health and safety**

	Pull production	*Kaizen*	Standard. work	5S	VSM	TPM	*Jidoka*	Multifunc. workers	**E-vector**
Pull production	1.000	1/5.000	1/9.000	1/7.000	1/3.000	1/7.000	1/9.000	1/3.000	**0.018**
Kaizen	5.000	1.000	1/3.000	1/5.000	5.000	1/3.000	1/3.000	5.000	**0.101**
Standard. work	9.000	3.000	1.000	1.000	5.000	3.000	1.000	5.000	**0.219**
5S	7.000	5.000	1/1.000	1.000	5.000	3.000	1.000	1.000	**0.214**
VSM	3.000	1/5.000	1/5.000	1/5.000	1.000	1/3.000	1/5.000	3.000	**0.049**
TPM	7.000	3.000	1/3.000	1/3.000	3.000	1/1.000	1/3.000	5.000	**0.129**
Jidoka	9.000	3.000	1/1.000	1/1.000	5.000	3.000	1.000	5.000	**0.219**
Multifunc. workers	3.000	1/5.000	1/5.000	1/1.000	1/3.000	1/5.000	1/5.000	1.000	**0.051**

Notes: CR = 0.120 (≤ 0.100 = acceptable, < 0.200 tolerable)

Lean practices for **job stress reduction**

	Pull production	*Kaizen*	Standard. work	5S	VSM	TPM	*Jidoka*	Multifunc. workers	**E-vector**
Pull production	1.000	1/7.000	1/7.000	1/5.000	3.000	1/3.000	1/3.000	1/3.000	**0.037**
Kaizen	7.000	1.000	1/7.000	3.000	3.000	5.000	1.000	1.000	**0.114**
Standard. work	7.000	7.000	1.000	3.000	7.000	5.000	1.000	3.000	**0.310**
5S	5.000	1/3.000	1/3.000	1.000	3.000	1.000	1/5.000	1/5.000	**0.70**
VSM	1/3.000	1/3.000	1/7.000	1/3.000	1.000	1/3.000	1/5.000	1/5.000	**0.026**
TPM	3.000	1/5.000	1/5.000	1/1.000	3.000	1/1.000	1/3.000	1/5.000	**0.053**
Jidoka	3.000	1/1.000	1/1000	1/5.000	5.000	3.000	1.000	1.000	**0.170**
Multifunc. workers	3.000	1/1.000	1/3.000	1/5.000	5.000	5.000	1/1.000	1.000	**0.220**

Notes: CR = 0.100 (≤ 0.100 = acceptable, < 0.200 tolerable)

Lean practices for **enhanced workplace**

	Pull production	*Kaizen*	Standard. work	5S	VSM	TPM	*Jidoka*	Multifunc. workers	**E-vector**
Pull production	1.000	1/5.000	1/3.000	1/7.000	3.000	1/7.000	1/3.000	1/3.000	**0.033**
Kaizen	5.000	1.000	1/5.000	1/3.000	7.000	1/5.000	5.000	7.000	**0.129**
Standard. work	3.000	5.000	1.000	1/3.000	5.000	3.000	3.000	7.000	**0.244**
5S	7.000	3.000	3.000	1.000	5.000	1.000	3.000	5.000	**0.245**
VSM	1/3.000	1/7.000	1/5.000	1/5.000	1.000	1/7.000	1/5.000	1.000	**0.025**
TPM	7.000	5.000	1/3.000	1/1.000	7.000	1/1.000	5.000	5.000	**0.223**
Jidoka	3.000	1/5.000	1/3.000	1/3.000	5.000	1/5.000	1.000	3.000	**0.066**
Multifunc. workers	3.000	1/7.000	1/7.000	1/5.000	1/1.000	1/5.000	1/3.000	1.000	**0.035**

Notes: CR = 0.150 (≤ 0.100 = acceptable, < 0.200 tolerable)

