UNIVERSIDADE FEDERAL DE SÃO CARLOS
CENTRO DE CIÊNCIAS EXATAS E DE TECNOLOGIA
PROGRAMA DE PÓS-GRADUAÇÃO EM ENGENHARIA DE PRODUÇÃO

GEANDRA ALVES QUEIROZ

ESTRATÉGIAS DE OPERAÇÕES E PRÁTICAS LEAN-GREEN: UM ESTUDO DE CASOS MÚLTIPLOS EM EMPRESAS DO SETOR AUTOMOTIVO

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Tese apresentada ao Programa de Pós-Graduação em Engenharia de Produção da Universidade Federal de São Carlos como parte dos requisitos para obtenção do título de Doutora em Engenharia de Produção

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UNIVERSIDADE FEDERAL DE SÃO CARLOS

Centro de Ciências Exatas e de Tecnologia
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Folha de Aprovação

Defesa de Tese de Doutorado da candidata Geandra Alves Queiroz, realizada em 21/10/2021.

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O presente trabalho foi realizado com apoio da Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - Brasil (CAPES) - Código de Financiamento 001.
O Relatório de Defesa assinado pelos membros da Comissão Julgadora encontra-se arquivado junto ao Programa de Pós-Graduação em Engenharia de Produção.

AGRADECIMENTOS

Nenhum grande objetivo é possível de ser alcançado sozinha, os meus agradecimentos a todos que de alguma forma participaram e estiveram ao meu lado na conclusão deste doutorado, em especial:

Ao Professor Dr. Alceu Gomes Alves Filho, profissional e pessoa que tenho grande admiração, pela orientação, compreensão, paciência, apoio, ensinamentos, conversas e incentivos durante todo o período de realização deste trabalho.

À Professora Dra. Ana Lúcia Vitale Torkomian pela atenção, pelas valiosas contribuições com meu trabalho e por me apoiar como minha orientadora formal.

Ao Professor Dr. Luis Antonio de Santa Eulalia pelas valiosas recomendações e contribuições para este trabalho, e por toda atenção e receptividade no período de doutorado sanduíche sob sua orientação na Université de Sherbrooke.

À Professora Dra. Ivete Delai pelas contribuições com esta pesquisa desde à pré-qualificação e pela atenção e paciência no desenvolvimento do artigo de revisão sistemática.

Aos Professores Dr. Luis Miguel Ferreira e Professora Dra. Rosangela Maria Vanalle por aceitarem compor a banca de defesa e pelas valiosas contribuições na arguição.

Ao Prof. Dr. Juan Francisco Núñez da Université de Sherbrooke pelas valiosas contribuições na validação do instrumento de pesquisa e trocas de conhecimento.

Aos demais professores do PPGEP que estiveram presentes durante o doutorado e a todos os outros professores que passaram por mim desde a pré-escola, obrigada pelos ensinamentos e por serem exemplo e fonte de inspiração.

A todos funcionários do PPGEP, especialmente aos secretários Robson e Lucas, pela presteza e atenção com todas as minhas dúvidas e solicitações.

Aos gestores das empresas que participaram desta pesquisa e contribuíram para os resultados desta tese.

À CAPES pela bolsa concedida para a realização deste doutorado e pela bolsa no programa PRINT que permitiu a realização do período sanduíche na Université de Sherbrooke no Canadá.

À Universidade Federal de São Carlos por possibilizar a realização do Doutorado.

Aos meu Pais, Cida e Vivaldo (*in memoriam)*, pelo incentivo desde à infância para que eu percorresse o caminho do estudo, pelo amor e valores que me ensinaram. Mãe, obrigada por toda a paciência com meu stress nesse último ano, por todas as comidinhas, cafés e orações.

Ao meu pequeno grande irmão Lucas Henrique pelo amor, companheirismo e momentos de alegria, obrigada por ser esse meu parceiro de vida.

Ao meu namorado Pedro Henrique e exemplo de determinação e foco, obrigada pelo carinho, amor, companheirismo e por me incentivar de todas as formas neste último ano de doutorado. Não foi fácil, mas cumprimos o combinamos de finalizar este desafio juntos.

A todos os meus familiares que torceram por mim, especialmente a minha madrasta e amiga Renilda pela amizade, torcida e carinho de sempre.

A todos os meus amigos. Desde os amigos da infância, adolescência e faculdade que me apoiaram e souberam entender os momentos de ausência. Àqueles que surgiram durante esta caminhada na Pós-graduação: os amigos da USP e UFSCAR, os amigos da corrida e os amigos da La Cabane. Em especial, agradeço a rede apoio de alguns amigos do doutorado, pela troca de informações, aprendizados e ansiedades divididas: Renata, Denise, Nayara, René, Luciano e Lucas. Obrigada pela amizade de vocês, quero levá-los para a vida toda.

Não poderia deixar de agradecer também a todas as instituições que trabalhei como docente, aos colegas professores, bem como aos alunos que passaram por mim durante o período que exerci à docência, me proporcionando preciosas trocas de conhecimento, crescimento pessoal e me permitindo reafirmar o propósito da realização deste doutorado.

Por fim, agradeço a Deus, pois a fé inspira, motiva e não nos deixa desistir.

RESUMO

A redução dos impactos ambientais tem sido tratada cada vez mais como fator de vantagem competitiva pelas organizações. Isto reflete diretamente nas estratégias de operações das empresas, tornando necessária a inclusão do desempenho ambiental como uma de suas prioridades competitivas. A integração das abordagens *Lean Manufacturing* e *Green Manufacturing* tem sido apontada como chave para melhorar a competitividade das organizações por ser uma maneira de equacionar a prioridade ambiente com as outras prioridades competitivas. No entanto, não há ainda artigos científicos que abordem, de maneira ampla, o conteúdo da estratégia de operações (prioridades competitivas e áreas de decisão) quando práticas *Lean* e *Green* são implementadas. Neste contexto, a primeira etapa deste estudo consistiu na realização de uma revisão sistemática da literatura apresentando algumas das principais relações entre *Lean* e *Green* e o conteúdo da estratégia de operações e destacando a ocorrência das sinergias ou dos *trade-offs* entre prioridades competitivas assim como as mudanças nas áreas de decisão quando práticas Lean e Green são implementadas. Os resultados deste estudo apontaram que a integração *Lean* e *Green* pode promover sinergias entre as prioridades competitivas, mas também pode promover *trade-offs* entre algumas prioridades competitivas, sendo o *trade-off* entre as prioridades custo e ambiente o mais frequentemente mencionado. Além disso, o *Lean* é apontado como uma base para a gestão dos sistemas de produção, e as práticas *Green* são utilizadas em geral como complemento e para sustentar a inclusão do ambiente como prioridade competitiva. Já a segunda etapa desta pesquisa foi a condução de estudos de caso em seis empresas do setor automotivo que implementam práticas *Lean* e *Green,* com a finalidade de identificar os conteúdos de suas estratégias de operações. Os resultados apontaram que as empresas atribuem níveis diferentes de importância à prioridade ambiente, bem como possuem diferentes níveis de integração entre *Lean-Green.* De modo geral, as empresas consideram que a abordagem *Lean-Green* gera sinergias entre as prioridades, sendo o *trade-off* entre custo e ambiente o único abordado nos casos. Confirmou-se que Lean pode contribuir para a redução de impactos ambientais, principalmente no que tange ao consumo de recursos. Além disso, verificou-se que as empresas que mais priorizam o ambiente em suas ações apresentaram mais alterações nas áreas de decisão. O cruzamento dos resultados teóricos com os resultados empíricos permitiu reforçar as proposições teóricas indicadas nesta tese. Todas as proposições formuladas a partir da revisão sistemática da literatura foram ilustradas nos casos estudados e complementadas com algumas questões.

Palavras-chave: estratégia de operações. prioridades competitivas. áreas de decisão. produção enxuta. manufatura verde.

ABSTRACT

The reduction of environmental impacts has increasingly been treated as a factor of competitive advantage by organizations. This reflects directly on the operational strategies of companies, making it necessary to include environmental performance as one of their competitive priorities. The integration of Lean Manufacturing and Green Manufacturing approaches has been pointed out as a key to improving the competitiveness of organizations because it is a way to equate the environmental priority with other competitive priorities. However, there are still no scientific articles that address all the content of operations strategy (competitive priorities and decision areas) when Lean and Green practices are implemented. In this context, the first step of this study consisted in conducting a systematic literature review presenting some of the main relationships between Lean and Green and the content of operations strategy and highlighting the occurrence of synergies or trade-offs between competitive priorities as well as changes in decision areas when Lean and Green practices are implemented. The results of this study pointed out that Lean and Green integration can promote synergies between competitive priorities, but it can also promote trade-offs between some competitive priorities, with the trade-off between cost and environment priorities being the most frequently mentioned. Furthermore, Lean is pointed out as a basis for the management of production systems, and green practices are generally used as a complement and to support the inclusion of the environment as a competitive priority. The second stage of this research was to conduct case studies in six companies in the automotive sector that implement Lean and Green practices, with the purpose of identifying the contents of their operations strategies. The results indicated that the companies attribute different levels of importance to the priority environment and have different levels of Lean and Green. In general, the companies consider that the Lean-Green approach generates synergies between priorities, with the trade-off between cost and environment being the only one addressed in the cases. It was confirmed that Lean can contribute to the reduction of environmental impacts reduction, especially regarding to resource consumption. Moreover, it was found that the companies that prioritize the environment more in their actions presented more changes in the decision areas. The crossing of the theoretical results with the empirical results allowed us to reinforce the theoretical propositions stated in this thesis. All the propositions formulated from the systematic literature review were illustrated in the cases studied and complemented with some questions.

Keywords: operations strategy. competitive priorities. decision areas. lean production. green manufacturing.

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LISTA DE SIGLAS

ACV - Avaliação do Ciclo de Vida

EO - Estratégia de Operações

GM - *Green Manufacturing*

GRI - *Global Report Intiativie (GRI)*

GSCM - *Green Supply Chain Management*

JIT - *Just in Time*

LCA - *Life Cycle Assessement*

LM - *Lean Manufacturing*

MFV - Mapeamento do Fluxo de Valor

OS - *Operations Strategy*

PmaisL - Produção mais Limpa

RSL - Revisão Sistemática da Literatura

SGA - Sistema de Gestão Ambiental

SLR - *Systematic Literature Review*

VSM - *Value Stream Mapping*

SUMÁRIO

1. INTRODUÇÃO

Neste capítulo é apresentado o problema que motivou o desenvolvimento desta pesquisa, bem como os objetivos e a justificativa para a realização deste trabalho. São apresentadas ainda uma introdução ao método de pesquisa adotado e, por fim, a estrutura desta tese de doutorado.

1.1 CONTEXTUALIZACAO E JUSTIFICATIVA

Desde os primórdios das relações de mercado, as empresas precisam atender aos desejos dos clientes, que variam conforme o contexto social e econômico. Nas últimas décadas tem crescido a preocupação, em todos os contextos, com as questões ambientais e com a indisponibilidade de recursos. Assim, a redução dos impactos ambientas gerados por processos e produtos é necessária e exigida pela sociedade em geral, por governos, por consumidores e pelas próprias empresas, afetando sua competitividade (BRAGLIA et al., 2020).

Essa demanda reflete diretamente nas estratégias de operações das empresas, uma vez que o objetivo de uma estratégia de operações é equilibrar as exigências do consumidor com os recursos da função produção alinhada à estratégia do negócio (SKINNER, Wickham, 1969; SLACK; CHAMBERS; JOHNSTON, 2010; VOSS, C. A., 2005).

Em 1969, Skinner (1969), em seu artigo seminal, destacava que a função produção deveria ser considerada estratégica e fonte de vantagem competitiva. A implementação de uma estratégia de operações apropriada, incluindo o desenvolvimento de capacidades operacionais, pode desempenhar papel crucial em como a empresa cria vantagens competitivas (HILMOLA *et al.*, 2015). Ainda, o sucesso dessa estratégia está relacionado com a definição do seu conteúdo, composto fundamentalmente por prioridades competitivas e ações implementadas nas diversas áreas de decisão (VOSS, 2005).

As prioridades competitivas sinalizam como a empresa pretende atender as necessidades do consumidor, pois constituem os objetivos de desempenho da função produção ou função operações (JABBOUR, A. B. L. de S.; ALVES FILHO, 2009). Estas prioridades são atingidas por meio de um padrão de decisões e um conjunto de ações implementado nas áreas de decisão da empresa, subdivididas em estruturais – como instalação, capacidade, tecnologia, cadeia de suprimentos – e infraestruturais – como recursos humanos, gestão da qualidade, planejamento e controle da produção, desenvolvimento de produto, sistema de medição de desempenho e organização (HAYES *et al.*, 2007; SKINNER, Wickham, 1969; WHEELWRIGHT, 1984). Assim, definir o conteúdo da estratégia de operações de modo alinhado às necessidades do mercado pode determinar a vantagem competitiva da empresa (VOSS, C. A., 2005).

Deste modo, considerando que a redução de impactos ambientais tem se tornado um requisito básico para a competitividade, a formulação de uma estratégia de operações que inclua o desempenho ambiental em seu conteúdo torna-se essencial, mas se trata também de um grande desafio para gestores e pesquisadores em Gestão de Operações (GAVRONSKI, 2012). Pois, além de custo, qualidade, velocidade e confiabilidade na entrega e flexibilidade, os gestores precisam estar atentos ao desempenho ambiental de suas operações, que será nomeada neste trabalho de prioridade "Ambiente" (ANGELL; KLASSEN, 1999; GUPTA *et al.*, 2018; LONGONI; CAGLIANO, 2015).

Uma proposta que vem sendo muito discutida na literatura é a integração da abordagem *Lean Manufacturing*, voltada para a gestão da produção, e da abordagem *Green Manufacturing*, que envolve práticas que buscam reduzir os impactos ambientais. O primeiro estudo foi apresentado em 1996 por Florida (1996) e discutia a integração destas abordagens, explorando como as organizações poderiam incluir a questão ambiental na manufatura por meio da abordagem integrada "*Lean-Green*" e argumentando que a redução dos desperdícios gerada pelo *Lean* contribui para o desempenho ambiental. Neste sentido, a literatura tem apontado a abordagem "*Lean-Green"* como chave para melhorar a competitividade das organizações por ser uma maneira de balancear a prioridade ambiente com as outras prioridades competitivas (FLORIDA, 1996; GARZA-REYES *et al.*, 2018;SUIFAN; ALAZAB; ALHYARI, 2019).

O *Lean Manufacturing* surgiu na década de 1950, é considerado uma filosofia de gestão e tem sido uma das abordagens mais utilizadas para gerenciar as operações (WOMACK; JONES, 2004). Ainda, o *Lean* pode ser definido como um conjunto de princípios e práticas que buscam eliminar todas as formas de desperdícios dos processos (MOSTAFA; DUMRAK; SOLTAN, 2013). Organizações de diversos setores da economia ao redor do mundo estão adotando as práticas *Lean* buscando se tornarem mais competitivas (LOSONCI; DEMETER, 2013).

Já o *Green Manufacturing* surgiu nos anos 90 como uma abordagem operacional e filosófica para a redução de impactos ambientais negativos de produtos e processos (Garza-Reyes, 2015). Em resumo, esta abordagem tem o objetivo de reduzir os impactos ambientais negativos gerados pelas operações e trata da busca pela redução da poluição, consumo de energia e emissões de substâncias tóxicas por meio do desenvolvimento de novos processos na fase de manufatura (KLEINDORFER; SINGHAL; VAN WASSENHOVE, 2005; PATHAK; SINGH, 2017; SILVA; SILVA; OMETTO, 2015).

Neste contexto, um estudo teórico realizado neste trabalho, e apresentado à frente, com uso de uma revisão sistemática da literatura de 260 artigos, evidenciou que não há artigos científicos que abordem, de maneira ampla, o conteúdo da estratégia de operações (prioridades competitivas e áreas de decisão) e as práticas de Lean Manufacturing (*Lean*) e de Green Manufacturing (*Green*), chamadas nesta pesquisa de práticas *Lean-Green*. Apenas dois trabalhos trataram diretamente da estratégia de operações. Longoni e Cagliano (2015b) forneceram evidências sobre como o envolvimento da alta-gestão e dos trabalhadores na formulação influencia a implementação da estratégia de operações apoiadas no alinhamento estratégico do *Lean* e da sustentabilidade. Já a pesquisa de Suifan et al. (2019) analisou os *trade-offs* entre as abordagens *Lean* e *Green* adotando um método de análise multicritério que mostrou que as prioridades competitivas podem ser diferentes em cada abordagem. Contudo, estas pesquisas não abordaram todo o conteúdo da estratégia de operações e as relações com as práticas *Lean* e Green.

Considerando o amplo número de artigos analisados que discutem as compatibilidades entre *Lean* e *Green*, mas que somente abordam alguns aspectos da estratégia de operações e não a discutem de maneira holística, esta pesquisa busca contribuir para preenchimento desta lacuna. Para isso, buscou-se como objeto de estudo, um setor em que há mais chances de as empresas estarem adotando tais práticas. Optou-se então pelo setor automotivo, pois, como mostrado no estudo de Caldera et al. (2017), é onde a maioria dos modelos e propostas de integração das práticas *Lean* e *Green* são desenvolvidas. Diante deste contexto, esta pesquisa busca encontrar resposta para o seguinte questionamento:

Quais são os conteúdos das estratégias de operações de empresas do setor automotivo que adotam práticas Lean e Green? Como são as relações entre os elementos desses conteúdos - prioridades competitivas, áreas de decisão e práticas *Lean* e *Green*?

Para responder a estes questionamentos, apresenta-se a seguir os objetivos desta pesquisa.

1.2 OBJETIVOS

Esta pesquisa de doutorado tem como objetivo geral: **Identificar e analisar os**

conteúdos das estratégias de operações de empresas do setor automotivo que adotam as abordagens *Lean* e *Green*. Para alcançar o objetivo geral desta pesquisa, faz-se necessário atingir os seguintes objetivos específicos:

- Investigar como a literatura até o momento explica as contribuições e alterações das abordagens *Lean* e *Green* nas prioridades competitivas e áreas de decisão.
- Verificar, por meio de estudos de caso, quais são e como são ordenadas as prioridades competitivas de produção e que mudanças foram implementadas nas áreas de decisão de empresas que adotam práticas *Lean* e *Green*.
- Identificar quais práticas foram implementadas, em que estágios de implementação se encontram.
- Explicar como as práticas *Lean* e *Green* promovem sinergias entre as prioridades competitivas ou provocam *trade-offs* sob a perspectiva estratégica (alterações e contribuições às prioridades competitivas e áreas de decisão).
- Investigar se, e como, o *Lean* facilita a implantação de práticas *Green* na Estratégia de Operações.

Tendo como norte os objetivos acima, busca-se chegar, com a realização da pesquisa, às contribuições tanto em âmbito teórico quanto prático. Os resultados poderão, pelo menos em parte, preencher uma lacuna identificada com a elaboração de uma revisão sistemática da literatura e fornecer uma explicação e uma discussão de conteúdos de estratégias de operações das empresas. Cada estratégia de operações é constituída por prioridades competitivas, mudanças implementadas nas áreas de decisão estruturais e infra estruturais, incluindo aquelas que envolvem a implementação de práticas *Lean* e *Green* destacadas neste trabalho.

Isso envolve apresentar as prioridades competitivas escolhidas e priorizadas, as práticas adotadas, as mudanças promovidas nas áreas de decisão, além de uma explicação das relações entre tais constructos. Trata-se do emprego de uma abordagem holística acerca das práticas *Lean* e *Green* sob uma perspectiva estratégica – explicitando algumas das principais relações, sinergias e *trade-offs*, entre práticas e prioridades competitivas das operações e as mudanças nas áreas de decisão.

Além disso, envolve apresentar empiricamente como são caracterizadas as estratégias de operações das empresas do setor automotivo que implantam práticas *Lean* e *Green*. Assim, tais resultados podem trazer, também, uma contribuição gerencial, uma vez que o entendimento dessas questões pode fornecer diretrizes para as organizações adotarem e implementarem estratégias de operações, abrangendo práticas Lean e práticas Green, de maneira efetiva, eficaz e eficiente, em setores e segmentos de atuação competitivos e dinâmicos e que devem atender a novas demandas de preservação ambiental.

A literatura sobre *Lean* e *Green* tem abordado fenômenos relacionados a essas práticas mas que apenas tangenciam, ou abrangem apenas em parte, aspectos estratégicos da empresa ou mais especificamente da estratégia de operações. Da perspectiva do referencial teórico construído sobre estratégia de operações e do paradigma proposto por Voss (1995,2005) "*Strategic Choices*", as decisões são tomadas e as práticas são implementadas na produção com o propósito de formar uma determinada estratégia, alinhada à estratégia competitiva, que traga vantagens competitivas no mercado. Nesta pesquisa, portanto, com a identificação e análise das estratégias de operações de empresas que adotam práticas *Lean* e práticas *Green*, pode-se discutir a pertinência e adequação da implementação de tais práticas para as organizações que buscam incluir a prioridade Ambiente em suas estratégias.

A seguir é apresentado uma síntese do método de pesquisa utilizado nesta tese de doutorado.

1.3 INTRODUÇÃO AO MÉTODO DE PESQUISA

A pesquisa é um processo sistemático, com etapas definidas, e racional, que tem como objetivo encontrar soluções aos problemas propostos e deve ser conduzida por um método científico (GILL, 1995). Neste sentido, o método de pesquisa é constituído pelos passos necessários para resolver problemas cientificamente (DEMO, 1995).

A seleção do método adequado está diretamente relacionada ao problema a ser estudado. Sua escolha dependerá de vários fatores relacionados à pesquisa, como a natureza do fenômeno, o objeto de pesquisa, recursos financeiros e disponibilidade de recursos humanos (LAKATOS; MARKONI, 1995). Nesta pesquisa foram utilizados dois métodos: uma revisão sistemática da literatura e um estudo de casos múltiplos.

A primeira etapa para a condução desta tese envolveu a definição de uma estrutura conceitual. Inicialmente, foi construído um referencial teórico acerca dos três constructos da pesquisa: Estratégia de Operações, *Lean Manufacturing* e *Green Manufacturing*. Com base na definição da estrutura conceitual foi possível, posteriormente, identificar lacunas para justificar a pesquisa e verificar as proposições teóricas empiricamente (YIN, R. K., 2017). A partir destes conceitos foram então estabelecidas proposições e delimitadas as fronteiras sobre o que foi pesquisado. Assim, após a fundamentação teórica foi conduzida a revisão sistemática da literatura.

A Revisão Sistemática da Literatura (RSL) é um método que busca o mapeamento e a avaliação do conhecimento existente sobre o tema pesquisado e fornece condições para uma definição consistente da questão de pesquisa que se busca investigar (DENYER; TRANFIELD, 2009). A aplicação da RSL provém da necessidade de pesquisadores em sintetizar a informação existente sobre algum fenômeno de maneira completa e imparcial, com o objetivo extrair conclusões ou fornecer base para pesquisas futuras, a partir de estudos individuais, ou fornecer base para pesquisas futuras (KITCHENHAM, 2004).

Os resultados da fundamentação teórica e da RSL foram usados para a definição da lacuna de pesquisa e do desenvolvimento do modelo teórico, ilustrado na Figura 1, o qual foi utilizado para embasar o roteiro do Estudo de casos múltiplos. Na figura estão indicadas as proposições a que se chegou e que são apresentadas no capítulo 4 desta tese.

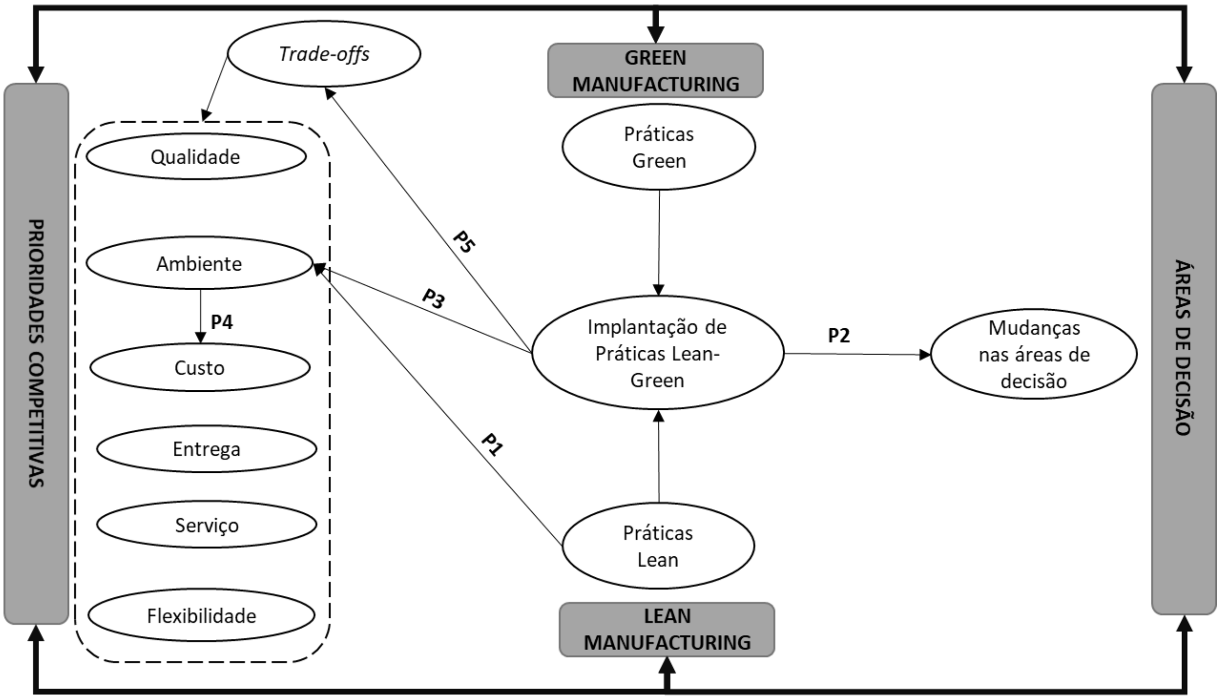

Figura 1- Modelo teórico.

- P1: Lean tem potencial para reduzir os impactos ambientais;
- P2: Lean não é suficiente para ser Green, é necessário a implementação de Práticas Green e mudanças nas áreas de decisão;
- P3: “Ambiente” é uma nova prioridade competitiva das operações nas empresas que implantam Lean;
- P4: A priorização do ambiente é dependente das estimativas de investimentos e custos e das expectativas de resultados.

- P5: A integração *Lean* e *Green* cria *trade-offs* entre as prioridades competitivas.

Com relação ao estudo de casos, este método se baseia em várias fontes de evidências e pode se beneficiar do desenvolvimento prévio de proposições teóricas para conduzir a coleta e a análise de dados. A principal tendência em todos os tipos de estudos de caso é que estes tentam esclarecer o motivo pelo qual uma decisão ou conjunto de decisões foram tomadas, como foram implantados e quais os resultados alcançados. Além disso, são utilizados para contribuir e ampliar o conhecimento existente sobre os fenômenos individuais, organizacionais, sociais, políticos e de grupo (YIN, R. K., 2017).

O estudo de caso deve ser utilizado quando o fenômeno pode ser estudado em seu ambiente natural e pode ser gerada uma teoria significativa a partir da compreensão adquirida por meio da observação empírica (YIN, 2017). Além disso, este método comporta questões do tipo “Por quê?” “O quê?” e “Como?”, as quais devem ser respondidas com uma compreensão completa da natureza e do fenômeno estudado (VOSS, C.; TSIKRIKTSIS; FROHLICH, 2002).

Esta pesquisa buscará realizar múltiplos casos sendo adotada como unidade de análise a unidade de produção das empresas estudadas, uma vez que segundo Yin (2017) podem produzir mais evidências sobre um mesmo fenômeno a partir de diferentes perspectivas e dar mais robustez a pesquisa. Já a natureza dos estudos se caracteriza como descritiva e explicativa nas diferentes fases da pesquisa. A parte descritiva foi realizada para descrever os conteúdos das estratégias de operações e as práticas *Lean* e *Green* utilizadas. Foi seguida pela parte explicativa, destacando como as práticas *Lean e Green* alteram as estratégias de operações, explicando os trade-offs e as sinergias geradas entre as prioridades competitivas bem como as mudanças provocadas nas áreas de decisão.

Considerando os objetivos desta pesquisa, foram definidos os critérios para seleção dos casos a serem estudados: empresas do setor automotivo que tenham adotado práticas *Lean* e *Green.* Com base nisso, foi definido o desenho experimental baseado na proposta de Yin (2017). O autor expõe quatro possibilidades para aplicação do método estudo de caso conforme mostra a Figura 2.

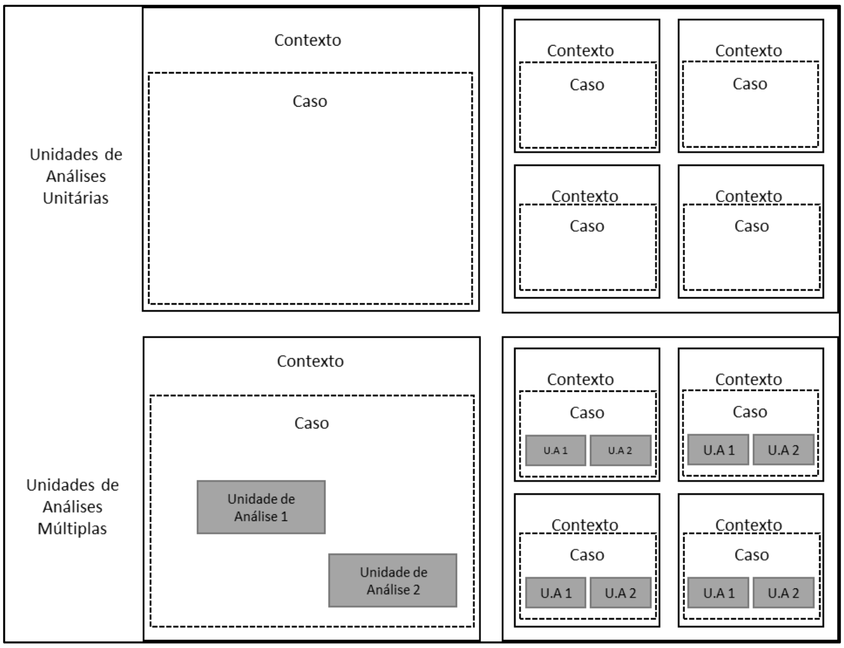

Figura 2 - Possibilidades de aplicação do estudo de caso.

Fonte: Baseado em Yin (2017).

Para esta pesquisa de doutorado foram utilizados casos em diferentes empresas em diferentes contextos no que se refere a diferentes níveis de implantação das práticas, e, dentro de cada caso, buscou-se evidências em apenas uma unidade de análise: as unidades de produção, entrevistando-se gestores de produção/manufatura e gestores de meio ambiente. Como pode ser visualizado na figura a seguir.

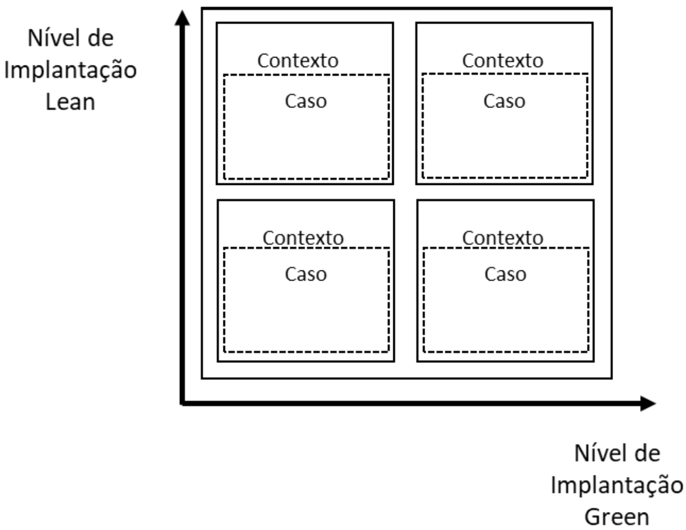

Figura 3 - Formato de estudo de Caso utilizado na pesquisa.

Fonte: Baseado em Yin (2017).

Em síntese, a coleta de dados teve como objetivo caracterizar as estratégias de operações (prioridades competitivas e as áreas de decisão) com a implantação de práticas *Lean-Green.* Deste modo, foram realizados seis estudos de casos em diferentes situações de implantação das Práticas *Lean-Green* com o objetivo de comparar as estratégias de operações. Na figura a seguir (figura 4) são apresentadas as principais etapas da pesquisa. O APÊNDICE B contém o material suplementar dos estudos de casos, apresentando os documentos referentes as normas éticas e o protocolo com os questionários para a coleta de dados nos casos estudados.

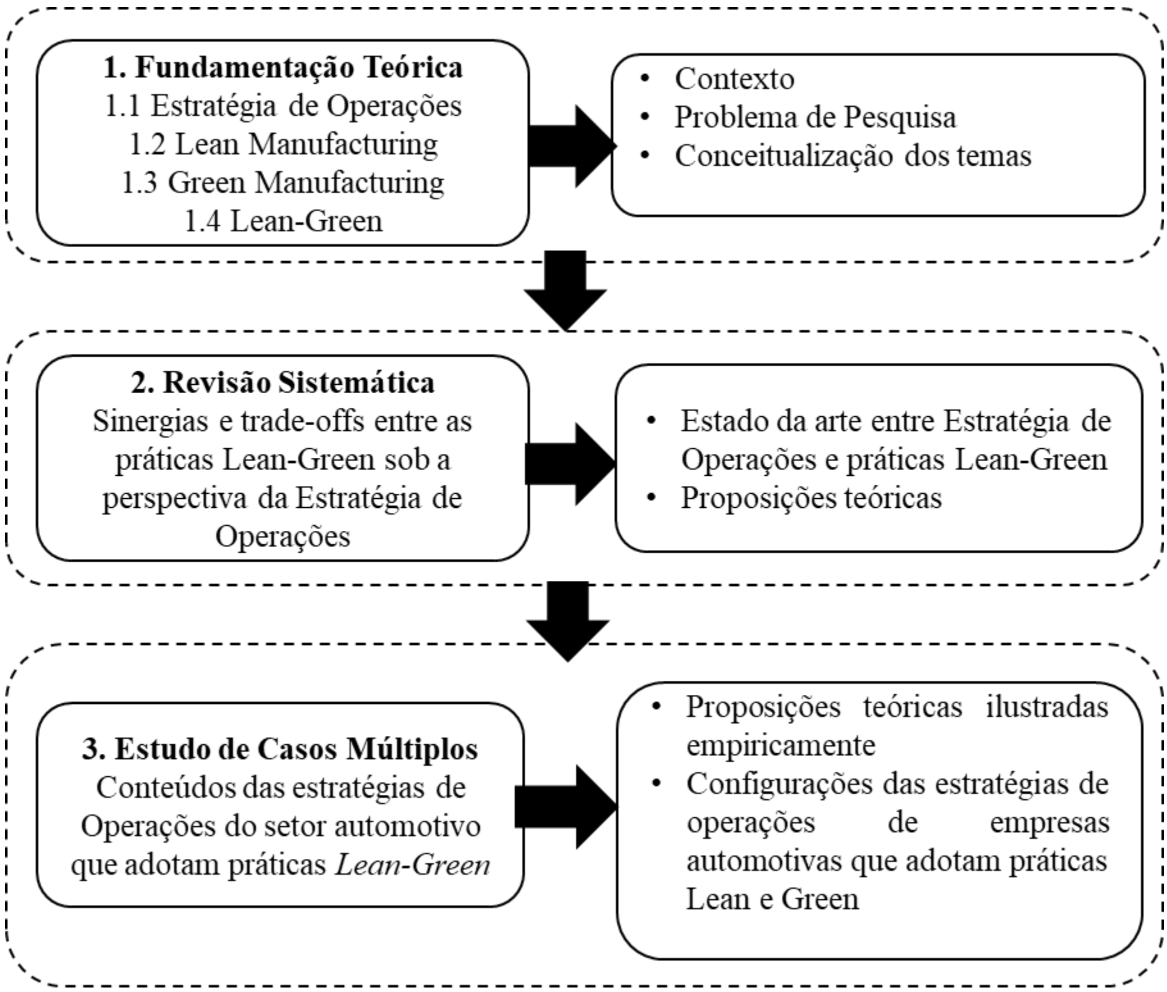

Figura 4 - Métodos e etapas da pesquisa.

A primeira etapa da pesquisa foi a fundamentação teórica acerca de Estratégia de Operações, *Lean Manufacturing*, *Green Manufacturing* e *Lean-Green*, consistindo de um estudo dos conceitos fundamentais de cada tema, o que permitiu a definição do problema de pesquisa, justificativa para realização deste trabalho e, por fim, a formulação dos objetivos desta tese. De modo detalhado, após o estudo dos conceitos fundamentais de cada constructo da pesquisa, buscou-se compreender por meio de uma revisão sistemática como a literatura de gestão de operações sobre Lean-Green aborda a relação entre eles bem como o estado da arte. Os resultados obtidos por meio da fundamentação teórica e da revisão de literatura foram base para as proposições teóricas ilustradas no estudo de casos múltiplos, a última etapa desta pesquisa. Além disso, os resultados obtidos nos estudos de casos múltiplos permitiram encontrar diferentes configurações de estratégias de operações, assim como nos estudos de Jagoda, Kiridena e Lin (2016) e Ward, Bickford e Leong (1996) que são apresentadas características diferentes dos conteúdos das estratégias que resultam em diferentes configurações. Na sequência será apresentada a estrutura da tese, descrevendo os capítulos e os conteúdos correspondentes.

1.4 ESTRUTURA DA TESE

Esta tese está dividida em sete capítulos. Vale ressaltar que os capítulos 3 e 4 desta tese estão estruturados no formato de artigos. Deste modo, não foi possível evitar que algumas informações aparecessem mais de uma vez neste documento. A estrutura desta tese de doutorado é apresentada na Figura 5.

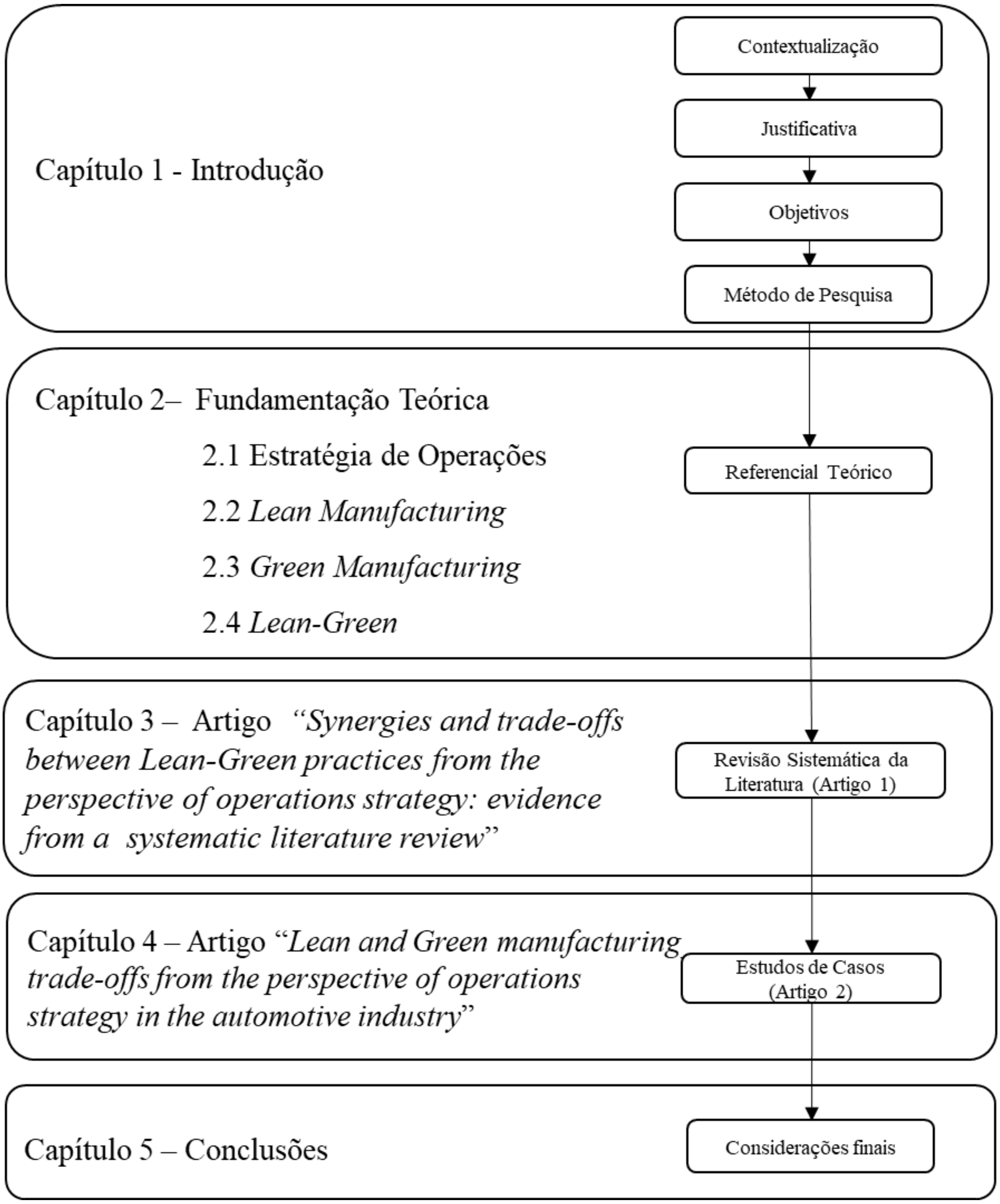

Figura 5 - Estrutura da Tese.

O primeiro Capítulo constitui esta Introdução, que é seguida por uma fundamentação teórica, apresentada no Capítulos 2, em que os conceitos da temática desta pesquisa são expostos. O Capítulo 3 contém o primeiro artigo resultante desta pesquisa, que é fruto dos resultados da Revisão Sistemática da Literatura realizada. Posteriormente, no Capítulo 4, apresenta-se o segundo artigo com os resultados obtidos no estudo de casos múltiplos. Por fim, são apresentadas as conclusões da pesquisa no Capítulo 5.

2. FUNDAMENTAÇÃO TEÓRICA

Neste capítulo é apresentada a fundamentação teórica desta tese de doutorado, a qual é constituída pelos principais conceitos acerca de Estratégia de Operações, *Lean Manufacturing, Green Manufacturing* e *Lean-Green.*

2.1 ESTRATÉGIA DE OPERAÇÕES

2.1.1 DEFINIÇÃO DE ESTRATÉGIA

A palavra estratégia originou-se do grego *"Strategos",* que significa papel de comandante do exército e as habilidades necessárias para exercer esse papel. Este termo é utilizado em vários contextos, desde o militar, voltado para a elaboração de planos de ações para combater os adversários (MINTZBERG *et al.*, 2000), até para referir ao entendimento da sobrevivência de microrganismos na adaptação de novos ambientes (HENDERSON, 1989). No âmbito empresarial, Wheelwright (1984) define estratégia como o foco de toda a organização na definição de negócios nas quais irá atuar e a correspondente aquisição e alocação de recursos.

A essência da estratégia é desenvolver atividades diferentes do que os concorrentes fazem. As empresas podem adotar um conjunto de melhores práticas para o negócio, ter eficiência operacional, porém podem não conseguir traduzir isto na obtenção de lucros sustentáveis. Assim, posições estratégicas podem ser baseadas nas necessidades dos consumidores, acessibilidade ao produto e variedades de produtos e serviços da empresa (PORTER, 1996).

No que diz respeito à formulação da estratégia corporativa, pode ser abordada sob duas perspectivas: *a top down* e a *bottom up.* Na vertente *top down* as decisões são tomadas na direção corporativa da organização e se desdobram para os níveis de negócio e para as áreas funcionais. Isto é, a alta administração decide como vai competir no mercado e, a partir disso, estabelece as mudanças nas unidades de negócio e nas áreas funcionais para implementar tal estratégia. No que diz respeito à formulação da estratégia pela perspectiva *bottom up* o processo seria o inverso, por meio da avalição das competências internas, experiências adquiridas e estrutura organizacional seriam determinados, com a participação da base da organização, os rumos e a atuação da empresa no mercado (SLACK; LEWIS, 2011). A perspectiva mais adotada na literatura é a *top down,* como indicado por Wheelwright

(1984), e será adotada neste trabalho.

A estratégia é composta por níveis de decisões hierárquicas, ou seja, podem ser subdividas em corporativas, de negócios e funcionais (WHEELWRIGHT, 1984). Na Figura 6 pode ser visualizada a representação da estratégia *top down.*

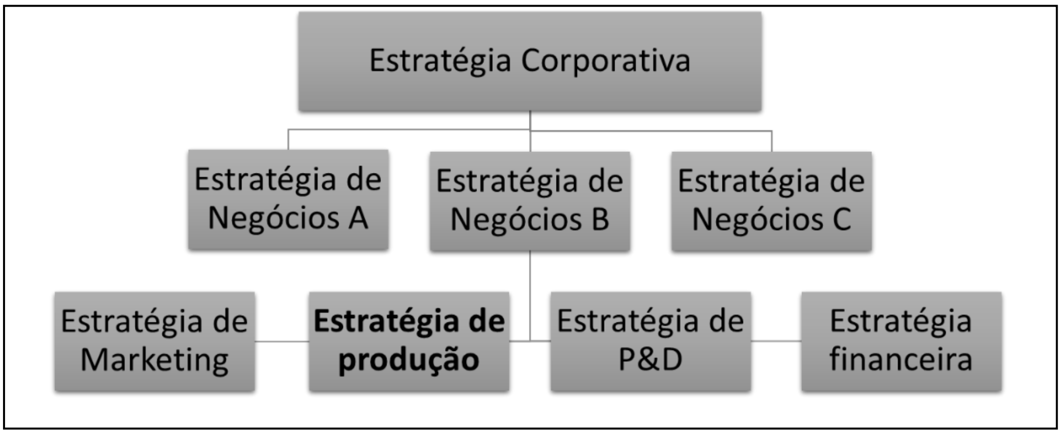

Figura 6 - Representação da estratégia Top – Down.

Fonte: Wheelwright, 1984.

A estratégia corporativa, conforme apresentado anteriormente, é o norte de toda a organização. Já a estratégia de negócios, também conhecida como estratégia competitiva, está relacionada com os planos que norteiam as ações para as subsidiárias, divisões ou linha de produtos da empresa, decidindo a maneira como cada unidade de negócio irá se posicionar em seus mercados. Por fim, tem-se o nível das estratégias funcionais que dizem respeito ao conjunto de decisões que cada área funcional irá tomar alinhada à vantagem competitiva escolhida na estratégia de negócios (WHELLWHRIGHT, 1984).

Mills, Platts e Gregory (1995) reforçam esta estrutura dos três níveis de estrutura e afirmam que a estratégia corporativa deve responder, fundamentalmente, em qual conjunto de negócios a organização deveria atuar; a estratégia de negócios deve direcionar como a empresa irá competir nos negócios x, y e z; e, por fim, nas estratégias funcionais é definido como cada função irá colaborar para garantir a vantagem competitiva do negócio. O processo de estratégia pode ser representado como apresentado Leong, Snyder e Ward (1990) na Figura 7.