B.3 RESPONDENT P_3

ESS DIMENSIONS

	Autonomy and empowerment	Health and safety	Job stress reduction	Enhanced workplace	**E-vector**
Autonomy and empowerment	1.000	1/5.000	3.000	1/3.000	**0.120**
Health and safety	5.000	1.000	5.000	5.000	**0.602**
Job stress reduction	1/3.000	1/5.000	1.000	1/3.000	**0.069**
Enhanced workplace	3.000	1/5.000	3.000	1.000	**0.208**

Notes: CR = 0.120 (≤ 0.100 = acceptable, < 0.200 tolerable)

Lean practices for **autonomy and empowerment**

	Pull production	*Kaizen*	Standard. work	5S	VSM	TPM	*Jidoka*	Multifunc. workers	**E-vector**
Pull production	1.000	3.000	1/5.000	1/7.000	1/9.000	1/9.000	1/5.000	1/5.000	**0.026**
Kaizen	1/3.000	1.000	1/3.000	1/3.000	1/5.000	1/7.000	1/3.000	1/9.000	**0.029**
Standard. work	5.000	3.000	1.000	1/3.000	1/5.000	1/5.000	1/5.000	3.000	**0.075**
5S	7.000	3.000	3.000	1.000	3.000	3.000	3.000	3.000	**0.270**
VSM	9.000	5.000	5.000	1/3.000	1.000	1.000	1.000	3.000	**0.168**
TPM	9.000	7.000	5.000	1/3.000	1/1.000	1/1.000	3.000	5.000	**0.219**
Jidoka	5.000	3.000	5.000	1/3.000	1/1.000	1/3.000	1.000	3.000	**0.136**
Multifunc. workers	5.000	9.000	1/3.000	1/3.000	1/3.000	1/5.000	1/3.000	1.000	**0.076**

Notes: CR = 0.150 (≤ 0.100 = acceptable, < 0.200 tolerable)

Lean practices for **health and safety**

	Pull production	*Kaizen*	Standard. work	5S	VSM	TPM	*Jidoka*	Multifunc. workers	**E-vector**
Pull production	1.000	1/5.000	1/7.000	1/5.000	1.000	1/5.000	1/3.000	1.000	**0.035**
Kaizen	5.000	1.000	1/3.000	1/5.000	3.000	1/5.000	1/3.000	1/5.000	**0.059**
Standard. work	7.000	3.000	1.000	1/3.000	7.000	1.000	7.000	3.000	**0.199**
5S	5.000	5.000	3.000	1.000	7.000	1.000	7.000	7.000	**0.308**
VSM	5.000	1/3.000	1/7.000	1/7.000	1.000	1/3.000	1.000	1/3.000	**0.034**
TPM	3.000	5.000	1/1.000	1/1.000	3.000	1.000	5.000	5.000	**0.219**
Jidoka	1/1.000	3.000	1/7.000	1/7.000	1/1.000	1/5.000	1.000	1/3.000	**0.056**
Multifunc. workers	1/x.000	5.000	1/3.000	1/7.000	3.000	1/5.000	3.000	1.000	**0.091**

Notes: CR = 0.130 (≤ 0.100 = acceptable, < 0.200 tolerable)

Lean practices for **job stress reduction**

	Pull production	*Kaizen*	Standard. work	5S	VSM	TPM	*Jidoka*	Multifunc. workers	**E-vector**
Pull production	1.000	1/5.000	1/7.000	1/7.000	1/5.000	1/5.000	1/5.000	1/5.000	**0.021**
Kaizen	5.000	1.000	1/3.000	1/5.000	1/3.000	1/3.000	1/3.000	1/5.000	**0.44**
Standard. work	7.000	3.000	1.000	5.000	3.000	1/3.000	3.000	3.000	**0.250**
5S	7.000	5.000	1/5.000	1.000	3.000	3.000	3.000	3.000	**0.215**
VSM	5.000	3.000	1/3.000	1/3.000	1.000	1/3.000	1.000	1/3.000	**0.067**
TPM	5.000	3.000	3.000	1/3.000	3000	1/1.000	5.000	5.000	**0.243**
Jidoka	5.000	3.000	1/3.000	1/3.000	1/1.000	1/5.000	1.000	1.000	**0.066**
Multifunc. workers	5.000	5.000	1/3.000	1/3.000	3.000	1/5.000	1/1.000	1.000	**0.094**