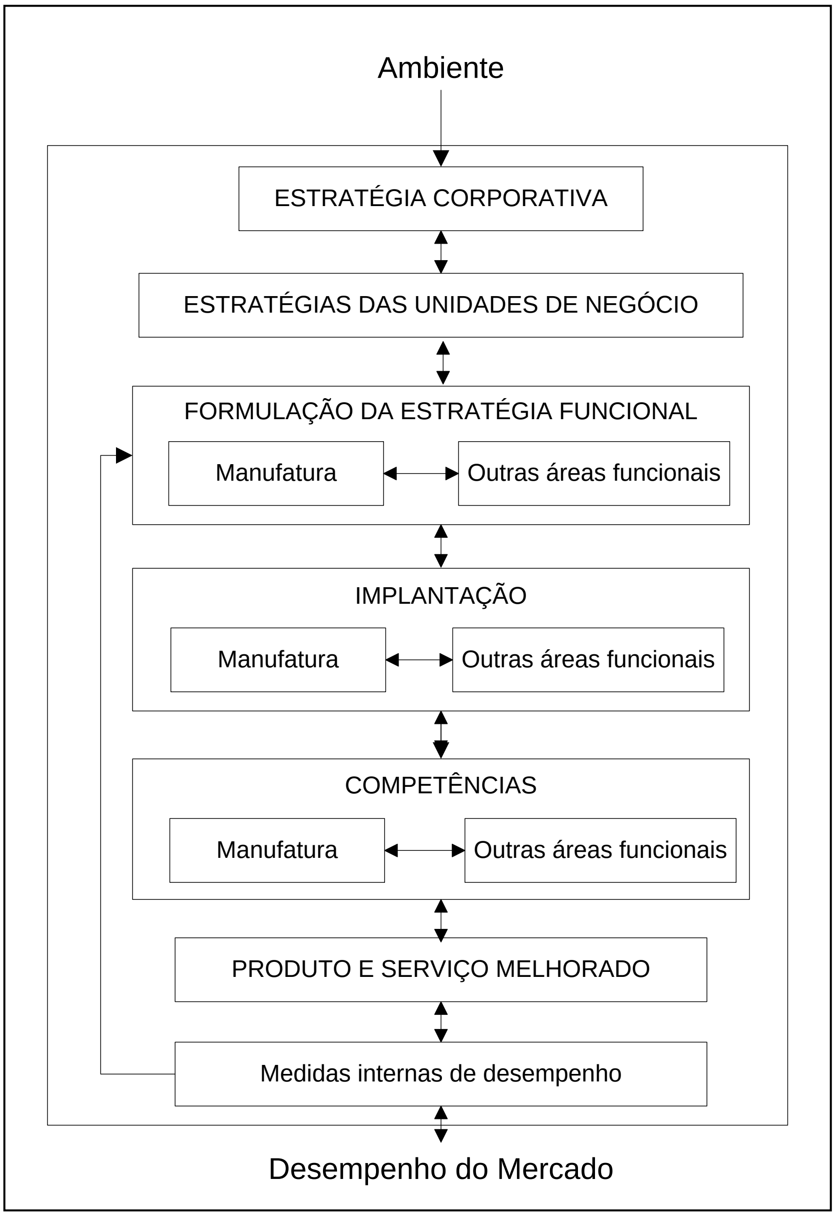

Figura 7 - Processo de Estratégia

Fonte: Traduzido de Leong, Snyder e Ward (1990).

O modelo sugerido por Leong, Snyder e Ward (1990) representa o processo de estratégia que ocorre em um ambiente que consiste em mercados (incluindo concorrentes e consumidores), e as partes interessadas, tais como o público em geral, acionistas e governos, é que direcionam a estratégia. A estratégia corporativa e a estratégia no nível de negócios determinam um padrão apropriado para as estratégias funcionais para cada unidade de negócios, com feedback, a partir das medidas internas de desempenho, nas competências funcionais vindas por meio dos processos internos da organização.

Neste estudo, o foco será na vertente conteúdo da estratégia de operações, a estratégia funcional que é considerada como fonte principal de vantagem competitiva nos últimos 40 anos e até hoje merece atenção (SKINNER, 1969; VOSS, C. A., 1995, 2005). No próximo tópico são apresentados os principais conceitos e pesquisas relacionados à estratégia de operações.

2.1.2 DEFINIÇÃO DE ESTRATÉGIA DE OPERAÇÕES

O estudo de Skinner (1969) foi o pioneiro em destacar e conceituar estratégia de operações, mostrando a importância de incorporar e alinhar os elementos operacionais da função produção com a estratégia competitiva da organização, uma vez que, segundo este autor a produção deveria ser considerada como estratégica e fonte de vantagem competitiva. É muito importante que as empresas reconheçam e estabeleçam uma relação entre a estratégia corporativa, estratégia competitiva e a estratégia de operações, para que os sistemas de produção sejam competitivos e colaborem para atingir as metas da organização (DANGAYACH; DESHMUKH, 2001). Pois as operações podem desempenhar um papel decisivo para que as organizações alcancem uma posição competitiva favorável (ALVES FILHO; NOGUEIRA; BENTO, 2015)

Neste sentido, define-se a estratégia de operações como uma sequência de decisões que ao longo do tempo permita que uma unidade de negócios alcance uma estrutura e uma infraestrutura de produção desejada e um conjunto de recursos específicos, ou seja, um padrão consistente de tomada de decisão na função de produção, alinhada à estratégia de negócios (WHEELWRIGHT, 1984).

Com o mesmo entendimento destes autores, Slack e Lewis (2011) elucidam que a estratégia de operações é o conjunto de decisões que moldam as capacitações de longo prazo de qualquer operação e contribui para a estratégia global conciliando os requisitos do mercado com os recursos das operações. Vale ressaltar que, na literatura, é possível encontrar os termos estratégia de manufatura (*manufacturing strategy)* ou estratégia de operações *(operations strategy*), como sinônimos de “estratégia de produção”. Além destas definições, no Quadro 2 podem ser visualizados outras definições para a estratégia de operações encontradas na literatura.

Quadro 1 - Definições de estratégia de produção.

Definição de estratégia de produção	**Autores**
Explora certas propriedades da função produção como arma competitiva.	(SKINNER, 1969)
Conjunto coordenado de metas e planos de ação com foco em garantir, a longo prazo, vantagem competitiva sob seus competidores.	(FINE; HAX, 1985)
A estratégia de produção é o uso efetivo das forças da manufatura como uma arma competitiva para atingir os objetivos do negócio e da organização.	(SWAMIDASS; NEWELL, 1987)
Decisões e ações relacionadas com a gestão de operações, em particular, com o foco em atingir os objetivos a longo prazo das empresas.	(BARNES, 2002)
Diretrizes para as operações com objetivo de alinhar os recursos capazes de implementar a estratégia competitiva de maneira eficiente.	(HAYES *et al.*, 2007)

Em resumo, a partir destes conceitos, esta pesquisa compreende que estratégia de operações se trata de um conjunto de objetivos, programas e ações adotadas e implementadas nas diversas áreas de decisão (FINE; HAX, 1985; HAYES et al., 2007), em consonância com a estratégia competitiva da empresa e demais áreas funcionais, para auferir vantagens competitivas sustentáveis (BARNES, 2002; SKINNER, 1969).

A estratégia de operações tem como objetivo o uso adequado dos meios de produção, visando atingir os objetivos do negócio e da organização (MILLS; PLATTS; GREGORY, 1995). Ou seja, tem como objetivo orientar a organização da função produção na estruturação e alinhamento dos recursos que irão propiciar a implementação eficaz da estratégia competitiva da empresa (HAYES *et al.*, 2007). De uma forma mais detalhada, como mostram Brown, Beassant e Lamming (2013), a estratégia de operações:

- Preocupa-se com o atendimento das necessidades existentes no mercado e a todos os potenciais segmentos de mercado;
- Busca fazer o melhor uso dos recursos e aproveitar esses recursos de forma isolada ou com parceiros do negócio;
- Implementa processos que permitirão à empresa competir e, idealmente, e criar vantagem competitiva;
- E atenta-se ao desenvolvimento de capacidades dentro das operações da empresa de modo superior a outros concorrentes, de maneira que os concorrentes não possam copiar ou consideram extremamente difícil fazer igual.

Neste sentido, é importante destacar, como mostram Slack e Lewis (2011), as quatro perspectivas da estratégia de operações:

1. A estratégia de operações surge de cima para baixo com base no que o grupo de negócios deseja executar *(Top down,)*, como ilustrado por Leong, Snyder e Ward (1990).

2.A estratégia de operações é uma atividade desenvolvida dos níveis mais baixos para os níveis mais altos na estrutura organizacional, em que as melhorias nas operações constroem a estratégia *(Bottom up).*

3.A estratégia de operações está relacionada com a tradução dos requisitos do mercado para ações nas operações.

4.A estratégia de operações envolve a exploração das competências e recursos das operações em mercados escolhidos.

Por fim, para obter bons resultados, a estratégia de operações deve ser alinhada verticalmente (com as estratégias corporativa e competitiva), ou seja, garantir a consistência entre os objetivos estratégicos da empresa e das operações e, alinhada horizontalmente (com as demais estratégias funcionais). Deve garantir ainda coerência entre as prioridades competitivas das operações (ou seja, custo, qualidade, entrega e flexibilidade) e as áreas de decisão, as quais compõem o conteúdo da estratégia de operações (SKINNER, 1974), o que será explicado no tópico a seguir.

2.1.3 O CONTEÚDO DA ESTRATÉGIA DE OPERAÇÕES

O conteúdo da estratégia de operações está relacionado às decisões tomadas pela empresa visando a eficácia da estratégia competitiva do negócio (KIM; ARNOLD, 1996). Trata-se de um conjunto de prioridades competitivas relacionadas às operações e por decisões nas áreas estruturais e infraestruturais da produção (GARRIDO; MARTIN-PEÑA; GARCIA-MUIÑA, 2007; HAYES *et al.*, 2007), o que é representado na Figura 8.

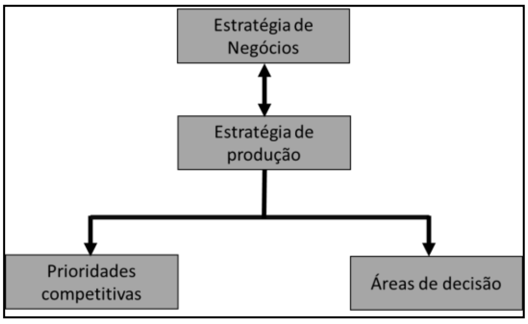

Figura 8- Conteúdo da estratégia de produção.

Fonte: Baseado em Leong, Snyder e Ward (1990)

Além de compreender do que é composta a estratégia de operações, é necessário atentar que este conteúdo tem uma ordem lógica para a tomada de decisões, como observado na Figura 9.

Figura 9 - A estrutura padrão de uma estratégia de produção.

Fonte: Baseado em Wheelwright (1984).

As decisões nas áreas estruturais e infraestruturais da empresa são norteadas por meio de diretrizes vindas das definições das prioridades competitivas, que por sua vez são determinadas a partir da estratégia competitiva da empresa (KIM; ARNOLD, 1996; WHEELWRIGHT, 1984). Neste sentido, o sucesso e o fracasso das empresas podem ser explicados pelas escolhas (áreas de decisão e prioridades competitivas) feitas e o alinhamento (ou o não alinhamento) dessas escolhas com a estratégia competitiva (VOSS, C. A., 2005).

As prioridades competitivas estão relacionadas aos objetivos de desempenho que a função produção adota para alinhar-se à estratégia competitiva da empresa (SKINNER, 1969). Ou seja, conforme a organização traça uma estratégia para atender aos requisitos do mercado, determina-se como as operações precisam ser desempenhadas (SLACK; LEWIS, 2011). As prioridades competitivas de produção também são chamadas de objetivos de desempenho, dimensões competitivas e missões da produção, e devem fazer parte bem como serão o norte dos programas a serem implantados pela função produção de uma empresa, ou seja, definem a forma como a empresa pretende competir no mercado para atender as necessidades de seus clientes (ALVES FILHO.; PIRES; VANALLE, 1995).

Em resumo, as prioridades competitivas representam como a empresa irá atender às necessidades dos clientes em relação às metas de desempenho para a função produção (JABBOUR; ALVES FILHO, 2009). No levantamento realizado por Jabbour e Alves Filho (2009), assim como já apontado no trabalho de Ward et al. (1998), foram identificadas as principais tendências em estratégia de operações, sendo as prioridades custo, qualidade, flexibilidade e entrega mencionadas em todos os estudos analisados. Neste trabalho serão adotadas as prioridades competitivas propostas por Garvin (1993), que representam as mais recorrentes nos estudos. Segundo Garvin (1993), as prioridades são custo, qualidade, entrega, serviço e flexibilidade.

No Quadro 2 podem ser visualizadas as prioridades competitivas consideradas nos estudos sobre o tema, seus respectivos objetivos, de acordo com os autores, os quais foram selecionados por serem considerados estudos clássicos sobre o tema.

Quadro 2 -Prioridades Competitivas

Prioridades Competitivas	**Objetivo**	**Autor**
Custo	Reduzir custo de produção e preço para os clientes	Slack e Lewis (2011), Garvin (1993)
	Produzir e distribuir produtos a baixo preço;	Leong, Snyder e Ward (1990)
	Custo de aquisição de um produto	Garvin (1993)
	Custo de produção e Produtividade do capital	Fine e Hax (1985)
Qualidade	Produzir produtos conforme as especificações	Slack e Lewis (2011)
	Estética	Garvin (1993)
	Qualidade percebida	Garvin (1993)
	Produção de produtos com alta qualidade e padrão de desempenho	Leong, Snyder e Ward (1990)
Flexibilidade	Capacidade de reagir às alterações no volume e mix de produtos e na programação da produção.	Slack e Lewis (2011), Garvin (1993).
	Variação no mix e volume de produtos produzidos	Leong, Snyder e Ward (1990); Garvin (1993)
Entrega	Reduzir o lead-time entre o começo e o final das operações	Slack e Lewis (2011)
	Ter o produto disponível e entregar mais rápido	Leong, Snyder e Ward (1990)
	Cumprir o prazo acordado de entrega do produto	Slack e Lewis (2011)
Serviço	Suporte no atendimento ao cliente	Leong, Snyder e Ward (1990); Garvin (1993).
	Fornecimento de informações ao cliente	Garvin (1993).

Além dessas cinco apresentadas e consideradas tradicionais, as prioridades “Inovação” e “Ambiente” têm sido apresentadas como prioridades competitivas das operações (MORAES, 2019).

A “Inovação” se refere à prioridade quem tem como foco inovar em técnicas de gestão e produção, assim como oferecer produtos de alto valor para o cliente. Três variáveis a ela relacionadas são: frequência da inovação em design; frequência da implementação de técnicas de produção inovadoras e adoção de métodos inovadores (THEODOROU; FLOROU, 2008). Assim, Lin e Tseng (2016) afirmam que a inovação deve ser incorporada à estratégia de operações e merecer a mesma atenção que as prioridades competitivas mais citadas na literatura.

Já a variável "Ambiente", citada também como desempenho ambiental ou variável ambiental na literatura, vem sendo incluída como prioridade competitiva da estratégia de operações (ANGELL; KLASSEN, 1999; DE BURGOS JIMÉNEZ; CÉSPEDES, 2001; DE MORAES, 2019; GAVRONSKI, 2012; MARCUS; FREMETH, 2009) (ANGELL; KLASSEN, 1999; ALFRED; ADAM, 2009; JIMENEZ; LORENTE, 2001; GRAVONSKI 2012). Pois, os impactos ambientais são em grande parte de responsabilidade das operações (DE BURGOS JIMÉNEZ; CÉSPEDES, 2001). Assim, priorizar o "ambiente" significa buscar reduzir os impactos ambientais.

É importante destacar que incluir a prioridade ambiente pode tornar a gestão de operações ainda mais complexa, uma vez que isso impacta de forma multidimensional o desempenho da empresa (AZZONE; NOCI, 1998). Assim, quando o ambiente é considerado uma prioridade competitiva, é essencial considerar as questões ambientais na estratégia de operações e, deste modo, fazem-se necessárias modificações ou um redesenho da estratégia de operações (JOHANSSON; WINROTH, 2010).

Ainda, com relação às prioridades competitivas, Skinner (1969) destaca a questão dos *trade-offs*. Para este autor a organização deve priorizar somente uma ou outra prioridade competitiva, buscando ser melhor que os concorrentes. A focalização é necessária, e Skinner (1969) exemplifica que não é possível obter baixo custo e alta qualidade ao mesmo tempo. Para isto, Skinner (1969) explica que as organizações devem tomar algumas decisões, como, por exemplo, quanto ao tamanho da unidade fabril, estoques – altos ou baixos, tipos de equipamentos, nível de padronização etc. Em resumo, Skinner (1974) trouxe o conceito de fábrica focada que diz respeito à impossibilidade de fábrica funcionar bem em todos os critérios.

Wheelwright (1984) também apresenta uma matriz produto *versus* processo para a tomada de decisões em termos da estrutura do processo, uma vez que para uma produção por lotes o processo deveria ser projetado para uma baixa padronização e no caso de uma produção em fluxo contínuo o processo deve ser altamente padronizado.

No entanto, estudos posteriores Sarmiento, Thurer e Whelan (2016) e Skinner (1996), consideram que é possível focar em mais de uma prioridade. Contudo, escolhas necessitam ser feitas e os *trade-offs* são inevitáveis, uma vez que um sistema de produção não pode ser excelente o suficiente para atender todos os critérios para criar vantagem competitiva.

No contexto em que há aumento de competitividade e torna-se necessário anteder mais de uma necessidade dos clientes, questiona-se o modelo de *trade-off* proposto por Skinner (1969). Este questionamento culminou na proposta de um modelo de capacidades cumulativas que implica em alto desempenho de forma simultânea em mais de uma prioridade competitiva (FLYNN; FLYNN, 2004; HAYES *et al.*, 2007).

Boyer e Lewis (2002) apontam que organizações japonesas desenvolviam capacidades produtivas com base em uma ordem previamente estabelecida, e as práticas adotadas permitiram redução de custo e produtos de qualidade ao mesmo tempo. Neste sentido, o modelo do "cone de areia", na Figura 10, foi proposto por Ferdows e De Meyer (1990).

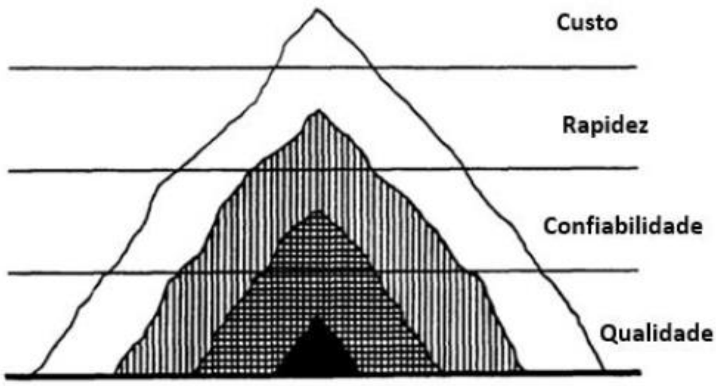

Figura 10 - Modelo do Cone de Areia
Fonte: Traduzido de Ferdows e De Meyer (1990, p.175)

O modelo estabelece que a organização pode alcançar todas as prioridades competitivas ao longo do tempo e que existe uma sequência mais adequada para a sua construção, sendo a qualidade considerada a base para a implantação de outras melhorias. Neste modo, Ferdows e De Meyer (1990) destacam que o importante é focar em evitar falhas no sistema e que, deste modo, os custos poderiam ser reduzidos por meio das outras capacidades, como uma melhor qualidade nos processos. Os autores também pontuam que melhorias obtidas por meio de boas práticas da produção são mais duradouras e estáveis.

Contudo, Flynn e Flynn (2004) não notaram evidências para a sequência das prioridades apresentadas no modelo do cone de areia. Os autores alegam que o desenvolvimento de capacidades cumulativas é complexo e não limitado a uma sequência específica, uma vez que sofre influência de diversos fatores.

Quando se trata da inclusão do “Ambiente” como uma nova prioridade competitiva, a literatura enfatiza que possíveis *trade-offs* podem surgir entre a prioridade “ambiente” e as outras prioridades (LONGONI; CAGLIANO, 2015b). No entanto, de acordo com Porter e Linde (1995), é possível atender os objetivos econômicos e ambientais dos produtos e processos visto que a preservação de recursos gera uma maior eficiência dos processos.

Ainda no que tange às prioridades competitivas, como afirma Skinner (1969), elas são atingidas por meio de um padrão de decisões em um conjunto de áreas: as estruturais e as infraestruturais. Programas e planos de ação são formulados e implementados para que as organizações atinjam os níveis definidos das prioridades competitivas a partir das mudanças nas áreas de decisão (CALIFE; NOGUEIRA; ALVES FILHO, 2010).

As áreas estruturais e infraestruturais podem ser consideradas como dois pilares da estratégia de operações e seus impactos são diferenciados. As estruturais se relacionam com o conjunto de processos e tecnologias, relacionadas ao que trará impacto no longo prazo, pois as decisões nestas áreas são de difícil de reversão e necessitam de um considerável investimento de capital (HAYES *et al.*, 2007; WHEELWRIGHT, 1984). Enquanto que as infraestruturais estão relacionadas às questões táticas, como os fatores operacionais e de gestão da produção, como, por exemplo, as políticas de recursos humanos, sistemas de gestão da qualidade, programas de melhoria, cultura organizacional e tecnologia da informação (HILL, 1994). Apesar das mudanças nas áreas infraestruturais não demandarem, relativamente, grandes investimentos de capital, não é recomendado mudar a direção das mudanças nessas áreas, pois pode-se ter um alto custo devido ao impacto cumulativo das ações tomadas e para a sustentabilidade das melhorias implantadas (WHEELWRIGHT, 1984).

Em resumo, as decisões estruturais influenciam atividades de projeto, já as infraestruturais estão relacionadas à força de trabalho, atividades de planejamento, controle e melhoria. A produção precisa ter uma infraestrutura adequada que oriente a forma de produzir diariamente para garantir o funcionamento das melhorias bem como da utilização dos recursos tangíveis, como as tecnologias de alto custo, equipamentos e instalações (SLACK; LEWIS, 2011). No Quadro 3 a seguir pode ser visualizado um resumo das áreas de decisão abordadas e seus respectivos conteúdos.

Quadro 3 - Conteúdo das áreas de decisão.

Área de decisão	Conteúdo	Autor
Instalação	Localização, Layout.	(HAYES *et al.*, 2007; MILTENBURG, 2005; SLACK; LEWIS, 2011)
	Tamanho e localização.	(SKINNER, 1969)
	Localização, grupo de produtos, tipo de processo e volume de produção.	(FINE; HAX, 1985)
Capacidade	Quantidade a ser produzida, forma de produção.	(HAYES *et al.*, 2007)
	Capacidade operacional, nº de unidades, variedade de produtos.	(SLACK; LEWIS, 2011)
Tecnologia	Equipamentos, sistemas e tipo de processo.	(HAYES *et al.*, 2007; SKINNER, 1969)
	Tipo de Processo.	(FINE; HAX, 1985)
	Tipo de processo, Tecnologias utilizadas nos processos, equipamentos, máquinas e sistemas.	(SLACK; LEWIS, 2011)
Cadeia de Suprimentos	Decisão de fazer ou comprar; relacionamento com os fornecedores.	(HAYES *et al.*, 2007)
	Grau de integração vertical	(SKINNER, 1969)
	Grau de confiabilidade com o fornecedor	(FINE; HAX, 1985)
	Estratégia de compra, relacionamento com o fornecedor, riscos da cadeia de suprimentos.	(SLACK; LEWIS, 2011)
Recursos Humanos	Definir as habilidades necessárias para os recursos humanos,	(HAYES *et al.*, 2007)
	Sistema de remuneração, incentivos e grau de especialização necessário para os recursos humanos.	(SKINNER, 1969)
	Gestão dos recursos humanos envolvendo políticas de incentivo, sistema de remuneração e projeto do trabalho.	(FINE; HAX, 1985)
Gestão da Qualidade	Política da qualidade e sistema de gestão da qualidade	(HAYES *et al.*, 2007)
	Gestão da qualidade e sistemas de medição de desempenho	(FINE; HAX, 1985)
Planejamento e Controle	Previsão e programação dos recursos da produção	(HAYES *et al.*, 2007)
	Planejamento, estoque e controle da qualidade.	(SKINNER, 1969)
Desenvolvimento de Produto	Decidir o que será comprado externamente e buscar inovação.	(HAYES *et al.*, 2007)
	Projeto do produto.	(FINE; HAX, 1985)
	Uso da engenharia de manufatura, risco tecnológico e estabilidade do projeto.	(SKINNER, 1969)
Sistema de Medição de Desempenho	Sistema dos indicadores de desempenho.	(HAYES *et al.*, 2007)
Organização	Estilo de gestão, estrutura da organização e tamanho do grupo de funcionários.	(SKINNER, 1969)
	Práticas de melhoria, sistemas de medição de desempenho e projeto de produto.	(SLACK; LEWIS, 2011)
	Estrutura organizacional e cultura.	(MILTENBURG, 2005)

Para este estudo, foram consideradas e analisadas, tanto na revisão sistemática da literatura quanto nos estudos de casos, as áreas de decisão apresentadas e seus respectivos conteúdos.

Por fim, é importante considerar os três paradigmas apresentados por Voss (2005, 1995) que podem determinar estas escolhas e o conteúdo da estratégia de operações. O primeiro deles pode ser caracterizado pela empresa competir por meio de suas capacidades, o que significa que o conteúdo da estratégia de operações é moldado pelo alinhamento das capacidades da manufatura com os requisitos de competitividade do mercado. Já no segundo paradigma, o conteúdo da estratégia de operações é formulado com base na estratégia competitiva, nas prioridades competitivas de produção estabelecidas e em escolhas e mudanças implementadas nas áreas de decisão a partir de uma abordagem contingencial em que fatores condicionantes (de contexto) são considerados. Por fim, o terceiro paradigma é sobre a adoção das melhores práticas (por exemplo, *Lean Manufacturing*, seis sigma) para alcançar vantagem competitiva, ainda neste paradigma entende-se que as empresas buscam as melhores práticas que supostamente funcionam em outras organizações como a base suas estratégias de operações. Assim as diretrizes propostas nestas melhores práticas é que direcionam o conteúdo da estratégia de operações. Por exemplo, o *Lean* é orientado para baixos estoques e busca constante pela qualidade, custo e velocidade de entrega.

Voss (1995) recomenda que os três paradigmas não devem ser tratados de forma isolada. Nesta pesquisa foram abordados aspectos referentes ao segundo paradigma, referente às escolhas e à estrutura das áreas de decisão, práticas Lean-Green adotadas, assim como as prioridades competitivas consideradas. No entanto, apesar da pesquisa não focar no entendimento das questões relacionadas a abordagem *Lean* como "best practice" para a definição da estratégia, a literatura sobre *Lean-Green* considera ser uma abordagem que pode auxiliar as organizações na busca de resultados orientados pela prioridade "Ambiente" e alinhados também às demais prioridades competitivas. Deste modo, nos tópicos a seguir serão conceituados brevemente *Lean Manufacturing, Green Manufacturing* e *Lean-Green.*

2.2 *LEAN MANUFACTURING*

2.2.1 CONCEITOS E PRINCÍPIOS DO LEAN MANUFACTURING

O *Lean Manufacturing,* em português conhecido como "Produção Enxuta", originou-se do Sistema Toyota de Produção (STP) no final da década de 1940, na Toyota no Japão. A implantação de um novo sistema de produção pela Toyota ocorreu em uma época em que os recursos eram escassos e a demanda por automóveis no Japão era pequena. Deste modo, o objetivo era melhorar os processos produtivos diante das dificuldades socioeconômicas em que o país se encontrava no pós-guerra (WOMACK, J; JONES; ROOS, 1991).

A Toyota adaptou a produção em larga escala e a produção em linha utilizados pela produção em massa de Henry Ford, que alcançavam altos níveis de eficiência, para uma produção em menor escala, de uma maneira mais adequada e interessante para a situação vivenciada pela Toyota na época. Neste sentido, as empresas tiveram a necessidade de buscar estratégias de produção com pequenos lotes, devido à escassez de recursos, fazendo com que se buscasse a eliminação contínua dos desperdícios e os processos produtivos seguissem fluxos contínuos, minimizando falhas, reduzindo setups, *lead times* e melhorando a produtividade. Do mesmo modo, devido às demandas variadas da época, outra característica essencial dos sistemas produtivos enxutos era a flexibilidade, para produzir uma variedade maior de produtos em pequenas quantidades (GODINHO FILHO; FERNANDES, 2004; HOLWEG, 2007; KRAFCIK, 1988) .

Os resultados muito superiores em qualidade dos produtos e em eficiência dos processos em relação às outras indústrias automotivas passaram a despertar interesse de outras organizações somente na década de 1980 (LIKER, 2005; WOMACK, J; JONES; ROOS, 1991) (LIKER, 2005). Há uma tendência das empresas multinacionais de diversos setores buscarem cada vez mais a implantação do *Lean* para promover o crescimento da organização como um todo (BOSCARI; DANESE; ROMANO, 2016; NETLAND, 2013).

Os bons resultados promovidos pela implantação do Lean têm sido reportados por vários pesquisadores em vários setores da indústria, como, por exemplo, no setor automotivo (WOLFF *et al.*, 2020) eletroeletrônico (DOOLEN; HACKER, 2005) aeroespacial, têxtil (HODGE et al., 2011), metalúrgico (SINGH, R. K. *et al.*, 2006)(SINGH et al., 2006), construção civil (PANDITHAWATTA; ZAINUDEEN; PERERA, 2020), e até mesmo de panificação (DEL ROCIO QUESADA CASTRO; POSADA, 2019). Isto mostra que esta abordagem pode ser implementada nos mais variados setores da indústria (SHAH; WARD, 2003).

Esta abordagem alterou significativamente o que era considerado *trade-off* entre a produtividade e a qualidade, resultando em uma nova maneira de pensar as operações, ou seja, tornou-se uma maneira mais viável de se organizar a produção para se obter, simultaneamente, altos níveis de produtividade, qualidade e complexidade dos produtos (HOLWEG, 2007; KRAFCIK, 1988).

O *Lean Manufacturing* é considerada uma abordagem que vai além de uma estratégia de gestão da produção; trata-se de um modo de pensar a gestão das organizações que busca a redução dos desperdícios na cadeia produtiva (WOMACK; JONES, 2004). Os autores clássicos Ohno (1997), Shingo (1996) e Womack e Jones (2004) resumem que o objetivo principal do *Lean* é o aumento da produtividade e a melhoria da qualidade por meio da eliminação sistemática e sustentável de desperdícios na cadeia produtiva, os quais são definidos como as atividades que não agregam valor ao produto. Os desperdícios são classificados em 7 categorias apresentados no quadro 4 de acordo com os estudos de Hines e Taylor (2000), Liker (2005) e Womack e Jones (2004).

Quadro 4 – Desperdícios do Lean Manufacturing

Desperdícios do *Lean Manufacturing*	
Superprodução	Produzir além da demanda ou muito cedo, resultando em excesso de estoque. Este desperdício pode ocasionar consumo desnecessário de matérias primas, ocupação do espaço físico para o armazenamento de produtos acabados e pode necessitar de mais mão-obra para controlá-los.
Defeitos	Representa os erros frequentes no processamento de materiais ou informações. Isto pode gerar produtos rejeitados no final da linha de produção, retrabalho para recuperação dos produtos defeituosos, custos elevados e insatisfação dos clientes
Transporte Excessivo	Movimento excessivo de bens ou informações, resultando em aumento no tempo, esforço e custo. Os materiais deverão fluir de uma etapa do processo para a seguinte o mais rápido possível, sem interrupções e sem armazenamento intermediário
Excesso de Estoque	É qualquer material ou produto em quantidade superior ao imediatamente necessário para o processo ou para o cliente, resultando em: custo excessivo, utilização excessiva de mão de obra e equipamentos para movimentação e controle, necessidade de mais espaço físico e podendo gerar problemas de qualidade por deterioração dos produtos armazenados em excesso.
Processamento Inadequado	Está relacionado com a execução do processo utilizando procedimentos, ferramentas ou sistemas não adequados ou desnecessários em detrimento a abordagens mais simples e eficientes. Além disso, pode estar relacionado com projeto de baixa qualidade do produto ocasionando defeitos e processamento desnecessário.
Espera	Longos períodos de inatividade de pessoas, informações ou bens, resultando em fluxos pobres e longos *lead-times*.
Movimentação desnecessária	Diz respeito ao movimento desnecessário de materiais ou pessoas por longas distâncias e transportes ineficientes devido à organização inadequada do posto de trabalho e/ou de toda a fábrica.

Além destes, o oitavo desperdício foi destaco por Liker (2005, p. 48): a não utilização da criatividade dos colaboradores, se referindo a "a perda de tempo, ideias, habilidades, melhorias e oportunidades de aprendizagem por não envolver ou ouvir os seus funcionários". Para que esta filosofia de gestão da produção seja implantada de maneira efetiva, é necessário considerar seus princípios básicos.

Liker (2005) apresenta o "Modelo Toyota" baseado em 20 anos de estudo sobre a empresa em que o autor descreve 14 princípios de gestão como a base do Sistema Toyota de Produção (STP). Tais princípios esboçam as características da Toyota e o diferencial na maneira de atuação da empresa em todo o mundo, os quais são apresentados na Figura 11.

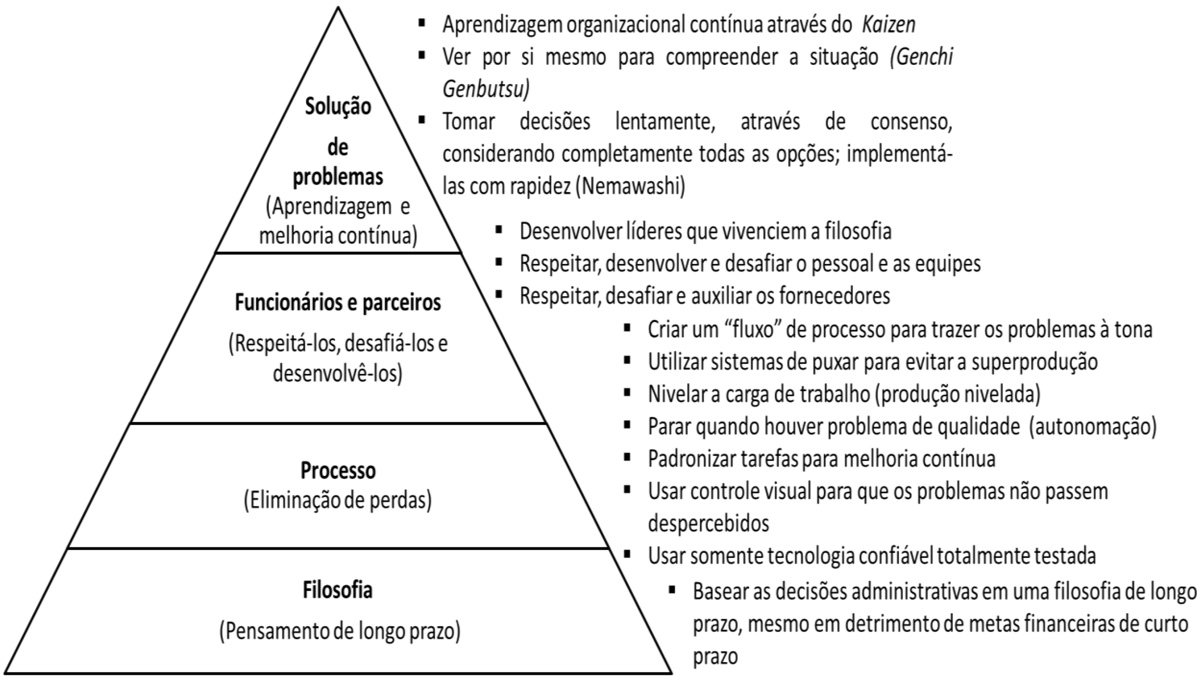

Figura 11 - 4Ps do Modelo Toyota

Fonte: Liker (2005).

O autor divide estes princípios em quatro categorias, chamadas por Liker (2005) dos 4 P's em razão da letra inicial dos nomes dados a essas categorias na versão original, em inglês: Filosofia (*Philosophy*), Processo (*Process*), Pessoal e Parceiros (*People and Partners*) e Solução de Problemas (*Problem Solving*). Este mesmo autor destaca que para que as empresas implantem o pensamento enxuto é essencial compreender e adotar os "4Ps", pois assim as melhorias serão implantadas em toda a organização e de maneira sustentável. Pois, esta filosofia baseada no modelo Toyota está relacionada a uma transformação cultural profunda e que é essencial o comprometimento administrativo com o investimento nos seus colaboradores e no cumprimento de uma cultura de melhoria contínua.

Womack e Jones (2004) expõe outros cinco princípios, apresentados na figura a seguir, do "Pensamento Enxuto" (*Lean Thinking).*

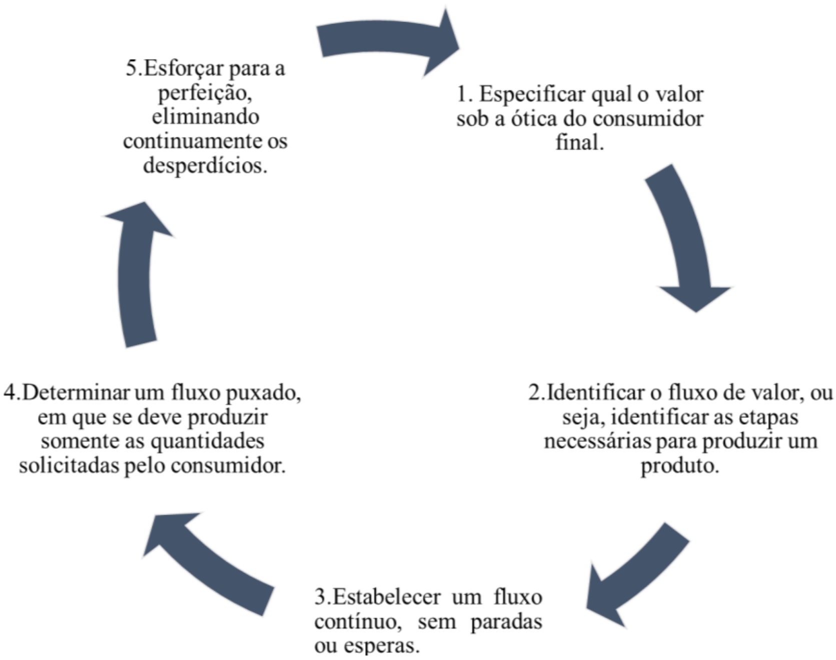

Figura 12 - Princípios do Pensamento Lean.

Fonte: Womack e Jones (2004).

Além destes princípios é importante entender o conceito de valor dentro dos sistemas produtivos, diante disso Hines e Taylor (2000) e Womack e Jones (2004) classificam os tipos de atividades que compõem os processos produtivos:

• Atividades que agregam valor (AV): são aquelas atividades que, aos olhos do cliente final, tornam o produto ou serviço mais valioso, ou seja, são atividades que o consumidor ficaria feliz em pagar;

• Atividades que não agregam valor (NAV): são aquelas atividades que, sob a ótica do consumidor final não agregam valor ao produto ou serviço, sendo desnecessárias, as quais são os desperdícios visíveis que devem ser eliminados imediatamente;

• Atividades necessárias, mas que não agregam valor: atividades que, aos olhos do cliente final, não aumentam o valor do produto ou serviço final, contudo são necessárias para a execução das atividades que realmente agregam valor ao produto.

Geralmente as empresas que não adotam o pensamento enxuto focam em melhorias nas atividades que agregam valor (AV), enquanto as atividades que não agregam valor (NAV) são inalteradas (HINES; TAYLOR, 2000) . O objetivo primário para a transformação *Lean* é fornecer o "valor", e que a transformação *Lean* não ocorrerá sem um forte comprometimento dos gestores, visto que para tornar-se enxuto é necessário alterar o pensamento tradicional destes líderes (HENDERSON; LARCO, 1999).

Shah e Ward (2003) após extensa revisão sobre o tema, definem o *Lean* como um sistema sociotécnico integrado que busca eliminar os desperdícios por redução ou minimização simultânea de variabilidade do fornecedor, interna ou do cliente. Complementarmente, Mostafa, Dumrak e Soltan (2013) afirmam que se trata de um conjunto de princípios para eliminar todas as formas de desperdício dentro de uma organização.

Ainda, *o Lean Manufacturing* pode ser considerado um modelo estratégico e integrado de gestão que busca auxiliar as organizações a alcançar determinados objetivos de desempenho, como qualidade e produtividade. Este modelo é composto por fundamentos, ideias, regras, ferramentas, práticas, tecnologias e metodologias, as quais no próximo tópico serão descritas e agrupadas como práticas *Lean* (GODINHO FILHO; FERNANDES, 2004)

Um esquema conhecido como a “Casa do STP”, apresentado na Figura 13, resume o STP de maneira clara e fácil de entender, e foi elaborado para que funcionários da Toyota e seus fornecedores pudessem compreender como as práticas funcionavam. A casa é utilizada como representação de um sistema estrutural e estável. Assim, é importante que todos os elementos que compõem a casa estejam bem conectados, visto que todo o sistema pode ficar fragilizado se as partes tiverem conexões fracas.

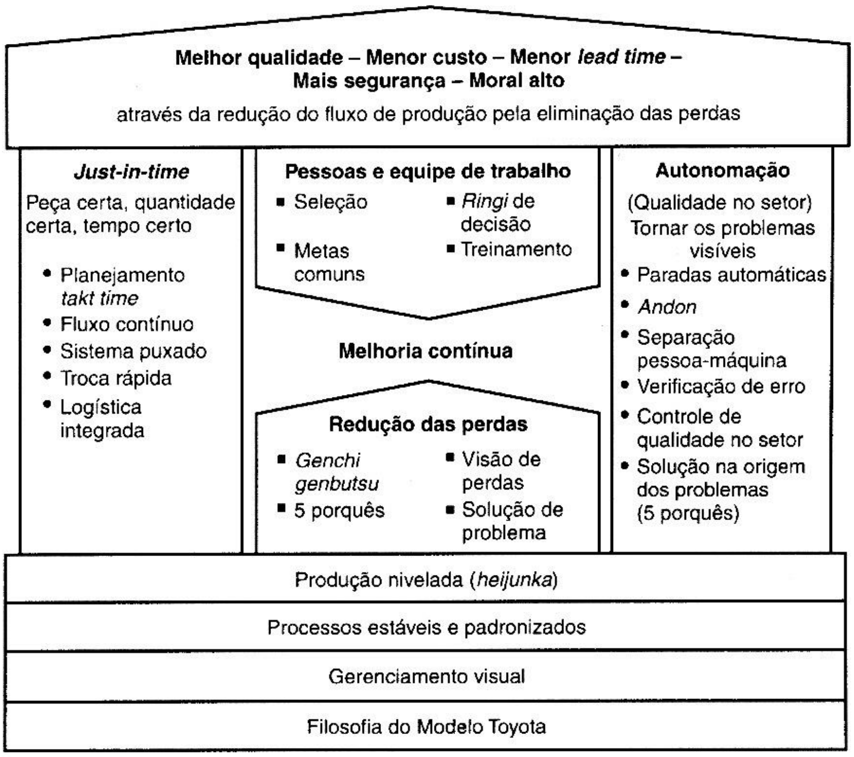

Figura 13 - Casa do Sistema Toyota de Produção

Fonte: Liker (2005).

Liker (2005) usou a representação de uma casa para evidenciar que cada elemento por si só é crítico, mas o essencial para a produção enxuta é o modo como os elementos reforçam uns aos outros. Neste sentido, o próximo tópico irá apresentar uma visão geral das práticas comumente encontradas nos ambientes *Lean.*

2.2.2 PRÁTICAS E IMPLANTAÇÃO LEAN

O objetivo deste tópico é apresentar uma visão geral das principais Práticas Lean com base nos trabalhos de revisão bibliográfica de Godinho Filho e Fernandes (2004) e Shah e Ward (2003), as quais estão sumarizadas no Quadro 5 a seguir, e apresentar os principais aspectos relacionados a implantação do Lean nas organizações.

Quadro 5 - Práticas Lean

Práticas Lean	Objetivo da Prática
Mapa de Fluxo de Valor (Value Stream Mapping)	Tem o objetivo de representar todo o fluxo de valor, entendendo o fluxo de materiais, pessoas e informações e apresenta as etapas necessárias para a produção de um produto, que vai desde o consumidor até o fornecedor. Por meio do mapa, busca-se identificar os desperdícios e representar os dados dos processos relacionados à eficiência, tempo de operação, tempo de agregação de valor, lead time, tamanho dos estoques e tempo para setup (MOSTAFA; DUMRAK; SOLTAN, 2013; ROTHER; SHOOK, 1999). se trata de uma ferramenta recomendada para orientar o processo de implantação do Lean (ZAHRAEE et al., 2014).
Programa 5s	Prática primordial para a implantação do Lean (GURUMURTHY; KODALI, 2009) pois se trata tarefas simples para organizar o ambiente de trabalho, as quais colaboram para melhorar a gestão visual e muitas vezes são a base para a implantação de outras práticas Lean. As quais são representadas por palavras em japonês iniciadas pela letra "S", as quais no português são traduzidas e acrescentadas pela palavra senso de utilização, organização, limpeza e disciplina (FELD, 2000; HENDERSON; LARCO, 1999).
Kaizen	Significa Kai (mudança) e Zen (Melhor), ou seja "mudança boa", busca a melhoria de um único processo ou de todo fluxo de valor visando agregar valor e eliminar os desperdícios (LEAN ENTERPRISE INSTITUTE, 2003). O Kaizen envolve mudar o modo como as coisas são, se trata de uma prática que busca solucionar problemas e promover a melhoria contínua de um único processo ou de todo fluxo de valor visando agregar valor e eliminar os desperdícios (OHNO, 1997).
Gestão Visual	Se trata da exposição de ferramentas, atividades, fluxo de trabalho, peças ou indicadores de desempenho que auxiliem no rápido entendimento da situação por todos os envolvidos para que haja integração entre todos os níveis da organização (ESPOSTO, 2008; HENDERSON; LARCO, 1999;LEAN ENTERPRISE INSTITUTE; 2003).
Trabalho Padrão	Busca padronizar e documentar os parâmetros ótimos dos processos. Ou seja, é a definição de padrão, procedimentos específicos e precisos de trabalho para cada atividade do operador em um processo de produção A padronização das atividades com relação ao conteúdo, tempo, sequência e resultado é fundamental para um fluxo enxuto e para garantir a estabilidade dos processos (SPEAR; BOWEN, 1999; LEAN ENTERPRISE INSTITUTE, 2003).
Just in Time (JIT)	Significa "no momento certo", tem como objetivo controlar a produção para que tudo seja produzido e entregue somente na quantidade requisitada e quando requisitado por meio por meio da redução de estoques que, tendem a esconder os problemas e são utilizados para evitar descontinuidades do processo produtivo quando há problemas de produção, como paradas para manutenção corretiva ou retrabalho (CORRÊA; GIANESI, 1993; SHINGO, 1996).
Kanban	Significa "sinal" ou "cartão", se trata de um sistema de informação visual que, baseado no sistema puxado, sinaliza o controle dos fluxos de produção ou transporte em uma empresa (FELD, 2000). Ou seja, funciona como um sinal de demanda do cliente, sinalizando para o início da produção ou a retirada de itens em um sistema de trabalho. Esta ferramenta pode controlar o nível de trabalho em processo e o prazo de entrega para os produtos, além disso, pode facilitar um feedback imediato sobre anormalidades (FELD, 2000; LIKER, 2005; OHNO, 1997).
Poka Yoke (Dispositivo à prova de erros)	São métodos para evitar erros e defeitos durante a execução da tarefa, em processos de fabricação e/ou na utilização de produtos, tais como montagem incorreta de uma peça, esquecimento de um componente ou até mesmo em um projeto de produto com formas físicas que tornam impossível a montagem incorreta e pode possibilitar cem por cento de inspeção por meio de controle manual ou mecânico nos processos de manufatura (FELD,2000).