Notes: CR = 0.150 (≤ 0.100 = acceptable, < 0.200 tolerable)

Lean practices for **enhanced workplace**

	Pull production	*Kaizen*	Standard. work	5S	VSM	TPM	*Jidoka*	Multifunc. workers	**E-vector**
Pull production	1.000	1/3.000	1/5.000	1/7.000	1/7.000	1/3.000	1/3.000	1/5.000	**0.023**
Kaizen	3.000	1.000	3.000	1/3.000	5.000	3.000	5.000	5.000	**0.206**
Standard. work	5.000	1/3.000	1.000	1/3.000	3.000	3.000	3.000	5.000	**0.148**
5S	7.000	3.000	3.000	1.000	7.000	5.000	5.000	7.000	**0.335**
VSM	7.000	1/5.000	1/3.000	1/7.000	1.000	1/5.000	3.000	1/3.000	**0.052**
TPM	3.000	1/3.000	1/3.000	1/5.000	5.000	1/1.000	7.000	7.000	**0.145**
Jidoka	3.000	1/5.000	1/3.000	1/5.000	1/3.000	1/7.000	1.000	1/3.000	**0.033**
Multifunc. workers	5.000	1/5.000	1/5.000	1/7.000	3.000	1/7.000	3.000	1.000	**0.059**

Notes: CR = 0.160 (≤ 0.100 = acceptable, < 0.200 tolerable)

B.4 RESPONDENT P4

ESS DIMENSIONS

	Autonomy and empowerment	Health and safety	Job stress reduction	Enhanced workplace	**E-vector**
Autonomy and empowerment	1.000	1/4.000	3.000	7.000	**0.227**
Health and safety	4.000	1.000	7.000	9.000	**0.616**
Job stress reduction	1/3.000	1/7.000	1.000	7.000	**0.122**
Enhanced workplace	1/7.000	1/9.000	1/7.000	1.000	**0.035**

Notes: CR = 0.160 (≤ 0.100 = acceptable, < 0.200 tolerable)

Lean practices for **autonomy and empowerment**

	Pull production	*Kaizen*	Standard. work	5S	VSM	TPM	*Jidoka*	Multifunc. workers	**E-vector**
Pull production	1.000	7.000	1/9.000	1/3.000	1/3.000	1/3.000	5.000	1/5.000	**0.064**
Kaizen	1/7.000	1.000	1/9.000	1/9.000	1/5.000	1/5.000	1/3.000	1/5.000	**0.017**
Standard. work	9.000	9.000	1.000	1/5.000	7.000	1.000	3.000	5.000	**0.238**
5S	3.000	9.000	5.000	1.000	7.000	7.000	3.000	3.000	**0.356**
VSM	3.000	5.000	1/7.000	1/7.000	1.000	1.000	1.000	1.000	**0.070**
TPM	3.000	4.000	1/1000	1/7.000	1/1.000	1/1.000	3.000	1/3.000	**0.091**
Jidoka	1/5.000	3.000	1/3.000	1/3.000	1/1.000	1/3.000	1.000	1/3.000	**0.045**
Multifunc. workers	5.000	5.000	1/5.000	1/3.000	1/1.000	3.000	3.000	1.000	**0.119**

Notes: CR = 0.190 (≤ 0.100 = acceptable, < 0.200 tolerable)

Lean practices for **health and safety**

	Pull production	*Kaizen*	Standard. work	5S	VSM	TPM	*Jidoka*	Multifunc. workers	**E-vector**
Pull production	1.000	1/3.000	1/5.000	1/7.000	1.000	1/4.000	1.000	3.000	**0.059**
Kaizen	3.000	1.000	1/4.000	1/7.000	1/5.000	1/5.000	1/3.000	1/3.000	**0.042**
Standard. work	5.000	4.000	1.000	1/3.000	6.000	1/3.000	2.000	6.000	**0.180**
5S	7.000	7.000	3.000	1.000	5.000	3.000	3.000	2.000	**0.290**
VSM	1/1.000	5.000	1/6.000	1/5.000	1.000	1/6.000	1.000	1/4.000	**0.053**
TPM	4.000	5.000	3.000	1/3.000	6.000	1/1.000	6.000	4.000	**0.235**
Jidoka	1/1.000	3.000	1/2.000	1/3.000	1/1.000	1/6.000	1.000	1/3.000	**0.056**
Multifunc. workers	1/3.000	3.000	1/6.000	1/2.000	4.000	1/4.000	3.000	1.000	**0.086**

Notes: CR = 0.190 (≤ 0.100 = acceptable, < 0.200 tolerable)

Lean practices for **job stress reduction**

	Pull production	*Kaizen*	Standard. work	5S	VSM	TPM	*Jidoka*	Multifunc. workers	**E-vector**
Pull production	1.000	1/5.000	1/9.000	1/7.000	1/3.000	1/5.000	1/2.000	1.000	**0.024**
Kaizen	5000	1.000	1/7.000	1/7.000	1/2.000	1/6.000	3.000	6.000	**0.075**
Standard. work	9.000	7.000	1.000	1.000	6.000	3.000	3.000	9.000	**0.282**
5S	7.000	7.000	1/1.000	1.000	9.000	3.000	1.000	7.000	**0.273**
VSM	3.000	2.000	1/6.000	1/9.000	1.000	1/6.000	1.000	1.000	**0.051**
TPM	5.000	6.000	1/3.000	1/3.000	6.000	1/1.000	6.000	7.000	**0.199**
Jidoka	2.000	1/3.000	1/3.000	1/1.000	1/1.000	1/6.000	1.000	2.000	**0.069**
Multifunc. workers	1.000	1/6.000	1/9.000	1/7.000	1/1.000	1/7.000	1/2.000	1.000	**0.026**

Notes: CR = 0.140 (≤ 0.100 = acceptable, < 0.200 tolerable)

Lean practices for **enhanced workplace**

	Pull production	*Kaizen*	Standard. work	5S	VSM	TPM	*Jidoka*	Multifunc. workers	**E-vector**
Pull production	1.000	1/7.000	1/7.000	1/9.000	1/5.000	1/6.000	1/3.000	1/5.000	**0.019**
Kaizen	7.000	1.000	3.000	1.000	6.000	1/8.000	3.000	3.000	**0.157**
Standard. work	7.000	1/3.000	1.000	1/8.000	3.000	1/5.000	2.000	3.000	**0.084**
5S	9.000	1/1.000	8.000	1.000	6.000	1.000	3.000	6.000	**0.256**
VSM	5.000	1/6.000	1/3.000	1/6.000	1.000	1/3.000	1/2.000	1.000	**0.047**
TPM	6.000	8.000	5.000	1/1.000	3000	1/1.000	5.000	5.000	**0.334**
Jidoka	3.000	1/3.000	1/2.000	1/3.000	2.000	1/5.000	1.000	1.000	**0.055**
Multifunc. workers	5.000	1/3.000	1/3.000	1/6.000	1/1.000	1/5.000	1/1.000	1.000	**0.048**

Notes: CR = 0.110 (≤ 0.100 = acceptable, < 0.200 tolerable)

B.5 RESPONDENT P_5

ESS DIMENSIONS

	Autonomy and empowerment	Health and safety	Job stress reduction	Enhanced workplace	**E-vector**
Autonomy and empowerment	1.000	3.000	5.000	5.000	**0.538**
Health and safety	1/3.000	1.000	4.000	6.000	**0.304**
Job stress reduction	1/5.000	1/4.000	1.000	1.000	**0.082**
Enhanced workplace	1/5.000	1/6.000	1/1.000	1.000	**0.076**

Notes: CR = 0.006 (≤ 0.100 = acceptable, < 0.200 tolerable)