Continua

Práticas Lean	**Objetivo da Prática**
Autonomação (Jidoka)	Objetiva dar ao operador ou à máquina a autonomia de interromper o processo sempre que for detectada qualquer anormalidade. A palavra "Jidoka" significa autonomação, mas "Ninben no tsuita jidoka" ou "Ninben no aru Jidoka" expressam o verdadeiro significado desta prática que a essência de que a máquina é dotada de inteligência e toque humano (GHINATO, 1995). é considerada como um dos pilares da Produção Enxuta uma vez que esta prática busca fornecer aos equipamentos a habilidade de diferenciar as peças boas das ruins automaticamente, eliminando a necessidade do monitoramento contínuo dos operadores, colaborando parar o aumento dos indicadores de produtividade e qualidade (OHNO, 1997).
TPM – Manutenção Produtiva Total	Conjunto de técnicas para garantir a confiabilidade e a produtividade de todas as máquinas do processo de produção. É uma prática essencial para a implantação de um sistema Lean. O termo "total" se deve-se a três fatores, primeiro porque é uma prática que que necessita da participação de todos os funcionários, segundo pois busca a produtividade total do equipamento, focando na eliminação das perdas sofridas pela máquina, como quebra, tempo de troca, pequenas paradas, refugo e retrabalho, e terceiro por atentar à todo o ciclo de vida do equipamento, ou seja, realizar medidas conforme o estado que o equipamento encontra em seu ciclo de vida (FELD, 2000; NAKAJIMA, 1988).
Single-minute Exchange of Dies – SMED	Prática conhecida como Troca Rápida de Ferramentas e que tem como princípio realizar setup em menor tempo possível, possibilitando aumento de flexibilidade e/ou disponibilidade da máquina no fluxo de produção, o objetivo é tornar possível a realização de mais setups num mesmo intervalo de tempo. O SMED busca reduzir os tempos de troca a um único dígito, ou seja, menos de dez minutos (FELD, 2000;LEAN ENTERPRISE INSTITUTE, 2003).
Manufatura Celular	Tem como objetivo alocar os equipamentos e estações de trabalho por produtos similares em uma sequência que permite o fluxo contínuo de materiais e componentes pelo processo, com mínimo transporte ou demora (ROTHER; HARRIS, 2001). O layout fica em formato de "U" para reduzir a distância percorrida do operador e possibilitar combinações de diferentes de tarefas, além disso, permite a realização da primeira e da última operação do processo pelo mesmo operador, colaborando para manutenção do ritmo e do fluxo de trabalho (LEAN ENTERPRISE INSTITUTE, 2003).
Produção Nivelada (Heijunka)	A Produção Nivelada, conhecida no japonês como Heijunka, tem o objetivo de distribuir o volume de produção de maneira uniforme no horizonte de tempo. Ou seja, ao invés de fabricar todos os produtos do tipo A no período da manhã e todos os produtos tipos B no período da tarde, a Produção Nivelada alterna pequenos lotes de A e B em cada período. Deste modo, esta prática colabora para a redução do lead time e a necessidade de menores quantidades de estoques e também auxilia para determinar de maneira mais precisa a quantidade necessária de equipamentos, materiais e pessoas (DENNIS, 2007).
Método dos 5 Porquês	Objetivo desta prática é questionar "Por que?" sempre que se encontrar um problema, a fim de se descobrir sua causa-raiz (LIKER, 2005). Ohno (1997) propõe que ao enfrentar um problema é preciso questionar "Por que?" cinco vezes. Esta prática integra o Kaizen, com a análise dos cinco porquês para um determinado problema, objetivando chegar à causa raiz dele (LIKER, 2005)
Relatório A3	É uma ferramenta de suporte que busca consolidar todas as informações sobre um projeto de melhoria, contendo desde o problema, situação atual, situação futura, plano de ação e ações corretivas em uma folha do tamanho A3 possibilitando uma visualização completa (LIKER, 2005). O propósito deste relatório é obter uma visão holística do problema e as etapas para sua solução, contendo todas as informações pertinentes e permitindo uma comunicação com todos os envolvidos (ESPOSTO, 2008).
Autonomação (Jidoka)	Objetiva dar ao operador ou à máquina a autonomia de interromper o processo sempre que for detectada qualquer anormalidade. A palavra "Jidoka" significa autonomação, mas "Ninben no tsuita jidoka" ou "Ninben no aru Jidoka" expressam o verdadeiro significado desta prática que a essência de que a máquina é dotada de inteligência e toque humano (GHINATO, 1995). é considerada como um dos pilares da Produção Enxuta uma vez que esta prática busca fornecer aos equipamentos a habilidade de diferenciar as peças boas das ruins automaticamente, eliminando a necessidade do monitoramento contínuo dos operadores, colaborando parar o aumento dos indicadores de produtividade e qualidade (OHNO, 1997).

Além de compreender o significado e o objetivo de cada prática é importante destacar como são implantadas. Não existem normas internacionais de certificação para gestão dos sistemas produtivos que determine uma sequência padrão quando se implementa o *Lean.* No entanto, na literatura de gestão de operações são discutidas as práticas essenciais dos sistemas *Lean* e é possível encontrar propostas de frameworks para implantação (DJASSEMI, 2014; KARIM; ARIF-UZ-ZAMAN, 2013; MOSTAFA; DUMRAK; SOLTAN, 2013; SRINIVASARAGHAVAN; ALLADA, 2006), os quais apresentam uma sequência em que tais práticas deveriam ser implantadas.

O MFV é uma das práticas mais frequentes quando se fala de implantação do Lean, uma vez que o MFV é considerado essencial para a implantação de sistemas Lean, a literatura aponta que assim como proposto por Rother e Shook (1999), esta ferramenta guia o processo de implantação das outras práticas uma vez que a elaboração do MFV representa os processos, problemas e desperdícios das empresas e a elaboração do MFV futuro com a situação ideal que a empresa deseja alcançar por meio da implantação de algumas práticas como 5s, *poka yoke*, redução de estoque, alteração no *layout*, entre outras (DAS; VENKATADRI; PANDEY, 2014; VINODH; ARVIND; SOMANAATHAN, 2010, 2011; ZAHRAEE *et al.*, 2014).

Karim e Zamam (2013) e Mostafa, Dumrak e Soltan (2013) propõem que o processo de implantação do Lean seja executada em um ciclo de melhoria contínua de avaliar, planejar, identificar, modelar, melhorar e continuar e estruturam no ciclo DMAIC (*Define, Measure, Analize, Improve and Control).* Já outros estudos apresentam uma sequência específica para implantação das práticas. Hodge et al. (2011), por exemplo, apresentam uma estrutura que estabelece prioridades iniciando por uma pirâmide a mudança cultural, seguida por gestão visual, programa 5s, melhoria contínua, trabalho padronizado e finalizando com práticas redução de setup e *Just-in-Time*. Narang (2004) mostra que uma prática pode ser pré-requisito para implantação de outra, como por exemplo a necessidade de se implantar a redução do setup por meio do SMED previamente ao Heijunka (nivelamento da produção). Na pesquisa de Simmons et al. (2010) é relatado que a primeira e mais importante etapa da implantação do Lean é o programa 5s, seguido pelo balanceamento de linha. Outro exemplo é a proposta de Mortimer (2006) que sequenciou a implantação das práticas em: MFV, SMED, balanceamento das operações, layout celular, fluxo contínuo e gestão visual.

Em resumo, como apontam Gurumurthy e Kodali (2010), é importante que as organizações estruturem um modelo de implantação do Lean para orientar os gestores e o processo de mudança. Outro ponto abordado na literatura que trata de práticas Lean e implantação do pensamento Lean são os fatores essenciais para a implantação que se trata do comprometimento da alta direção, envolvimento de todos os funcionários, mudança cultural, além de ter em mente o princípio básico da melhoria contínua. Do mesmo modo, a resistência das pessoas e a dificuldade na adaptação de conceitos e práticas são algumas dificuldades encontradas no processo de implantação (BERTOLINI; ROMAGNOLI, 2013; BHASIN, 2012; MACEDO *et al.*, 2014; SAURIN; MARODIN; RIBEIRO, 2011).

Assim, é muito importante o entendimento da direção estratégica da empresa e alinhamento com a alta direção para a definição clara dos objetivos com a implantação do Lean (SINGH, R. K. *et al.*, 2006). Além disso, é essencial o comprometimento de longo prazo, definição de metas, planejamento, envolvimento dos funcionários e treinamento adequado das práticas a serem implantadas (WOMACK;JONES, 2004).

Longoni e Cagliano (2015) reforçam a proposição de Womack e Jones (2004) de que é essencial ter uma boa estrutura organizacional, com comprometimento e envolvimento dos gestores, para desdobrar e implantar a estratégia nas operações. Ainda, estes autores complementam que a literatura de gestão de operações vem apresentando sinergias entre o Lean e práticas *Green*, porém os estudos não fornecem diretrizes de como elas devem ser alinhadas. Os autores sugerem que, para superar esta lacuna, é preciso considerar o conteúdo e o processo de implantação da estratégia de produção. Assim, no próximo tópico desta fundamentação teórica serão apresentados os principais conceitos e práticas relacionadas a abordagem “*Green Manufacturing”*.

2.3 *GREEN MANUFACTURING*

2.3.1 EVOLUÇÃO DA QUESTÃO AMBIENTAL

Após a Revolução Industrial foi possível observar o crescimento da produção em larga escala para atender uma demanda crescente por bens e serviços. Contudo, o consumo de recursos foi acelerado, ocasionando um cenário de degradação ambiental, uma vez que questões ambientais eram totalmente negligenciadas nos projetos de produtos e processos (GRAEDEL; ALLENBY, 1998; GUNGOR; GUPTA, 1999).

Neste cenário, além de aumentar exponencialmente o consumo de recursos, ocorreram graves acidentes e desastres ambientais, motivando a introdução do conceito de desenvolvimento sustentável (HAAPALA *et al.*, 2013). O debate sobre o desenvolvimento sustentável ganhou destaque em 1987 pelo *World Commission Report on Environment and Development* (1987), também conhecido como "Relatório Brundtland". Este relatório teve o objetivo de mostrar a possibilidade de uma nova era de crescimento econômico baseado em políticas que sustentam e expandem a base dos recursos naturais. Estas ideias defendem que o desenvolvimento sustentável é absolutamente essencial para reduzir a crescente pobreza. No Relatório Brundland (1987, p. 46) foi apresentada a definição de desenvolvimento sustentável: "aquele que permite às gerações atuais satisfazer suas necessidades sem comprometer a capacidade das futuras gerações".

Leite (2014) expõe que a sustentabilidade é reconhecida, cada vez mais, como essencial para a sociedade e, consequentemente, para as organizações. As empresas têm buscado produzir bens e serviços que gerem o menor impacto social e ambiental. Conforme publicado pelo Agenda 21 (1992), a maior causa da constante degradação dos recursos naturais globais é a maneira insustentável do consumo e a produção, principalmente nos países industrializados.

De acordo com *Lowell Center for Sustainable Production – LCSP* (1998), a produção sustentável visa gerar bens e serviços por meio de sistemas e processos não poluentes, buscando reduzir o consumo de energia e de recursos naturais. Deve ser viável economicamente, saudável e segura para colaboradores, consumidores e comunidades e, além disso, ter como objetivo ser gratificante para os funcionários envolvidos. Ainda, esta referência aponta que estas condições podem gerar, sempre no longo prazo e com frequência no curto prazo, negócios mais economicamente viáveis e produtivos.

No contexto organizacional, o desenvolvimento sustentável é conhecido como sustentabilidade empresarial e pelo tripé delineado por Elkington (1999). Este tripé, conhecido no inglês como *Triple Bottom Line*, propõe equilíbrio entre as dimensões social, ambiental e econômica, o qual tem sido frequentemente empregado no contexto empresarial na busca do desenvolvimento sustentável (DELAI; TAKAHASHI, 2011). As diretrizes do *Global Report Intiativie (GRI)* indicam que a sustentabilidade empresarial deve buscar o equilíbrio no contexto complexo das relações entre as necessidades económicas, ambientais e sociais, de modo a não prejudicar o desenvolvimento futuro (GRI, 2021). No que diz respeito à sustentabilidade voltada à manufatura, é necessária a consideração simultânea do tripé da sustentabilidade e suas implicações para a produção e entrega de bens e/ou serviços (HAAPALA *et al.*, 2013). Neste trabalho considera-se apenas aspectos das dimensões ambiental e econômica do tripé proposto, discutindo como a redução dos impactos ambientais é tratada no contexto empresarial, em específico nas operações.

As discussões sobre a questão ambiental nas organizações, alinhadas à evolução e à disseminação do conceito de desenvolvimento sustentável, foram sofrendo alterações. Inicialmente, o gerenciamento das questões ambientais tinha um caráter corretivo, apenas para cumprir as exigências estabelecidas por lei e, assim, a preservação do meio ambiente era vista como um custo adicional, eram as medidas "fim de tubo" (*end of pipe*). Posteriormente, evoluiu-se para uma postura proativa, em que prevalecia a prevenção e buscava-se a conservação e substituição de insumos menos poluentes e o uso de tecnologias limpas. As soluções para os problemas ambientais passaram a ser vistas como meios para aumentar a produtividade da empresa. Atualmente, o meio ambiente é visto como prioridade competitiva das empresas. As organizações vêm adotando posturas proativas e preventivas, minimizando ações corretivas, antecipando problemas, envolvendo todos os funcionários de maneira sistemática e periódica e ampliando as ações ambientais por toda a cadeia de valor, melhorando o desempenho econômico e ambiental da empresa (GRAEDEL; ALLENBY 1998; BARBIERI, 2007; SILVA; SILVA; OMETTO, 2015).

Diante deste contexto, devido à necessidade de integrar as questões de sustentabilidade ambiental nos processos produtivos de fabricação, têm sido adotados os termos *Sustainable Manufacturing* e *Green Manufacturing*, como apresentados nos estudos de Kleindorfer, Singhal e Wassenhove (2005), Maruthi e Rashmi, (2015), Silva, Silva e Ometto (2015), Pathak e Singh (2017), Salem e Deif (2017), Deif (2011), para referenciar as práticas ou conjunto de práticas direcionadas à manufatura ambientalmente sustentável. O *Green Manufacturing*, de acordo com Salem e Deif (2017), está no centro da revolução para alcançar a sustentabilidade.

Silva, Silva e Ometto (2015) baseados em *Sustainable Manufacturing Initiative* (2011), por meio de uma revisão bibliográfica, mostram que este termo veio do processo evolutivo da questão ambiental na manufatura, a Figura 8 apresentada por estes autores representa esta evolução e os principais aspectos relacionados a cada fase.

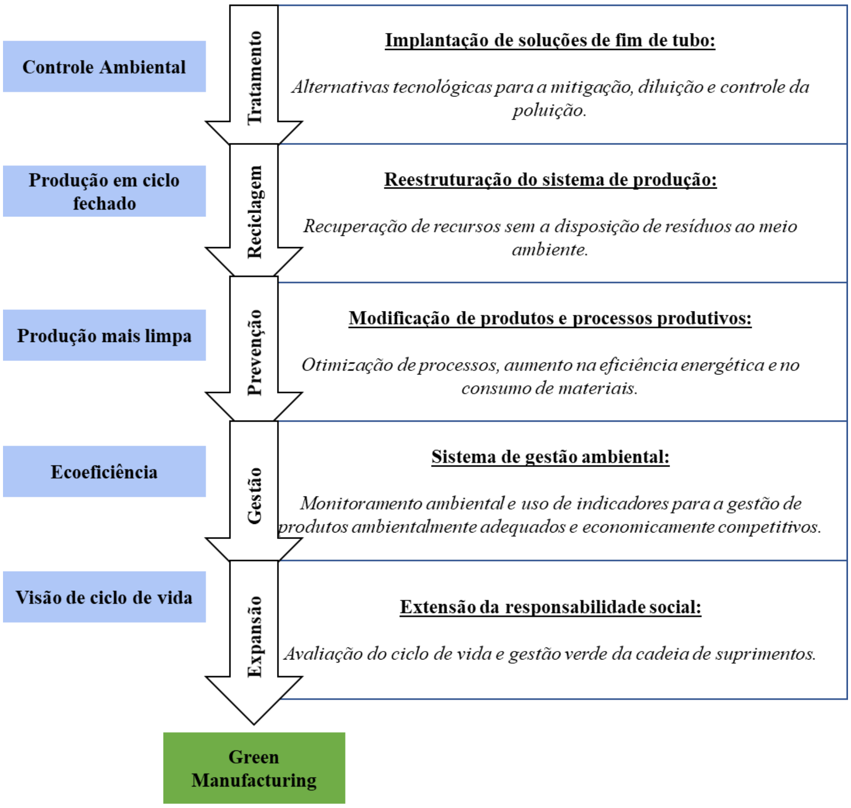

Figura 14 -Evolução da visão e das práticas de Green Manufacturing

Fonte: Silva, Silva e Ometto (2015, p. 643.).

O que é observado é que as ações voltadas para os sistemas produtivos eram focadas no controle, utilizando de soluções fim-de-tubo para recuperação de recursos. A segunda fase consistiu em reestruturação do sistema de produção focando em recuperar os recursos e adotando assim a reciclagem como alternativa para redução dos impactos ambientais gerados. Na terceira fase, o objetivo é a prevenção, em que se tem como foco a otimização dos processos focando em eficiência e muitas vezes alterando processos e produtos. A quarta fase evoluiu para a inclusão de todas as ações pontuadas nas fases anteriores sob um sistema de gestão estruturado com indicadores de gestão focados na ecoeficiência. A quinta fase se trata de uma visão ambiental estendida da responsabilidade, ou seja, para todo o ciclo de vida do produto, rompendo as fronteiras da organização e envolvendo todos os elos da cadeia (SILVA; SILVA; OMETTO, 2015). A partir do entendimento da evolução do conceito da abordagem *Green Manufacturing* no próximo tópico serão apresentadas algumas definições.

2.3.2 CONCEITOS E PRÁTICAS DE *GREEN MANUFACTURING*

Não existe uma definição consolidada para *Green Manufacturing*, esse novo paradigma na comunidade industrial. Deste modo, nesta e na próxima seção busca-se apresentar e agrupar alguns conceitos e definições convergentes sobre o assunto. *Green Manufacturing* é a abordagem para a manufatura que considera todo o ciclo de vida do produto, desde o projeto do produto, fabricação, manutenção e até a disposição final (WU; CHEN, 2015).

O termo *Green Manufacturing* foi estabelecido para se referir ao novo paradigma de fabricação que implementa várias estratégias para a preservação ambiental (objetivos e princípios) e técnicas (tecnologia e inovações) para se tornar mais ecoeficiente. Ou seja, o objetivo deste novo paradigma de fabricação busca minimizar o uso de recursos, resíduos e poluição e, além disso, considerar os aspectos econômicos, buscando melhor desempenho econômico. Ainda, esta abordagem pode melhorar a qualidade do produto e do processo de produção, gerando redução de custo e expansão da fatia de mercado para organização, por meio do aumento da satisfação do consumidor, que busca cada vez mais produtos com menor impacto ambiental (DEIF, 2011).

Um sistema de manufatura *Green*, projetado adequadamente, pode reduzir custos por meio uso eficiente de matérias-primas, energia e trabalho, agregando valor ao produto (PAUL; BHOLE; CHAUDHARI, 2014). O objetivo central do *Green Manufacturing* é a produção de produtos viáveis com o mínimo de impacto ambiental e social (MITTAL; SANGWAN, 2014).

Em resumo, o *Green Manufacturing* concentra a atividade de compras, a produção e a distribuição, incluindo a logística reversa, a fim de minimizar a poluição industrial e conservar os recursos naturais. Essa estratégia promove a redução do consumo de combustível fóssil, evita o uso de material tóxico na produção e distribuição e melhora a eficiência dos recursos (energia, materiais e outros recursos naturais) através dos três R's (reutilização, redução e reciclagem). Além disso, esta estratégia aplica metodologias científicas, como técnicas de análise do ciclo de vida, design para o ambiente (ecodesign) e fabricação em circuito fechado (simbiose industrial) (PAUL; BHOLE; CHAUDHARI, 2014)

É importante destacar que a redução do impacto ambiental é o foco principal do paradigma *Green*, este trabalho utiliza-se da seguinte definição de impacto ambiental:

> “qualquer alteração das propriedades físicas, químicas, biológicas do meio ambiente, causada por qualquer forma de matéria ou energia resultante das atividades humanas que afete diretamente ou

> indiretamente: A saúde, a segurança, e o bem-estar da população; As atividades sociais e econômicas; A biota; As condições estéticas e sanitárias ambientais; e A qualidade dos recursos ambientais" (Artigo 1º da Resolução n.º 001/86 do Conselho Nacional do Meio Ambiente (IBAMA, 1986, p.1).

Assim, foram levantadas, com base nos estudos de Thanki Govindan e Thakkar (2016) e Silva, Silva e Ometto (2015) as práticas voltadas às operações que buscam a redução dos impactos ambientais dos sistemas produtivos, ou seja, práticas de *Green Manufacturing*, as quais podem ser visualizadas no Quadro 6.