Lean practices for **autonomy and empowerment**

	Pull production	*Kaizen*	Standard. work	5S	VSM	TPM	*Jidoka*	Multifunc. workers	**E-vector**
Pull production	1.000	1/5.000	1/3.000	1/4.000	1/5.000	1/2.000	1/3.000	1/4.000	**0.030**
Kaizen	5.000	1.000	4.000	5.000	4.000	5.000	3.000	1.000	**0.305**
Standard. work	3.000	1/4.000	1.000	1/2.000	1.000	1.000	1/2.000	1/3.000	**0.063**
5S	4.000	1/5.000	2.000	1.000	1.000	2.000	3.000	5.000	**0.194**
VSM	5.000	1/4.000	1/1.000	1/1.000	1.000	3.000	1/3.000	1.000	**0.101**
TPM	2.000	1/5.000	1/1.000	1/2.000	1/3.000	1/1.000	1/2.000	1/4.000	**0.050**
Jidoka	3.000	1/3.000	2.000	1/3.000	3.000	2.000	1.000	1/3.000	**0.102**
Multifunc. workers	4.000	1/1.000	3.000	1/5.000	1/1.000	4.000	3.000	1.000	**0.154**

Notes: CR = 0.120 (≤ 0.100 = acceptable, < 0.200 tolerable)

Lean practices for **health and safety**

	Pull production	*Kaizen*	Standard. work	5S	VSM	TPM	*Jidoka*	Multifunc. workers	**E-vector**
Pull production	1.000	1/5.000	1/4.000	1/3.000	1/4.000	1/3.000	1/2.000	1/4.000	**0.036**
Kaizen	5.000	1.000	3.000	1.000	1.000	5.000	3.000	1.000	**0.193**
Standard. work	4.000	1/3.000	1.000	1/4.000	1/3.000	3.000	3.000	1/3.000	**0.087**
5S	3.000	1/1.000	4.000	1.000	1.000	4.000	3.000	1.000	**0.190**
VSM	4.000	1/1.000	3.000	1/1.000	1.000	4.000	5.000	1.000	**0.199**
TPM	3.000	1/5.000	1/3.000	1/4.000	1/4.000	1/1.000	1/3.000	1/4.000	**0.046**
Jidoka	2.000	1/3.000	1/3.000	1/3.000	1/5.000	3.000	1.000	1/3.000	**0.065**
Multifunc. workers	4.000	1/1.000	3.000	1/1.000	1/1.000	4.000	3.000	1.000	**0.184**

Notes: CR = 0.040 (≤ 0.100 = acceptable, < 0.200 tolerable)

Lean practices for **job stress reduction**

	Pull production	*Kaizen*	Standard. work	5S	VSM	TPM	*Jidoka*	Multifunc. workers	**E-vector**
Pull production	1.000	1/2.000	1/3.000	1/4.000	1/3.000	2.000	1/2.000	1/3.000	**0.052**
Kaizen	2.000	1.000	4.000	1/3.000	1/1.000	3.000	1/2.000	1.000	**0.144**
Standard. work	3.000	1/4.000	1.000	1/2.000	1/3.000	4.000	3.000	1/3.000	**0.107**
5S	4.000	3.000	2.000	1.000	1.000	2.000	3.000	1.000	**0.198**
VSM	3.000	1.000	3.000	1/1.000	1.000	3.000	4.000	1.000	**0.186**
TPM	1/2.000	1/3.000	1/4.000	1/2.000	1/3.000	1/1.000	1/2.000	1/4.000	**0.044**
Jidoka	2.000	2.000	1/3.000	1/3.000	1/4.000	2.000	1.000	1/3.000	**0.087**
Multifunc. workers	3.000	1/1.000	3.000	1/1.000	1/1.000	4.000	3.000	1.000	**0.182**

Notes: CR = 0.100 (≤ 0.100 = acceptable, < 0.200 tolerable)

Lean practices for **enhanced workplace**

	Pull production	*Kaizen*	Standard. work	5S	VSM	TPM	*Jidoka*	Multifunc. workers	**E-vector**
Pull production	1.000	1/4.000	1/3.000	1/2.000	1/3.000	3.000	1/2.000	1/4.000	**0.058**
Kaizen	4.000	1.000	3.000	1/2.000	1.000	4.000	3.000	1/2.000	**0.163**
Standard. work	3.000	1/3.000	1.000	1/4.000	1/3.000	3.000	1.000	1/3.000	**0.080**
5S	2.000	2.000	4.000	1.000	1.000	5.000	3.000	1.000	**0.205**
VSM	3.000	1/1.000	3.000	1/1.000	1.000	2.000	1/3.000	1/4.000	**0.118**
TPM	1/3.000	1/4.000	1/3.000	1/5.000	1/2.000	1/1.000	1/3.000	1.000	**0.053**
Jidoka	2.000	1/3.000	1/1.000	1/3.000	3.000	3.000	1.000	1/2.000	**0.113**
Multifunc. workers	4.000	2.000	3.000	1/1.000	4.000	1/1.000	2.000	1.000	**0.212**

Notes: CR = 0.130 (≤ 0.100 = acceptable, < 0.200 tolerable)

B.6 RESPONDENT P_6

ESS DIMENSIONS

	Autonomy and empowerment	Health and safety	Job stress reduction	Enhanced workplace	**E-vector**
Autonomy and empowerment	1.000	1.000	3.000	3.000	**0.406**
Health and safety	1/1.000	1.000	1.000	1.000	**0.237**
Job stress reduction	1/3.000	1/1.000	1.000	2.000	**0.208**
Enhanced workplace	1/3.000	1/1.000	1/2.000	1.000	**0.148**

Notes: CR = 0.008 (≤ 0.100 = acceptable, < 0.200 tolerable)

Lean practices for **autonomy and empowerment**

	Pull production	*Kaizen*	Standard. work	5S	VSM	TPM	*Jidoka*	Multifunc. workers	**E-vector**
Pull production	1.000	1/7.000	1/5.000	1/7.000	1/3.000	1/7.000	1/3.000	1/9.000	**0.020**
Kaizen	7.000	1.000	1.000	1.000	5.000	1/3.000	5.000	1.000	**0.141**
Standard. work	5.000	1/1.000	1.000	3.000	7.000	1/3.000	4.000	1/5.000	**0.142**
5S	7.000	1/1.000	1/3.000	1.000	7.000	1/3.000	4.000	1/5.000	**0.117**
VSM	3.000	1/5.000	1/7.000	1/7.000	1.000	1/5.000	1.000	1/7.000	**0.032**
TPM	7.000	3.000	3.000	3.000	5.000	1.000	4.000	1.000	**0.247**
Jidoka	3.000	1/5.000	1/4.000	1/4.000	1/1000	1/4.000	1.000	1/5.000	**0.038**
Multifunc. workers	9.000	1/1.000	5.000	5.000	7.000	1/1.000	5.000	1.000	**0.263**

Notes: CR = 0.008 (≤ 0.100 = acceptable, < 0.200 tolerable)

Lean practices for **health and safety**

	Pull production	*Kaizen*	Standard. work	5S	VSM	TPM	*Jidoka*	Multifunc. workers	**E-vector**
Pull production	1.000	1/3.000	1/6.000	1/8.000	1/3.000	1/5.000	1/3.000	1.000	**0.025**
Kaizen	3.000	1.000	1/6.000	1/8.000	3.000	1/5.000	3.000	1.000	**0.068**
Standard. work	6.000	6.000	1.000	1.000	7.000	3.000	3.000	8.000	**0.258**
5S	8.000	8.000	1/1.000	1.000	8.000	8.000	8.000	8.000	**0.390**
VSM	3.000	1/3.000	1/7.000	1/8.000	1.000	1/5.000	1.000	3.000	**0.043**
TPM	5.000	5.000	1/3.000	1/8.000	5.000	1/1.000	5.000	5.000	**0.147**
Jidoka	3.000	1/3.000	1/3.000	1/8.000	1/1.000	1/5.000	1.000	1.000	**0.042**
Multifunc. workers	1/1.000	1/1.000	1/8.000	1/8.000	1/3.000	1/5.000	1/1.000	1.000	**0.027**

Notes: CR = 0.090 (≤ 0.100 = acceptable, < 0.200 tolerable)