Quadro 6 - Práticas Green

Prática Green	**Objetivo da Prática**
Credenciamento ambiental de fornecedores	Integração dos critérios de desempenho ambiental na seleção de fornecedores (GOEBEL *et al.*, 2018).
Análise do ciclo de vida do produto	Ferramenta que busca encontrar oportunidades para a melhoria do desempenho ambiental de produtos em diversos pontos de seu ciclo de vida, capaz de incrementar o nível de informação dos tomadores de decisão na indústria e nas organizações governamentais e não-governamentais (SILVA; SILVA; OMETTO, 2015).
Logística reversa	O processo de planejamento, implementação e controlo do fluxo eficiente e rentável de matérias-primas materiais, inventário em processo, produtos acabados e informação relacionada a partir do ponto de consumo até ao ponto de origem para efeitos de recapturar o valor ou eliminação adequada (ROGERS; TIBBEN-LEMBKE, 1988).
Sistema de Gestão Ambiental (SGA)	Com relação aos sistemas de gestão ambiental (SGA) , estes são compostos por processos, políticas e protocolos de auditoria direcionados às operações que causam desperdício de materiais ou emissões de poluentes e têm como foco fornecer instrumentos às empresas para permitir a redução dos prejuízos ao meio ambiente, mas de uma maneira que os benefícios deste sistema ultrapassem os custos de sua implantação (MATTHEWS, 2003) Com o objetivo de normatizar e certificar seus sistemas de gestão ambiental, as organizações têm adotado a ISO 14001, norma internacional para SGA.
Gerenciamento de Resíduos	A gestão de resíduos sólidos é o tratamento, o consumo, a reutilização, eliminação e tratamento de resíduos sólidos que são utilizados nos processos produtivos (ZHU; SARKIS, 2004). Musee, Lorenzen e Aldrich (2007) resumem esse gerenciamento em três etapas: os resíduos, a fonte, a identificação e quantificação, avaliação qualitativa das causas dos resíduos e finalmente viável derivação de alternativas para a minimização de resíduos.
Programa para reduzir o consumo de material	Estes dois programas são pautados no princípio dos 3Rs. O primeiro termo “Reduzir” é associado com a minimização no consumo de recursos e na geração de resíduos, o termo de "Reutilização" é definido como a reutilização de um produto, ou parte dele, após o seu primeiro ciclo de vida na sua utilização inicial e o terceiro termo “Reciclar” refere-se à conversão de materiais que já foram utilizados em produtos inteiramente novos. Em termos de eficiência de recursos e transição para um modelo empresarial circular, a reciclagem é considerada a opção menos sustentável (YANG.; ZHOU; XU, 2014).
Programa de reciclagem	

Quadro 6 - Práticas Green

Prática Green	Objetivo da Prática
Programas de compartilhamento de recursos entre processos	Estes programas são caracterizados também como "Simbiose Industrial" em que se tem como objetivo a troca de materiais, energia, água e subprodutos entre parceiros de negócios colaborativos para obter vantagem competitiva quando situados em locais próximos (CHERTOW, 2000). Além disso, esta prática objetiva reutilizar resíduos de um processo industrial como recurso para outro processo industrial, a relação simbiótica pode ser estabelecida entre processos (em termos de troca de recursos) ou entre empresas (em termos de troca de valores) (HOLGADO; MORGAN; EVANS, 2016).
Produção Mais Limpa (PmaisL)	Aplicação contínua de uma estratégia ambiental preventiva integrada aos processos e produtos de modo a reduzir os riscos aos humanos e ao ambiente (UNEP, 2004). Abrange questões econômicas, técnicas e ambientais relacionadas aos processos e produtos e tem o objetivo de melhorar a eficiência no uso de matérias-primas, água e energia por meio da otimização, não-geração ou reciclagem dos resíduos e emissões geradas (CNTL,2003).
Programa de redução do consumo de água	Aumentar a eficiência no uso água por meio da análise de processos que utilizam este recurso (CNTL, 2003).
Programa de conservação de energia	Os programas de conservação de energia buscam a conscientização para a redução no consumo de energia elétrica bem como busca utilizar de dispositivos que requerem quantidades menores de energia a fim de reduzir o consumo de eletricidade. (ZHU; SARKIS, 2004).
Programas de educação ambiental para a comunidade	O foco principal dos programas de educação ambiental é promover a mudança do de comportamento das pessoas com relação ao meio ambiente, por meio do conhecimento ambiental. O qual envolve a promoção de uma cidadania conhecedora do ambiente biofísico e os problemas associados, consciente de como ajudar a resolver esses problemas e motivada para trabalhar para a solução destes problemas. Além disso, tornar a educação ambiental busca tornar a sociedade capaz de e é avaliar as questões ambientais, encontrar soluções viáveis para quaisquer problemas identificados e, finalmente, para criar projetos para uma cultura de comportamento em prol da preservação ambiental (POOLEY; O'CONNOR, 2000). .
Publicação de relatórios de desempenho ambiental	Relatórios que apresentam os indicadores de desempenho ambiental das organizações com o objetivo de comunicar aos *Stakeholder*. Este relatório pode conter informações ambientais financeiras como as despesas com proteção ambiental e informações ambientais não financeiras, ou informações qualitativas (por exemplo, políticas de exploração de recursos naturais), ou informações quantitativas (água e consumo de eletricidade, gestão de resíduos, etc.) (PAVALOAIA, 2015)
Tratamento de Efluentes	Tornar os efluentes líquidos adequados para o lançamento em cursos d'água. Podem ser usadas diversas técnicas como precipitação química, coagulação-floculação, flotação, troca iônica, adsorção, filtração por membranas, extração líquido-líquido (CNTL, 2003).

Vale ressaltar que a PmaisL é uma das estratégias direcionadas à ecoeficiência das operações mais comumente utilizadas e que comtempla várias práticas dentro do contexto de *Green.* Desde modo, como a PmaisL se trata de um programa *Green* consolidado para as operações esta pesquisa, tanto na RSL quando nos estudos de casos, buscou destacá-la como uma prática.

Além das práticas apresentadas no Quadro 6, é importante destacar que existem abordagens que aplicam o conceito de *Green* e que contemplam mais de uma prática *Green* e, portanto, são consideradas práticas mais amplas ou programas *Green* direcionados a áreas específicas da empresa, sendo elas: projeto de produtos ambientalmente sustentáveis (*ecodesign),* gestão verde da cadeia de suprimentos (*green supply chain management)* e o conceito de economia circular *(circular economy).*

O *Ecodesign* pode ser definido como qualquer ação tomada durante o projeto e desenvolvimento de produtos com o objetivo de minimizar o impacto ambiental do produto durante todas as etapas do seu ciclo de vida, sem comprometer outros critérios essenciais tais como custo, qualidade, funcionalidade e estética (JOHANSSON, 2002). Esta prática voltada ao desenvolvimento de produtos faz uso da prática de Análise do Ciclo de Vida (ACV), uma vez que os impactos ambientais observados ao longo de um ciclo de vida do produto são, na sua grande maioria, determinados na fase de projeto; fase esta na qual se definem os materiais, o processo de fabricação, as embalagens, entre outras características relacionadas ao produto (GRAEDEL; ALLENBY, 1998). Nesta abordagem pode ser encontrada também uma prática voltada às embalagens dos produtos conhecida como “Eco-Label”, que se refere à prática de marcar os produtos com um rótulo distintivo para mostrar que sua fabricação está em conformidade com as normas ambientais reconhecida (PRASAD; KHANDUJA; SHARMA, 2016)

Já a abordagem *Green Supply Chain Management* pode fazer uso da ACV, logística reversa, credenciamento ambiental dos fornecedores, entre outras práticas *Green*, pois se trata da ampliação do escopo da Gestão da Cadeia de Suprimentos tradicional uma vez que passa a incluir os aspectos ambientais nos outros objetivos de desempenho. A inclusão da variável ambiental à gestão da cadeia busca ponderar o impacto das atividades da cadeia de valor e sua influência na natureza (SRIVASTAVA, 2007). O objetivo da GSCM é eliminar ou minimizar os impactos ambientais negativos e o desperdício de recursos (água, energia, materiais e produtos) desde a extração, aquisição de matéria primas até o uso e disposição final do produto (HERVANI; HELMS; SARKIS, 2005). Ou seja, GSCM inclui o projeto do produto, fornecimento e seleção de materiais, processos de fabricação, entrega do produto final e a gestão do fim de vida desse produto após sua vida útil (SRIVASTAVA, 2007). Sarkis, Zhu e Lai (2011) após um estudo da literatura, definiu a GSCM como a integração das preocupações ambientais nas práticas interorganizacionais.

Cabe mencionar aqui o conceito “economia circular”, no inglês *circular economy,* que é aplicado aos sistemas de produção e consumo com o objetivo de manter produtos, componentes, materiais e energia em circulação, a fim de continuar adicionando, recriando e mantendo seus valores durante um longo período de tempo (ESPOSITO; TSE; SOUFANI, 2018). O objetivo da economia circular é fechar o ciclo de materiais dentro do ciclo de vida do produto, ou seja, em vez de descartar os materiais, o foco é mantê-los para reduzir o consumo de recursos. A disponibilização dos produtos por mais tempo no ciclo de vida, seguindo uma lógica circular, é que irá colaborar para o crescimento econômico (RITZÉN; SANDSTRÖM, 2017).

Este conceito é considerado referência para o alcance dos objetivos de desenvolvimento sustentável na transição de um modelo linear de produção de bens, que considerava as matérias primas com fontes ilimitadas, para um modelo circular em que os materiais e resíduos são incorporados ao processo produtivo visando primeiramente reutilização, posteriormente a recuperação e a reciclagem como última opção (MILLAR; MCLAUGHLIN; BÖRGER, 2019).

Interligado a este conceito é possível encontrar o termo Ecologia Industrial (*Industrial Ecology)* e prática de Simbiose Industrial (Programas de compartilhamento de recursos entre processos). O Conceito de Ecologia industrial exige que um sistema industrial seja visto não isoladamente de seus sistemas vizinhos, mas em conjunto com eles. É uma visão de sistema com a qual se busca otimizar o ciclo total de materiais, desde o material virgem, ao material acabado, ao componente, ao produto, ao produto obsoleto, e ao descarte final. Os fatores a serem otimizados incluem recursos, energia e capital (GRAEDEL; ALLENBY, 1995).

Por fim, vale pontuar uma prática que foi mencionada no estudo de Thanki e Thakkar (2016), conhecida como Contabilidade do Fluxo de Materiais – *(Material Flow Cost Accounting - MFCA),* tem o objetivo de mensurar da contabilidade de custos do fluxo de materiais e de avaliar o desempenho ambiental por meio da avaliação monetário do fluxo de materiais dentro do sistema de produção.

No próximo tópico será apresentado uma breve discussão sobre conceito de *Lean-Green.*

2.4 *LEAN-GREEN*

O estudo pioneiro sobre *Lean e Green* foi apresentado em 1996 por Florida (1996) e discute a integração destas abordagens, explorando como as organizações podem incluir a questão ambiental na manufatura por meio da abordagem "*Lean-Green"* e argumentando que a redução dos desperdícios gerada pelo *Lean* contribui para o desempenho ambiental. EPA (2007) exemplifica, como pode ser visto no Quadro 7.

Quadro 7 - Desperdícios Lean e Impactos Ambientais (EPA, 2007).

Desperdícios *Lean*	**Possíveis Impactos Ambientais**
Superprodução	-Uso de energia e matéria prima desnecessariamente;
	-Produção extra pode gerar produto obsoleto sendo necessário o descarte;
	-Uso extra de materiais perigosos resultando em emissões, disposição dos resíduos no meio, exposição do trabalhador, entre outros.
Estoque	-Necessidade de mais embalagens para o estoque em processo;
	-Descarte devido a deterioração ou danos causados no estoque;
	-Aumento no consumo de energia para armazenar os produtos (calor, refrigeração, iluminação).
Movimentação e transporte desnecessário	-Mais energia para transportar;
	-Emissões do transporte;
	-Danos e vazamento durante o transporte.
Defeitos	-Materiais e energia desperdiçados;
	-Produtos defeituosos necessitam de reciclagem ou descarte.
Processamento inadequado	-Maior consumo de materiais por unidade de produção;
	-Aumento no consumo de energia, aumento nas emissões e quantidade de resíduos;
Espera	-Desperdício de energia a partir de aquecimento, refrigeração e iluminação durante o tempo ocioso de produção.

Alguns estudos, como Vais et al. (2006) e Vinodh, Arvind, e Somanaathan (2011), têm demonstrado que *Lean* pode trazer benefícios ambientais e que isto pode ser atribuído a uma utilização mais eficiente dos recursos (tais como água e outros insumos). Da mesma forma, Florida (1996), King e Lenox (2001), Dües, Tan, e Lim (2013), Chiarini (2014) e Garza-Reyes et al. (2018) sugerem que a implementação de práticas *Lean* pode oferecer vantagens e sinergias significativas com o desempenho ambiental das empresas sem comprometer as outras prioridades competitivas. É importante destacar que *Lean e Green* são considerados complementares (GHOBAKHLOO; AZAR; FATHI, 2018; NG; LOW; SONG, 2015; SALVADOR; PIEKARSKI; FRANCISCO, 2017). Além disso, de acordo com estes estudos, a estrutura organizacional e a cultura do *Lean* facilita o desenvolvimento da gestão ambiental e a formação de uma empresa *"Green".*

No entanto, geralmente o Lean não considera diretamente os impactos ambientais, e existem pontos cegos no Lean com relação ao meio ambiente, como os riscos ambientais das melhorias e de suas práticas (US EPA, 2007), o que é indicado na Figura 15.

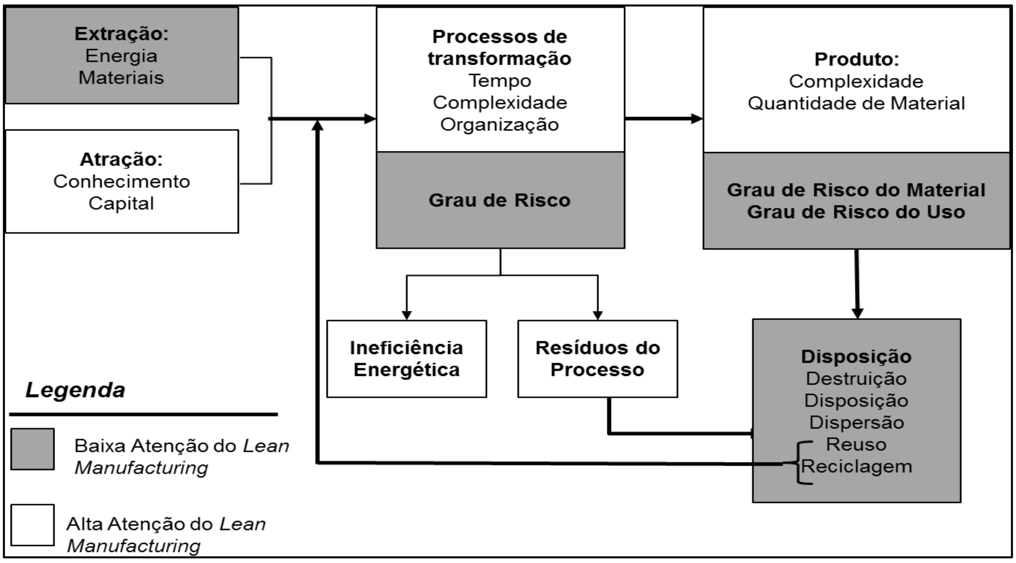

Figura 15 - "Pontos cegos" do Lean: Riscos e Impactos Ambientais.
Fonte: EPA (2007).

A Figura 15 evidencia que o *Lean* não tem como objetivo os riscos e impactos relativos ao meio ambiente, na cor cinza são destacados os aspectos que o *Lean* negligencia. Portanto, o grau de risco ambiental dos produtos e processos, os possíveis impactos ambientais, assim como os custos relacionados à extração de matérias primas e aos resíduos gerados durante a produção, não são ponderados pelo *Lean* (EPA, 2007).

Neste sentido, as organizações necessitam implementar práticas *Green* para preencher esta lacuna (NG; LOW; SONG, 2015). Assim, é necessário integrar o Green ao Lean explicitamente, considerando os aspectos ambientais nos indicadores de desempenho e práticas *Lean* (BELHADI, TOURIKI, & EL FEZAZI 2018; CHERRAFI ET AL. 2016; DUARTE & CRUZ MACHADO 2017; DÜES ET AL. 2013; BEN RUBEN ET AL. 2017).

Pois *Lean* e *Green* têm objetivos diferentes e assim podem surgir *trade-offs* entre as prioridades competitivas (LONGONI; CAGLIANO, 2015b).

A literatura que trata da abordagem *Lean-Green* sugere que o primeiro passo para implantar esta abordagem é mensurar o desempenho ambiental das operações enxutas e incluir as práticas *Green* no sistema de gestão (KING; LENOX, 2001; YANG; HONG; MODI, 2011). Outra proposta é desenvolver projetos *Kaizen* para a solução de problemas ambientais (EPA, 2007). Pois, ao incluir o *Green* no *Lean* a empresa pode aumentar sua capacidade de melhoria contínua buscando simultaneamente redução de custo e de impacto ambiental (TORIELLI *et al.*, 2010).

Do mesmo modo, é necessário que os gestores de produção e gestores ambientais passem a ter uma visão integrada, responsabilidade compartilhada sobre todos as prioridades competitivas e incentivar a integração da abordagem *Lean-Green* (KLASSEN, 2000). Neste sentido, no Quadro 8, são apresentadas práticas *Lean-Green* encontradas na literatura. As quais buscam contemplar de maneira integrada os objetivos *Lean* e *Green.*

Quadro 8 - Práticas Lean-Green

Práticas *Lean-Green*	**Objetivo da Prática**
Mapa de Fluxo de Valor Ambiental ou *Environmental Value Stream Mapping*	Busca incluir os aspectos ambientais, tais como consumo de energia, água e materiais e emissões, no Mapa de Fluxo de Valor e colabora para coletar, visualizar e analisar os dados ambientais dos processos (AGUADO; ALVAREZ; DOMINGO, 2013).
7s/Green 5s	Busca incluir os sensos de segurança) e sustentabilidade. (ANVARI; ZULKIFLI; YUSUFF, 2011).
Análise de Causa raiz para problemas ambientais	A prática da análise das causas-raiz pode ser estendida para identificar causas potenciais de problemas ambientais nos processos (BEN RUBEN; VINODH; ASOKAN, 2017).
OEEE - Overall Environmental Equipment Effectiveness -	O OEEE é o resultado de indicadores perceptuais utilizados para representar a capacidade de uma estação de trabalho, levando em conta sua disponibilidade, desempenho, qualidade e sustentabilidade. O do OEEE, é identificar as perdas devidas à sustentabilidade e estabelecer um entendimento completo do processo de produção em termos de disponibilidade, desempenho, qualidade e sustentabilidade. A identificação e medição destas ineficiências permitirá à empresa implementar as ações corretivas necessárias para melhorar o processo de produção (DOMINGO; AGUADO, 2015).
Lean and Green Supply Chain	Combinar as três abordagens Lean, Green e Supply Chain buscando cooperação para redução de custos, foco no consumidor, qualidade e gestão ambiental (SANT’ANNA *et al.*, 2017).
Kaizen with green goals	As atividades Kaizen devem ter como objetivo a redução dos impactos e custos ambientais (CALDERA; DESHA; DAWES, 2017).
SBSC - Sustainable Balanced Score Card	Uma adaptação na ferramenta de planejamento estratégico do BSC incluindo sustentabilidade em finanças, clientes, processos internos e perspectivas de aprendizado e crescimento (ZHU, X. *et al.*, 2017).
Lean 3R	Reciclagem e reutilização de produtos e/ou materiais utilizados nos processos como um dos focos do Lean (FERCOQ; LAMOURI; CARBONE, 2016).
Green Lean Six sigma	Integrar os aspectos ambientais no programa Lean Seis Sigma (CHERRAFI *et al.*, 2016).
Total Quality Environmental Management - TQEM	Prática que estende os princípios da gestão de qualidade para incluir práticas e processos de fabricação que afetam a qualidade ambiental (CAMPOS; VAZQUEZ-BRUST, 2016).
Green MRP	MRP modificado para incluir considerações ambientais com o objetivo de minimizar o impacto ambiental dos resíduos gerados, procurando aumentar o potencial de planejamento para os componentes e resíduos do processo (MELNYK *et al.*, 2001).

Portanto, com base nos conceitos de Lean e Green, nas discussões sobre a integração destas abordagens, bem como das práticas integradas, esta pesquisa entende que *Lean-Green* pode ser definido como uma abordagem que suporta a busca pelo desenvolvimento sustentável, nos pilares econômico, ambiental e social de um sistema de produção (BHATTACHARYA; NAND; CASTKA, 2019) e tem como foco a redução de desperdícios e foco no uso eficiente de recursos (DUES ET al. 2013; GARZA-REYES, 2015; COBRA ET AL. 2016).

2.5 CONSIDERAÇÕES FINAIS SOBRE O CAPÍTULO

Com base nos conceitos apresentados neste capítulo podemos sumarizar que a estratégia competitiva trata dos objetivos de longo prazo da empresa para gerar vantagem competitiva perante os concorrentes. Esses objetivos dependem da escolha de onde a organização irá competir e do alinhamento das expectativas dos *stakeholders:* consumidor final, governo, acionistas e sociedade. Para que esta estratégia seja executada, as organizações contam com as áreas funcionais da empresa, entre elas a produção, que é tratada como uma das mais importantes e responsável por balancear exigências do consumidor e recursos disponíveis. Assim, uma estratégia de operações alinhada à estratégia corporativa é fundamental para o alcance de uma posição competitiva. Em síntese, as escolhas nas áreas de decisão e a definição das prioridades, além de como tais decisões estão ou não alinhadas à estratégia competitiva, conforme Voss (1995), podem determinar o sucesso ou o fracasso das empresas.

Neste sentido, diante de uma nova demanda de preservação ambiental, além das tradicionais prioridades competitivas, como custo, qualidade, entrega, flexibilidade e serviço, as estratégias de operações precisam incluir a prioridade ambiente (ANGELL; KLASSEN, 1999; LONGONI; CAGLIANO, 2015b). Assim, foi destacado que são necessárias mudanças e adaptações nas estratégias.

Um dos paradigmas de Voss (1995, 2005), sobre as escolhas e visões da estratégia de operações, é a adoção de melhores práticas para garantir vantagem competitiva e atingir os objetivos estratégicos. Uma das abordagens de melhoria e filosofia para gestão da produção mais reconhecidas e adotadas nas operações é o *Lean Manufacturing* (NETLAND, 2013; LOSONCI; DEMETER; 2013). Alves Filho, Nogueira e Bento (2015) expõem casos do setor automotivo que adotam o LM com o objetivo de melhorar a eficiência alcançando redução de custos e melhoria na qualidade. Alinhadas ao *Lean*, considerada a necessidade de mudanças nas operações para inclusão da prioridade "ambiente", podem ser adotadas práticas para a redução dos impactos ambientais das operações tratadas na abordagem *Green Manufacturing* (SILVA; SILVA; OMETTO, 2015).

O *Lean Manufacturing*, com origem no Sistema Toyota de Produção, é composto por um conjunto de práticas pautadas em princípios, apresentados por Liker (2005) e Womack e Jones (2004), focados na resolução de problemas e eliminação de desperdícios para agregar valor ao cliente. Tais princípios surgiram no setor automotivo e hoje são difundidos e aplicados nos mais diversos setores com o objetivo de melhorar os resultados em eficiência, redução de custo e melhoria na qualidade e para garantir vantagem competitiva. Ainda, para que o *Lean* e suas práticas sejam implantadas, como como enfatizam Womack e Jones (2004), é essencial o comprometimento de longo prazo, definição de metas, planejamento, envolvimento dos funcionários e treinamento adequado das práticas a serem implantadas.

Longoni e Cagliano (2015) reforçam a proposição de Womack e Jones (2004) de que é essencial ter uma boa estrutura organizacional, com comprometimento e envolvimento dos gestores, para desdobrar e implantar a estratégia nas operações. Ainda, estes autores complementam que a literatura de gestão de operações vem apresentando sinergias entre a produção enxuta e práticas *Green*, porém os estudos não fornecem diretrizes de como elas devem ser alinhadas. Os autores sugerem que, para superar esta lacuna, é preciso considerar o conteúdo e o processo de implantação da estratégia de operações.

Assim, este capítulo buscou sintetizar também, por meio de uma fundamentação teórica exploratória, os principais conceitos relacionados à *Green Manufacturing*, os quais foram utilizados como base para a condução da Revisão Sistemática da Literatura e da parte empírica desta pesquisa. Com base nestes conceitos é possível destacar que a evolução da questão ambiental nas organizações, bem como as práticas *Green*, pode depender de vários fatores, desde o cumprimento da legislação até a busca por maior vantagem competitiva.

Deste modo, baseado no que foi apresentado nesta fundamentação teórica e nas figuras apresentadas nos estudos de Cobra *et al.* (2015) Khan, Talib e Kowang (2020) e Khodeir e Othman (2018) pode-se compreender um pouco da evolução das três temáticas ao longo do tempo.

Figura 16 - Evolução Lean-Green.

Na Figura 16 procura-se destacar o que foi observado nos estudos: o fato de que o meio ambiente tem sido tratado como prioridade competitiva recentemente e é a abordagem mais recente entre as três tratadas nesta pesquisa. Além disso, mostra que ainda não há estudos que contemplem os três constructos abordados de maneira integrada. Deste modo, no capítulo seguinte será apresentada uma Revisão Sistemática da Literatura na tentativa de, ao menos parcialmente, suprir esta lacuna de pesquisa

3. REVISÃO SISTEMÁTICA DA LITERATURA - SYNERGIES AND TRADE-OFFS BETWEEN LEAN-GREEN PRACTICES FROM THE PERSPECTIVE OF OPERATIONS STRATEGY: EVIDENCE FROM A SYSTEMATIC LITERATURE REVIEW

Este capítulo irá apresentar o artigo de revisão sistemática da literatura que teve como foco buscar compreender a integração entre *Lean* e *Green* sob a perspectiva do conteúdo da estratégia de operações, destacando as sinergias e trade-offs entre as prioridades competitivas e as mudanças nas áreas de decisão com a implantação das práticas Lean-Green. O presente artigo intitulado "*Synergies and trade-offs between Lean-Green practices from the perspective of operations strategy: evidence from a systematic literature review*. No Apêndice A consta o material suplementar desta pesquisa, contendo o protocolo da RBS, bem como a lista de todos os estudos encontrados e o *codebook* utilizado na análise de conteúdo.