Lean practices for **job stress reduction**

	Pull production	*Kaizen*	Standard. work	5S	VSM	TPM	*Jidoka*	Multifunc. workers	**E-vector**
Pull production	1.000	1/3.000	1/7.000	1/7.000	1.000	1.000	1.000	1.000	**0.054**
Kaizen	3.000	1.000	1/7.000	1/7.000	5.000	1/5.000	1.000	4.000	**0.082**
Standard. work	7.000	7.000	1.000	1.000	4.000	1.000	5.000	7.000	**0.257**
5S	7.000	7.000	1/1.000	1.000	7.000	1.000	6.000	6.000	**0.274**
VSM	1/1.000	1/5.000	1/4.000	1/7.000	1.000	1/5.000	1.000	3.000	**0.044**
TPM	1/1.000	5.000	1/1.000	1/1.000	5.000	1/1.000	6.000	6.000	**0.210**
Jidoka	1/1.000	1/1.000	1/5.000	1/6.000	1/1.000	1/6.000	1.000	4.000	**0.052**
Multifunc. workers	1/1.000	1/4.000	1/7.000	1/6.000	1/3.000	1/6.000	1/4.000	1.000	**0.027**

Notes: CR = 0.110 (≤ 0.100 = acceptable, < 0.200 tolerable)

Lean practices for **enhanced workplace**

	Pull production	*Kaizen*	Standard. work	5S	VSM	TPM	*Jidoka*	Multifunc. workers	**E-vector**
Pull production	1.000	1/3.000	1/7.000	1/7.000	1.000	1/5.000	1.000	1.000	**0.035**
Kaizen	3.000	1.000	1/5.000	1/5.000	4.000	4.000	4.000	4.000	**0.163**
Standard. work	7.000	5.000	1.000	1.000	4.000	1.000	6.000	6.000	**0.265**
5S	7.000	5.000	1/1.000	1.000	6.000	1.000	6.000	6.000	**0.273**
VSM	1/1.000	1/4.000	1/4.000	1/6.000	1.000	1/5.000	1.000	1.000	**0.037**
TPM	5.000	1/4.000	1/1.000	1/1.000	5.000	1/1.000	4.000	4.000	**0.157**
Jidoka	1/1.000	1/4.000	1/6.000	1/6.000	1/1.000	1/4.000	1.000	1.000	**0.036**
Multifunc. workers	1/1.000	1/4.000	1/6.000	1/6.000	1/1.000	1/4.000	1/1.000	1.000	**0.036**

Notes: CR = 0.008 (≤ 0.100 = acceptable, < 0.200 tolerable)

B.7 RESPONDENT P_7

ESS DIMENSIONS

	Autonomy and empowerment	Health and safety	Job stress reduction	Enhanced workplace	**E-vector**
Autonomy and empowerment	1.000	3.000	1.000	3.000	**0.375**
Health and safety	1/3.000	1.000	1/3.000	1.000	**0.125**
Job stress reduction	1/1.000	3.000	1.000	3.000	**0.375**
Enhanced workplace	1/3.000	1/1.000	1/3.000	1.000	**0.125**

Notes: CR = 0.000 (≤ 0.100 = acceptable, < 0.200 tolerable)

Lean practices for **autonomy and empowerment**

	Pull production	*Kaizen*	Standard. work	5S	VSM	TPM	*Jidoka*	Multifunc. workers	**E-vector**
Pull production	1.000	1/9.000	1/5.000	1/3.000	1/5.000	1.000	3.000	1/5.000	**0.026**
Kaizen	9.000	1.000	9.000	9.000	9.000	9.000	9.000	9.000	**0.502**
Standard. work	5.000	1/9.000	1.000	5.000	5.000	3.000	3.000	1/9.000	**0.094**
5S	3.000	1/9.000	1/5.000	1.000	1/5.000	1/3.000	3.000	1/7.000	**0.029**
VSM	5.000	1/9.000	1/5.000	5.000	1.000	3.000	6.000	1/6.000	**0.066**
TPM	1/1.000	1/9.000	1/.3000	3.000	1/3.000	1.000	3.000	1/9.000	**0.033**
Jidoka	1/3.000	1/9.000	1/3.000	1/3.000	1/6.000	1/3.000	1.000	1/9.000	**0.017**
Multifunc. workers	5.000	1/9.000	9.000	7.000	6.000	9.000	9.000	1.000	**0.233**