Synergies and trade-offs between Lean-Green practices from the perspective of operations strategy: evidence from a systematic literature review

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Abstract

Lean Manufacturing and Green Manufacturing have been widely discussed in the operations management and sustainability literature as a solution to balancing efficiency gains and environmental sustainability. This body of Lean and Green literature focuses mainly on the integration between them, introducing frameworks and tools, but there are no studies available that investigate this integration and the relationship with the Operations Strategy content: competitive priorities and decision areas. Considering the relevance of operations strategy, the current needs of organizations and the lack of studies on the relationships between LG practices and the content of operations strategies, this study aims to provide a more strategic perspective considering the relationships between LG practices from the point of view of the OS content. We try to identify synergies and potential trade-offs between competitive priorities and changes in decision areas when LG practices are implemented. So far, no systematic review has been found to map them. We performed a systematic literature review to answer three questions: RQ1. Do the implementation of Lean and Green practices affect operations' competitive priorities causing synergies or trade-offs? RQ2. What decision area(s) are modified with the implementation of each practice? Content analysis was applied to 260 selected articles. Competitive priorities, decision areas, Lean practices, Green practices and Lean-Green practices were identified and discussed, highlighting trade-offs, synergies and changes in decision areas. The results suggest that Lean and Green are synergistic in most practices, but must be managed according to the operations strategy, especially as their focuses are essentially different and trade-offs may occur.

Keywords: *Lean Manufacturing; Green Manufacturing; competitive priorities; decision areas; sustainability*

1. Introduction

Society, governments, investors and companies themselves have increasingly demanded the elimination or reduction of environmental impacts of products and production processes (ERDIL; AKTAS; ARANI, 2018; VINODH; RAMESH; ARUN, 2016). And to meet these demands, companies seek to adopt programs and practices that reduce such impacts, but, at the same time, provide for the achievement of their competitive production priorities (GARZA-REYES, 2015; LONGONI; CAGLIANO, 2015b). An operations strategy (OS) aligned with market requirements is essential, as it can determine the company's competitive advantage (VOSS, C. A., 2005).

Lean and Green practices have been seen as a way to improve and balance all the operations competitive priorities; the relationship between these two strands has been explored by the Lean-Green (LG) integration literature. Leong et al. (2020) point out that the LG approach can obtain the maximum operational performance without compromising the environment. Complementary, Caldera et al. (2019) consider that LG enable the transition to sustainable business. Florida (1996), Garza-Reyes et al. (2018a), Vinodh et al. (2011) demonstrate that Lean aims to reduce wastes in value chain, which can contribute to reducing cost and defects and increase of natural resources (e.g. water, energy and materials) efficiency. Lean and Green are complementary and Lean enables the development of environmental management capability helping to "green" the organization (GHOBAKHLOO; AZAR; FATHI, 2018; NG; LOW; SONG, 2015; SALVADOR; PIEKARSKI; FRANCISCO, 2017). However, Lean does not take into account environmental impacts directly, thus, the organizations need to implement Green tools in Lean to fill this gap (NG; LOW; SONG, 2015). To refer to Lean and Green integration, the term "Lean-Green" has been used (DUARTE; CRUZ MACHADO, 2017; MOLLENKOPF *et al.*, 2010; THANKI, S.; GOVINDAN; THAKKAR, 2016; ZHU, X. *et al.*, 2017) and it will be used in this work.

Research about the LG has addressed three main topics. Some studies explore the relationship between Lean and Green, they present the synergies and differences among them. The authors argue that the approaches are very compatible but some trade-offs may appear and should be considered (Ghobakhloo et al., 2018; Hajmohammad et al., 2013; Jabbour et al., 2013;Rothenberg et al., 2001).

Another proposes tools and frameworks to integrate Lean and Green describing requirements and steps to implement them as well as barriers and enablers to do so (ALVES; ALVES, 2015; BEN RUBEN; VINODH; ASOKAN, 2017; CHERRAFI *et al.*, 2016; DOMINGO; AGUADO, 2015; ERDIL; AKTAS; ARANI, 2018; FARIAS *et al.*, 2019b; HAJMOHAMMAD *et al.*, 2013a; NG; LOW; SONG, 2015; PRASAD; KHANDUJA; SHARMA, 2016; RAGHU KUMAR; AGARWAL; SHARMA, 2016; THANKI, S.; GOVINDAN; THAKKAR, 2016; VINODH; BEN RUBEN; ASOKAN, 2016). Finally, the last group focus on the implementation of LG. In general, these studies show improvements in cost reduction, quality and environmental performance, mainly through reduction in energy consumption and waste generation (CHIARINI, 2014; GARZA-REYES *et al.*, 2018c).

However, there are studies that show some negative results in the environment, such as the increase of emissions when Just–in-Time (JIT) is implemented (AZEVEDO, Susana Garrido; CARVALHO; CRUZ-MACHADO, 2016; BALL, 2015; CAMPOS; VAZQUEZ-BRUST, 2016; FERRONE, 1996; GALEAZZO; FURLAN; VINELLI, 2014; GHOBAKHLOO; AZAR; FATHI, 2018; MOR; SINGH; BHARDWAJ, 2016; ROTHENBERG; PIL; MAXWELL, 2001; SARTAL; MARTINEZ-SENRA; CRUZ-MACHADO, 2018).

Despite these efforts, an integrated and holistic understanding of how LG are linked with all operations strategy content (namely, competitive priorities and decision areas) is still missing. Chatha and Butt (2015) presented an extensive literature review about OS providing a historical overview and the current status of this topic, but the results did not show any study that discussed LG and the entire OS content. Only two studies were found that somehow correlated OS with LG: Longoni and Cagliano (2015b) provided evidence about how the cross-functional executive involvement and worker involvement, in the formulation and implementation of the OS supporting the strategic alignment of Lean and sustainability; and, Suifan et al. (2019) analyze the trade-offs between LG and through a multi-criteria decision-making shows that competitive priorities can differ in each approach. However, both studies still do not provide a wide understanding about the relationships between LG and OS.

Considering the relevance of the production function for the organizations competitiveness, the current stakeholders requirements, and the lack of studies on LG practices from the perspective of the consolidated background of OS, this study aims to provide a broad perspective of possible impacts of adopting LG practices on the content of OS, highlighting the occurrence of synergies and tradeoffs between competitive priorities and the changes promoted in decision areas. Thus, this work seeks to take a step towards systematizing contributions from studies that addressed issues related to constructs in the field of OS - competitive priorities and decision areas - when LG practices are implemented. With this objective, a Systematic Literature Review (RSL) and a content analysis of 260 articles were carried out to provide an explanation and discussion of important themes on the content of production strategies and the role of LG practices in this content. This is an attempt to contribute to the solution of trade-offs and to the implementation of practices aligned with corporate sustainability objectives, allowing the development of well-positioned production systems that can meet new market demands and be consistent with the global strategy of the company.

The paper is organized as follows. We present a brief theoretical background about OS and LG and the research design, explaining the process of data collection and the method used to select studies and perform content analysis. Subsequently, we discuss our findings, which include descriptive evidence regarding the sample of articles and the results from the content analysis to answer the research questions. Lastly, we highlight the main implications, and we propose some avenues for future research.

2. Theoretical Background

OS is the set of decisions that seeks to balance production resources with market needs to contribute to the overall strategy of organizations (SLACK; LEWIS, 2011). Skinner (1969) published the first study discussing OS; it was emphasized that the production function should be considered strategic and as a source of competitive advantage. The implementation of an adequate OS, including the development of production function capabilities, plays a crucial role for companies in the business environment, and must be in line with the way the company seeks to create competitive advantages (HILMOLA *et al.*, 2015).

The success of an OS is related to the definition of its content, which is composed of competitive priorities (CP) and actions to be implemented in decision areas (DA) (VOSS, C. A., 2005). CP are related to the performance objectives that the production function adopts to align itself to the company's competitive strategy (SKINNER, Wickham, 1969), which are: cost, quality, delivery, flexibility and service (Skinner, 1969; Garvin,1993). Moreover, as indicated by Longoni and Cagliano (2015a), “environment” can be considered another competitive priority of the operations. These priorities are achieved through a pattern of decisions and actions implemented in the set of DA of the company, such as facilities, capacity, technology, supply chain, human resources, quality, production planning and control, product development, performance measurement systems and organization (SKINNER, Wickham, 1969; WHEELWRIGHT, 1984).

The content of OS can be seen through the lens of the "strategic choices" paradigm (one of the three proposed by (VOSS, C. A., 1995, 2005) in which strategic decisions in processes and infrastructures of organizations guide the implementation of practices (or actions) and changes in decision areas aimed at improving the performance of operations and gaining competitive advantages. This is the perspective chosen in this work to examine the impacts promoted by the adoption of LG practices in decision areas and competitive production priorities.

Lean Manufacturing (LM) is considered one of the most used approaches to improve operations performance and increase competitiveness (Losonci and Demeter, 2013) . LM is a set of principles and practices that aims to eliminate all kinds of waste in an organization (Mostafa et al., 2013). It is an approach that goes beyond a production management strategy and it can be considered a management philosophy (BHASIN; BURCHER, 2006) and an integrated socio-technical system (SHAH; WARD, 2007). The main LM practices are 5s, Kaizen, Value Stream Map (VSM), Just in Time (JIT), SMED , Total Productive Maintenance (TPM), Kanban, Standardized Work, Visual Management and 5 Why's (root cause analysis) (SHAH; WARD, 2003).

Regarding the concept of Green Manufacturing (GM) or Sustainable Manufacturing (SM), it emerged in the 1990s as a philosophy and operational approach to reduce the negative environmental impacts of products (GARZA-REYES, 2015). It concerns the search to reduce pollution, energy consumption and generation of toxic substances through the development of new processes in the manufacturing phase (KLEINDORFER; SINGHAL; VAN WASSENHOVE, 2005; PATHAK; SINGH, 2017; SILVA; SILVA; OMETTO, 2015). According to Pampanelli et al. (2014) and Silva et al. (2015), GM or SM encompasses different tools to reduce environmental impacts generated by production processes, such as: Cleaner Production, (Life Cycle Assessment (LCA), Environmental Management System (EMS), Circular Economy (CE), Eco-design/Design for Environment, Green/Sustainable Supply Chain, and 3R (Recycling, Remanufacturing and Reuse) (SILVA; SILVA; OMETTO, 2015).

LG integration has been considered the approach that support achieving the sustainability performance (economic, environmental and social dimensions) of a production system (BHATTACHARYA; NAND; CASTKA, 2019). There are many proposals in literature, like framework to LG integration, cases that show positive and negative environmental results from Lean implementation and some integrated tools as Environmental Value Stream Mapping - E-VSM (AGUADO; ALVAREZ; DOMINGO, 2013), 7s that is 5s plus S (safety) and S (sustainability) (ANVARI; ZULKIFLI; YUSUFF, 2011) and Green Lean Six Sigma (CHERRAFI *et al.*, 2016) . Figure 1 presents the constructs that will be discussed in this SLR.

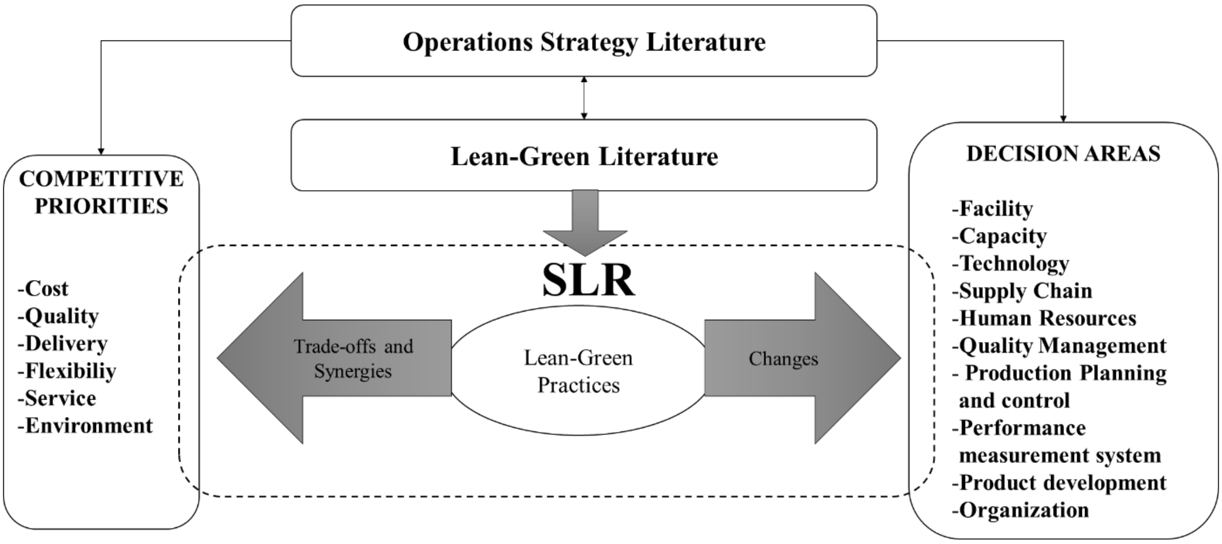


Figure 1 – Relationships between the concepts, research method, and results.

(Figura 17 - Relações entre os conceitos, método de pesquisa e resultados.)

Source: created by authors.

A SLR was carried out to identify in the literature contributions that highlighted impacts of the implementation of LG practices on operations' competitive priorities and on decision areas.

3. Research Design

This SLR followed the three macro stages proposed by Denyer and Tranfield (2009) as well as the Prisma Statement Flow Diagram proposed by Moher et al. (2009). The SLR process is detailed in Figure 2, which illustrates the summary of the SLR protocol to ensure transparency and reliability of the process. The complete and detailed version of the SLR protocol is attached in the supplementary material of this paper. Initially, the SLR protocol was elaborated and validated jointly by all authors. Throughout the SLR development, meetings between the authors were held to evaluate the results and resolve any disagreement.

3.1 Research Question formulation

We established the SLR research question needed to achieve the aim of the project, which was to understand how Lean-Green are related to the OS content. Considering this, the research questions addressed in this review are:

> *RQ1. Do the implementation of Lean and Green practices affect operations' competitive priorities causing synergies or trade-offs?*
>
> *RQ2. What decision area(s) are modified with the implementation of each practice?*

3.2 Search strategy

Studies were searched in three databases chosen according to their scientific scope to provide better results. The Scopus from Elsevier and The Web of Science from Thomson Reuters Institute of Scientific Information were chosen as they are regularly updated and have a wide breadth of coverage in most scientific subjects (Chadegani et al., 2013). Also, seeking to improve the scope of searches, we included the EBSCO, because it is an extensive database in management.

After a preliminary review of the literature in OS (CHATHA; BUTT, 2015; SKINNER, Wickham, 1969; SLACK; LEWIS, 2011; WHEELWRIGHT, 1984), LM (KRAFCIK, 1988; SHAH; WARD, 2003), and GM (GAVRONSKI *et al.*, 2012; KLEINDORFER; SINGHAL; VAN WASSENHOVE, 2005; PATHAK; SINGH, 2017), the strings were developed to conduct the search in the databases. We covered several keywords related to the constructs from the RQs: OS, CP, DA, LM, and GM. The search method consisted of the use of strings, defined in such a way as to return results that simultaneously contained at least one keyword referring to each construct. In the search string we considered all the synonyms of the constructs, and we detailed all the CPs and the DAs. A more detailed string was chosen for a wider range of articles since there are articles that focus only on one CP or one DA. Furthermore, we did not limit the field "year" to obtain the largest number of articles on the theme. The search in the databases was first carried out in January 2019 and then updated in November 2020. In all databases, we did the search in title, abstract, and keywords, by focusing on journal articles (excluding books and conference papers). Figure 2 presents the strings used in the searches and the summary of the SLR protocol.

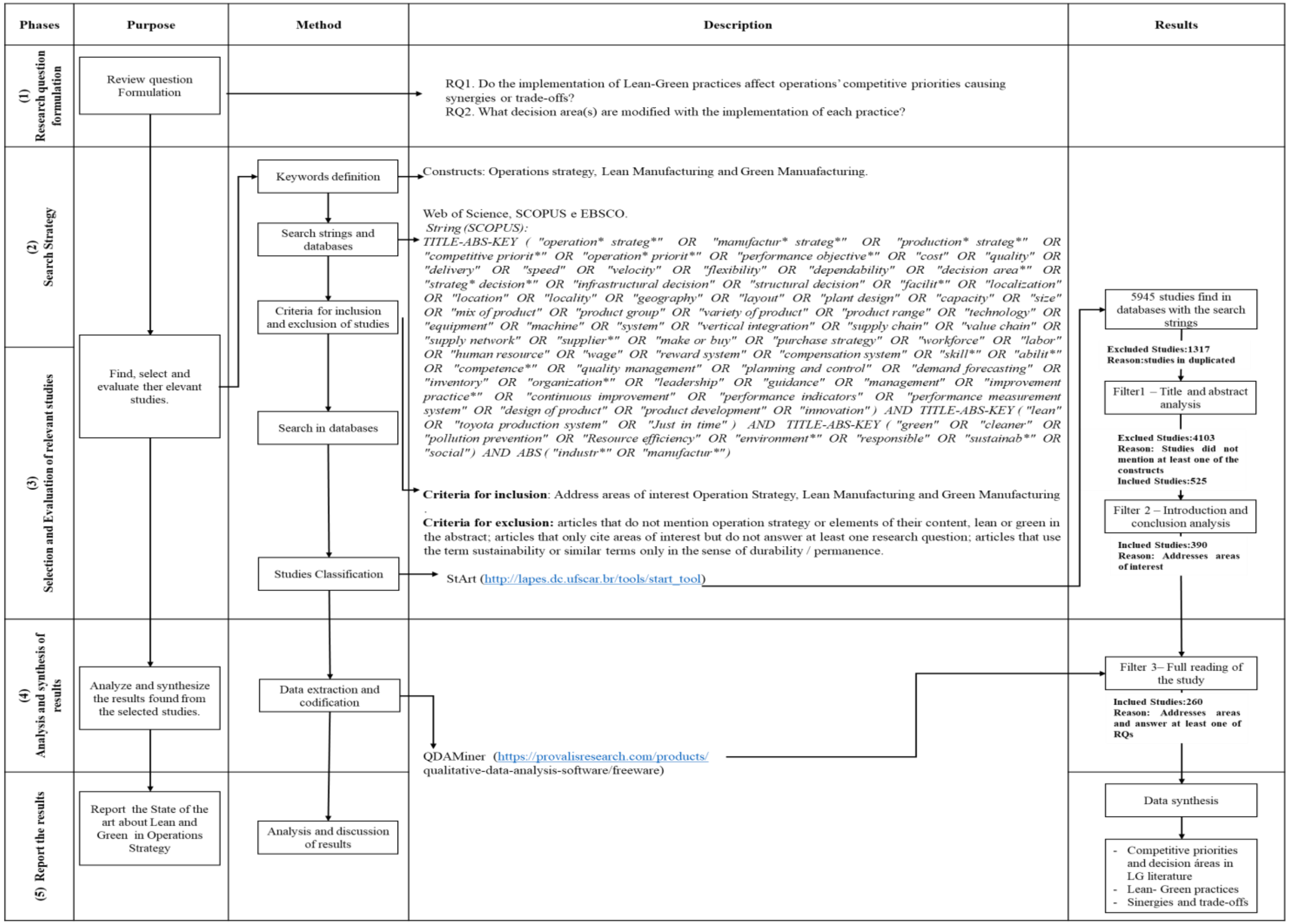


Figure 2– Summary of SLR Protocol.
(Figura 18 - Resumo do Protocolo da RBS.)

Source: created by authors.

3.3 Selection and evaluation of relevant studies

Studies were selected through three filters. The initial search resulted in 5945 studies; it is worth mentioning that 1317 duplicates were excluded in Filter 1. To select the articles for this review we applied two sets of inclusion and exclusion criteria presented in Figure 2. The first one was applied during the screening phase; it searched title, abstract and keywords and included articles that presented at least one term of each construct, related with content of the OS, LM and GM. For example, a document that presented one CP, like "quality", one Lean practice (LP) like "Kanban" and one Green practice (GP) like "Life Cycle Analysis", was selected for the next step. The articles that did not mention at least one decision area or competitive priority or any GP, were excluded.

Then, in Filter 2 (eligibility) we read the (each) paper's introduction and conclusion and included those that fulfilled the search inclusion criteria: full content access, written in English, published in scientific peer-reviewed journals and discussed at least one element of each construct. For example, the study of (ŠIŠKOVÁ; DLABAČ, 2013) cites "Lean" but does not discuss any practice, referring only to some aspect of OS and GM. We also found cases of using the term "sustainability" just to refer to the stability of the practices implemented, as the study of (PHAM; THOMAS, 2011). Studies like these were also excluded following the exclusion criteria "Articles that use the term sustainability or similar terms only in the sense of durability/permanence".

The third filter was then applied to the full paper using the same inclusion and exclusion criteria as by filter 2. In this filter 128 papers were excluded. As a result, a total of 260 selected to content analysis to answer the proposed RQs. The main reason for the excluded papers was because the paper mentioned the three constructs but did not answer the research questions. One example is the study of (HANSON; MELNYK; CALANTONE, 2011) that only cites a LP "JIT" as an example of an initiative in operations. Therefore, considering this sample of 260 papers, the next topic will present how the analysis of this work was done.

3.4 Analysis and synthesis of the results

After Filter 3 was done an analysis of 260 papers in full and aimed at extracting specific information from studies related to the research topic. In this filter, the articles were analyzed in a descriptive manner, seeking to generate a classification of the articles by year, country of the first author, journal, country of empirical studies, research method, industrial sector, and main focus. Moreover, a content analysis was made by following the recommendations of (KRIPPENDORFF, 2004) seeking to answer the research questions (RQs). The QDA Miner Software (Version 5) was used as a tool to facilitate the analysis process (individual papers and cross-papers). According to Hutchisona et al. (2010) this software collaborates in the organization of ideas and comparison between the cited.

The data were coded following the basic requirements proposed by Krippendorff (2004). The codes are very important to help identify relationships and establish connections among the many studies that write about the same topics (GIBBS, 2009). We used the (a) concept-based coding, extracting data from the texts, and others that emerged from the reading, related with database coding, as suggested by Gibbs (2009). The codebook, attached in supplementary material, was defined based on the constructs found in the literature of OS content (competitive priorities and decision areas), LM and GM. In this codebook we specified what the initial codes are from the literature and those from the final process.

The content analysis process started looking for the LP and GP, CP and DA in the studies. Later, the frequency analysis of the constructs was carried out seeking for which LG practices and elements from OS are discussed in LG literature. This whole process was supported and supervised by three senior researchers. Once the papers were codified, the content of OS and the practices from LM and GM were identified, it was possible to find the relationship between them all. In the supplementary material are specified all the competitive priorities, decision areas, lean practices, green practices and lean-green practices found and studied where they were addressed. The next topic presents the analyses (Step 5) and discussions.

4. Results and discussion

The results concerning LG from the perspective of OS are discussed in two parts. First, we describe the sample (Section 4.1) and then how Lean-Green is related to the OS content. (Section 4.2).