Notes: CR = 0.200 (≤ 0.100 = acceptable, < 0.200 tolerable)

Lean practices for **health and safety**

	Pull production	*Kaizen*	Standard. work	5S	VSM	TPM	*Jidoka*	Multifunc. workers	**E-vector**
Pull production	1.000	1/9.000	1/9.000	1/9.000	1/5.000	1/9.000	1/9.000	1/9.000	**0.013**
Kaizen	9.000	1.000	5.000	5.000	5.000	1/5.000	1.000	5.000	**0.231**
Standard. work	9.000	1/5.000	1.000	1.000	5.000	1/3.000	3.000	1.000	**0.112**
5S	9.000	1/5.000	1/1.000	1.000	3.000	1/3.000	1.000	3.000	**0.100**
VSM	5.000	1/5.000	1/5.000	1/3.000	1.000	1/3.000	3.000	1.000	**0.064**
TPM	9.000	5.000	3.000	3.000	3.000	1.000	7.000	5.000	**0.338**
Jidoka	9.000	1/1.000	1/3.000	1/1.000	1/3.000	1/7.000	1.000	1/3.000	**0.067**
Multifunc. workers	9.000	1/5.000	1/1.000	1/3.000	1/1.000	1/5.000	3.000	1.000	**0.074**

Notes: CR = 0.170 (≤ 0.100 = acceptable, < 0.200 tolerable)

Lean practices for **job stress reduction**

	Pull production	*Kaizen*	Standard. work	5S	VSM	TPM	*Jidoka*	Multifunc. workers	**E-vector**
Pull production	1.000	1/9.000	1/3.000	1/5.000	1/5.000	1/3.000	1/3.000	1/7.000	**0.024**
Kaizen	9.000	1.000	5.000	5.000	3.000	3.000	5.000	1.000	**0.289**
Standard. work	3.000	1/5.000	1.000	1/5.000	1/3.000	1/5.000	1/5.000	1/7.000	**0.034**
5S	5.000	1/5.000	5.000	1.000	3.000	1.000	1.000	1/3.000	**0.118**
VSM	5.000	1/3.000	3.000	1/3.000	1.000	3.000	1.000	1/3.000	**0.102**
TPM	3.000	1/3.000	5.000	1/1.000	1/3.000	1.000	1.000	1/3.000	**0.086**
Jidoka	3.000	1/5.000	5.000	1/1.000	1/1.000	1/1.000	1.000	1/5.000	**0,085**
Multifunc. workers	7.000	1/1.000	7.000	3.000	3.000	3.000	5.000	1.000	**0.264**

Notes: CR = 0.070 (≤ 0.100 = acceptable, < 0.200 tolerable)

Lean practices for **enhanced workplace**

	Pull production	*Kaizen*	Standard. work	5S	VSM	TPM	*Jidoka*	Multifunc. workers	**E-vector**
Pull production	1.000	1/9.000	5.000	1/3.000	1/9.000	1.000	1/3.000	1.000	**0.044**
Kaizen	9.000	1.000	9.000	7.000	3.000	3.000	7.000	7.000	**0.390**
Standard. work	1/5.000	1/9.000	1.000	1/7.000	1/9.000	1/5.000	1/3.000	1/7.000	**0.016**
5S	3.000	1/7.000	7.000	1.000	1/3.000	5.000	5.000	1.000	**0.115**
VSM	9.000	1/3.000	9.000	3.000	1.000	5.000	7.000	3.000	**0.228**
TPM	1/1.000	1/3.000	5.000	1/5.000	1/5.000	1.000	3.000	1/5.000	**0.055**
Jidoka	3.000	1/7.000	3.000	1/5.000	1/7.000	1/3.000	1.000	1/7.000	**0.039**
Multifunc. workers	1/1.000	1/7.000	7.000	1/1.000	1/3.000	5.000	7.000	1.000	**0.114**

Notes: CR = 0.140 (≤ 0.100 = acceptable, < 0.200 tolerable)