4.1 Descriptive Analysis

It is observed that half of the studies were published in the last four years (Figure 3). The first two publications were Florida (1996) and Ferrone (1996), and the year with the largest number of publications was 2019. This growth may be attributed to two main reasons. First, the need to integrate sustainability issues in productive systems has awakened the interest of academia in studying practices that focus on that. Secondly, based on the initial proposals of LG integration, studies have focused on their validation and implementation.

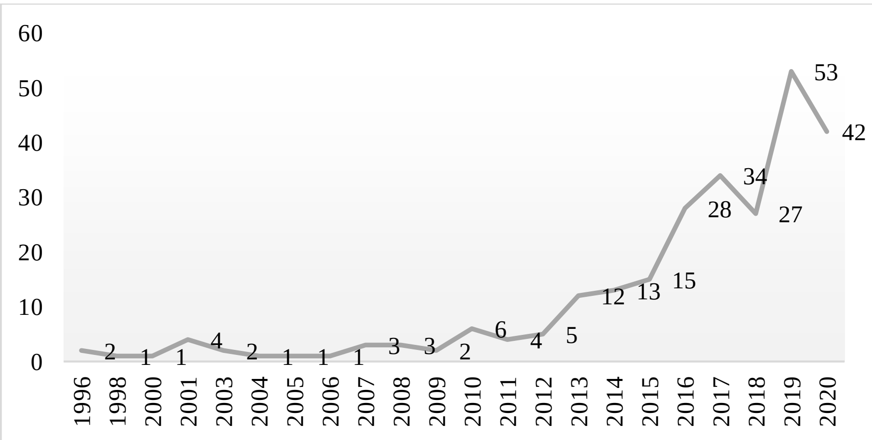


Figure 3 - Year of publication of retrieved articles.

(*Figura 19 - Ano de publicação dos estudos.)*

Source: created by the authors.

In terms of the number of publications per journal, studies were found in 127 different journals and the top 10 journals account for 50,8 % of the studies analyzed. The Journal of Cleaner Production is the outlet with the highest number of publications on this topic, with 47 publications, which corresponds to 18% of the total articles. Figure 3 presents this ranking and the journals that have up to three articles.

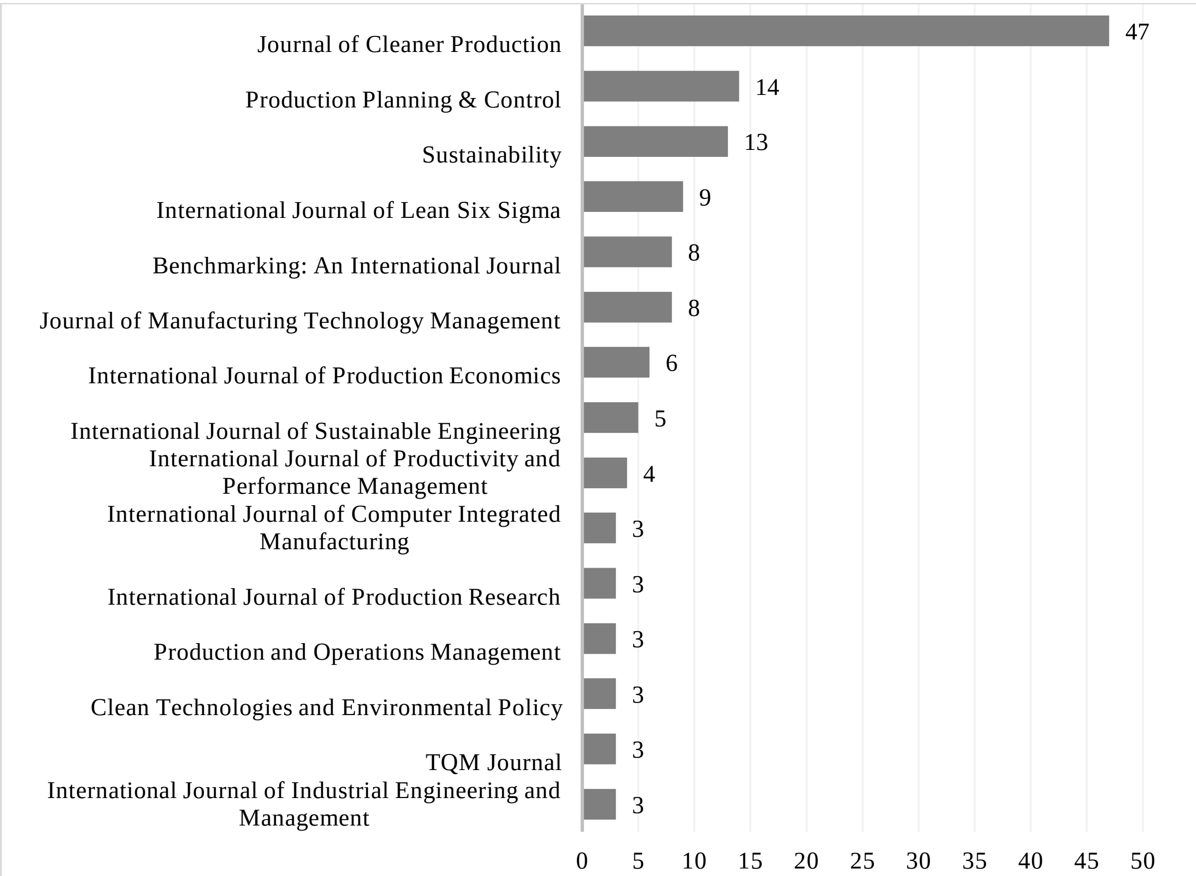


Figure 4 - Top 10 publishing journals.

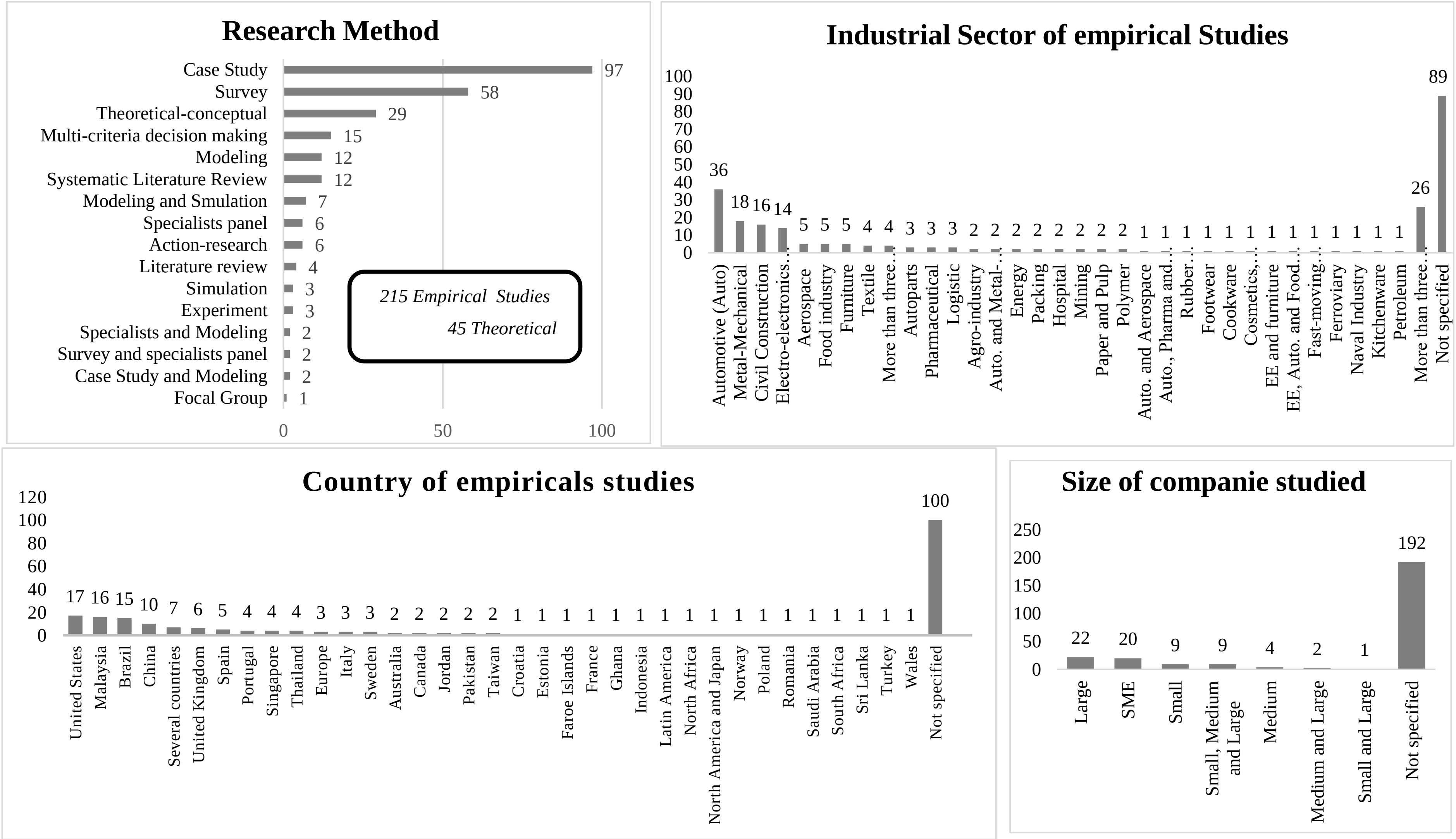
(*Figura 20 – Os 10 Períodicos mais frequentes)*

Source: created by the authors.

Figure 5 presents the research methods used in the studies and some characteristics of the samples for the empirical papers. There is a trend to adopt empirical studies (82,7%) that applied mainly case studies (37% of the sample) and survey (22%).

Furthermore, it presents the classification of the empirical studies regarding the industrial sector and the country, where the study was done and the size of the organizations. Regarding the industrial sector where empirical research was done, the three more frequent sectors were automotive, metal-mechanical, civil construction and electro-electronics, corresponding to 39% of the empirical studies. As for the location, the majority (around 45%) of the research was done in India, the United States, Malaysia, Brazil, China and United Kingdom. According to UNCTAD development status classification, only the US is classified as a developed economy, the other ones are classified as developing economies. Therefore, these data can mean that countries that focus on developing their economies are seeking practices to improve competitiveness sustainably.

Regarding the size of studied companies, only 67 studies identified it, with 33% studying large companies, around 3 % SMEs companies, 13% the small companies; 13% were done with a mixed sample including small, medium and large and another 6% represent medium companies.



F igure 5- Methodological approach
Source: created by the author

Figura 21 – Abordagem metodológica.

Regarding authors' countries, the studies are concentrated in approximately 48 countries and most of the contributors are affiliated to Indian institutions (n = 44, 17%), followed by the United States (n = 34, 13%), United Kingdom (n = 22, 8%) and Brazil (n=21, 8%). The author S. Vinodh from India was the individual researcher with the highest number of papers (10) (BEN RUBEN; VINODH; ASOKAN, 2017, 2019; R; VINODH; P, 2020; RUBEN; ASOKAN; VINODH, 2017; RUBEN; VINODH; ASOKAN, 2018; VASANTHAKUMAR; VINODH; VISHAL, 2017; VINODH; ARVIND; SOMANAATHAN, 2011; VINODH; BEN RUBEN; ASOKAN, 2016; VINODH; RAMESH; ARUN, 2016). The supplementary material presents the table with these 260 studies, their correspondent number, author and journal. .Furthermore, it is important to classify the studies according to their research focus, this classifications is in Section B – Number 2 of this material.

Most studies founded aimed to present steps, frameworks and guidelines to integrate the two approaches. Another present one or more specific hybrid tools that are integrated tools, like E-VSM, that take VSM from Lean and the environmental aspects from Green. The other major focus of LG literature is to try to discuss the main links between these approaches, as the synergies and trade-offs between them, highlighting the negative and positive impacts that each one has on the other. However, there is no study that discusses LG from the OS perspective.

4.2 Discussion

First, it is relevant to present the CP and DA that are discussed in LG literature. The priority "cost" was the most frequent in these studies, which is related with one of the main goals of Lean Manufacturing, i.e., cost reduction (SALVADOR; PIEKARSKI; FRANCISCO, 2017; THANKI, S. J.; THAKKAR, 2016a). Cost reduction used to be the motivation of companies that aim to become green: they seek to reduce costs of materials and energy inputs as well as costs of waste disposal (GUPTA *et al.*, 2018).

Regarding the priority "environment", most of the studies discuss the reduction of the negative environmental impacts from the production process that implements Lean. These studies consider this competitive priority as a new one aiming to reduce mainly energy consumption, emissions, water consumption, waste generation and toxic substances. Also, some researchers call the negative environmental impacts in Lean operations "Green waste" or “Environmental waste” (CHOUDHARY *et al.*, 2019a; GARZA-REYES *et al.*, 2018c; PAMPANELLI; FOUND; BERNARDES, 2014; VINODH; ARVIND; SOMANAATHAN, 2011).

Next, “quality” and “delivery” are both focuses of Lean implementation (BALL, 2015; SUIFAN; ALAZAB; ALHYARI, 2019). Quality is discussed, as in Belhadi et al., 2018; Florida, 1996, as a reduction or elimination of defects which can decrease the consumption of raw materials and costs of production. The priority delivery is addressed when the studies discuss order lead-time, that is one of the metrics considered in Lean implementations. According to Dües et al. (2013), customer satisfaction is driven by the reduction of lead time and, as indicated by Alves and Alves (2015), one of the results from Lean is to allow faster deliveries.

The other priorities found in the studies, less frequently in Lean systems, were social, service and flexibility. The priority social is related with improving workers’ health, safety and morale, local supply and with reduction of corruption risk (CHERRAFI *et al.*, 2016). Service is mentioned as the improvements in customer satisfaction through Lean and Green implementation (DÜES; TAN; LIM, 2013). Regarding flexibility, the capacity to increase the mix of products that can be targeted by LP is mentioned (DOMINGO; AGUADO, 2015; RUIZ-BENITEZ; LÓPEZ; REAL, 2017).

In addition to the CP, we observed the DA of OS cited in these studies. It is possible to note that Performance Measurement System is the most frequent decision area in these studies. This can be explained because the inclusion of an environmental performance indicator is one of the highest requirements to consolidate GP in industrial operations (BEN RUBEN; VINODH; ASOKAN, 2017; PAMPANELLI; FOUND; BERNARDES, 2014; THANKI, S.; GOVINDAN; THAKKAR, 2016) and the performance measurement systems in LM are an important aspect (SIEGEL *et al.*, 2019). Aligned with this, as highlighted by Leong et al. (2020), it is necessary to use support technologies allow the operational data to be registered for an effective improvement process.

Regarding Supply Chain, the literature discusses mainly supplier relationship (collaboration, selection, purchasing) and logistics (Azfar, 2017), mainly trade-offs or synergies from the JIT deliveries and the integration of the supply chain to implement LCA, or to analyze environmental impact from the Life Cycle perspective. Human Resources is another much discussed decision area, including essential changes and the importance of employee involvement in the training to implement and to sustain both Lean and Green (ALVES; ALVES, 2015; CAMPOS; VAZQUEZ-BRUST, 2016; SIEGEL *et al.*, 2019).

Quality Management is a decision area that is also studied, including the implementation of quality programs, like six sigma or Total Quality Control, or ISO standard (PUVANASVARAN *et al.*, 2012). Technology is normally related to the improvement of equipment to reduce resources consumption, which includes information systems and Industry 4.0 initiatives (CAMPOS; VAZQUEZ-BRUST, 2016; LEONG, W. D. *et al.*, 2020). Product development, on the other hand, addresses improving the design of product aiming to improve environmental performance since the beginning of the project (Caldera et al., 2017; Dües et al., 2013). Organization area is related to issues of the leadership structure for Lean and Green integration to attain success in the implementation of the practices (ALVES; ALVES, 2015; CHERRAFI *et al.*, 2016). Production, Planning and Control discussions include the impacts of a schedule to achieve environmental optimization. Facilities are mentioned to address layout change or facilities projects, like positive environmental impacts to implement cellular manufacturing because of less motion and transportation (DIAZ-ELSAYED *et al.*, 2013). Finally, capacity, the least addressed decision area, was discussed to talk about the size of batch and capacity planning (CALDERA; DESHA; DAWES, 2019).

About how LG affect the operations' competitive priorities causing trade-offs synergies and decision area(s) modified with implementation of LG, we found the relationships between LG and OS are studied in three different ways by the studied authors. The first group focuses on discussing the positive and negative environmental effects of LP on GM, thus Lean and Green are analyzed separately. The other one discusses the GP adopted as a complement to LP by Lean-oriented companies to address negative environmental impacts of their operations. In this group, Lean and Green are analyzed separately. Finally, in contrast to the previous groups, the third one discusses the effects of Lean and Green together through the analysis of the so-called hybrid practices or Lean-Green Practices on some OS aspect.

4.2.1 Lean Practices

It was possible to find a wide range of cited LP, covering 26 different practices in total, as presented in Figure 6. They are used in these studies to show how they can help to achieve better environmental performance, such as by reducing energy consumption, the consumption of materials, wastes generation and emissions and the benefits already known from lean, such as reduction of lead time and cost, as well as improvement of quality and productivity. Moreover, there are some practices, like VSM and TQM, that are mentioned as a foundation for integrating Lean with Green and make a hybrid practice showing synergies between them, these practices are presented in section 4.2.3. However, some studies mention that there are practices that can increase the negative environmental impact.

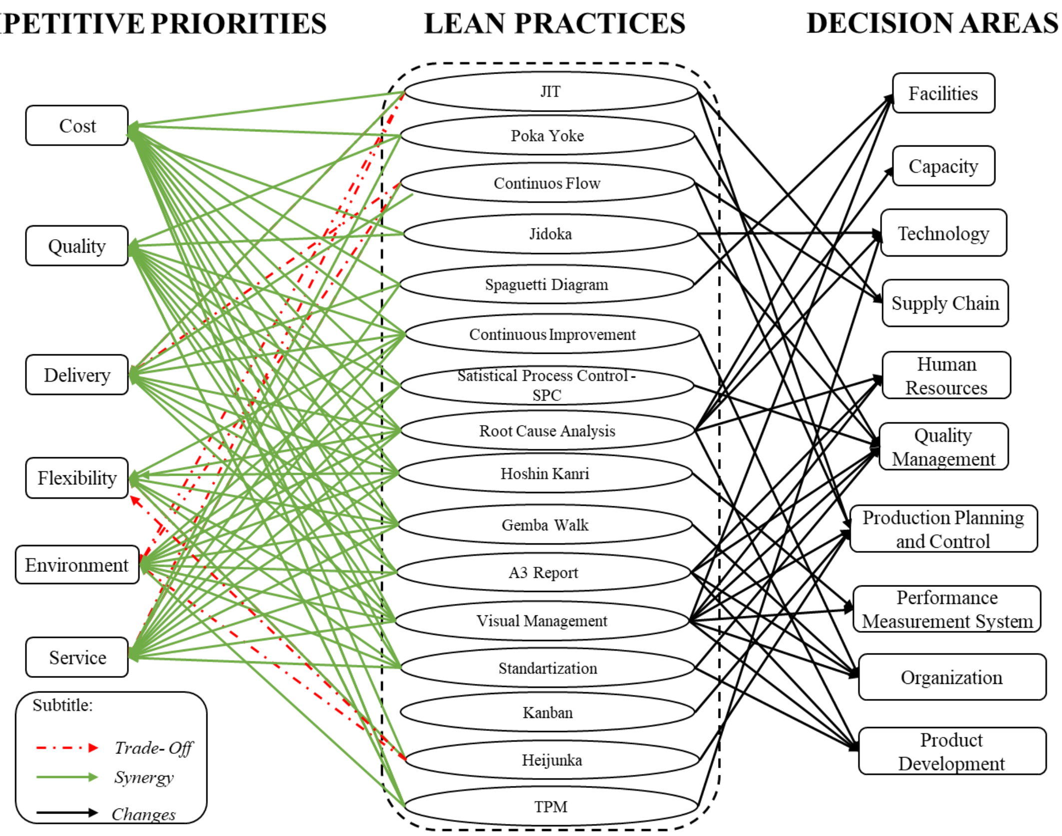


Figure 6– LP and OS.

(Figura 22 - Práticas Lean e Estratégia de Operações.)

Source: created by the authors.

As regards the synergy with the priority "environment", all the LP are considered sinergic because of their main focus on waste reduction. Several studies, e.g. Vinodh et al. (2011) , have demonstrated that LP can bring environmental benefits and that this can be attributed to more efficient use of resources (e.g. water and other inputs). Similarly, Chiarini (2014), Dües et al. (2013), Florida (1996), Garza-Reyes et al. (2018) and King and Lenox (2001) argue that LP implementation can offer significant advantages and synergies with the green performance of companies, which are mainly related to the reduction in consumption of materials, energy and water.

However, some sutides show that LP can present certain trade-offs with the priority "environment" (KLEINDORFER; SINGHAL; VAN WASSENHOVE, 2005; LONGONI; CAGLIANO, 2015a; PAMPANELLI; FOUND; BERNARDES, 2014; SALVADOR; PIEKARSKI; FRANCISCO, 2017). One of the most frequent trade-offs cited refers to delivery and environment. LP may negatively impact the environment, since the JIT (JIT) delivery process results in more deliveries, and then more emissions from the vehicles (CAMPOS; VAZQUEZ-BRUST, 2016; LONGONI; CAGLIANO, 2015b; MOLLENKOPF *et al.*, 2010; SALVADOR; PIEKARSKI; FRANCISCO, 2017).

Another trade-off identified is related to environment and quality. Pil and Rothenberg (2003) exemplify that sometimes more resources consumption is necessary to maintain a good quality of product. They show that in paint process, a large amount of water is necessary to have good quality. Therefore, quality-oriented practices such as TQM and Six Sigma can generate this trade-off, which means the reduction of resource consumption can be limited due to technical requirements of the process and the product.

Moreover, flexibility and environment can present trade-offs. Small batches allow more product variety, but they may increase the amount of setups (DÜES; TAN; LIM, 2013). In this sense, to maintain the programming level in variety and volume of items produced, Heijunka is used. Consequently, more setups are necessary. Therefore, as pointed out by Dües et al. (2013) and King and Lenox (2001), more cleaning products are required and increased disposal of unused process material, that way, as exposed for Fu et al. (2017) the increase in the disposal of chemical products results in unrecyclable sewage and waste chemical reagents, eventually increasing the environmental burden. In the same way, the increase in consumption of these products can be caused by the practice 5s, that focuses on improving the cleaning and organization of the work environment and elimination of unnecessary items which can contribute to quality and cost (HO; MOHD HASHIM; MOHD IDRIS, 2015; JABBOUR, C. J. C. *et al.*, 2013; RUBEN; ASOKAN; VINODH, 2017).

4.2.2 Green Practices

Figure 7 presents six practices focusing on reducing environmental impact in production process, product design and supply chain. They are presented as a complement to LP in companies, or they are part of a framework seeking to integrate Lean and GP. There are also some studies that highlight that it is essential to implement GP in Lean systems to resolve trade-offs with other competitive priorities. Also, there are cases that show their application is done separately from Lean, aiming only to reduce environmental impacts and comply with the legislation.

In terms of synergies between the competitive priorities from GP, it was possible to note that all contribute and focus on efficient use of resources, as a result, the priority cost can be improved. It is increasingly related to cost reduction of material; water and energy consumption as well as waste disposal costs have dramatically increased over the past decade (GUPTA *et al.*, 2018). Furthermore, there are empirical studies that present the cost reduction through improvements in environmental aspects (CHERRAFI *et al.*, 2016; MILLER; PAWLOSKI; STANDRIDGE, 2010; PARMAR; DESAI, 2020; PRASAD; KHANDUJA; SHARMA, 2016; TORIELLI *et al.*, 2010).

Wiengarten et al. (2013) argue that GP can reduce material and production costs, reduce transportation and logistics cost, increase product quality and reduce warehouse costs. Moreover, improving the environment can lead to cost reductions from any punitive or restrictive measures that may be introduced through legislation (BALL, 2015; PARMAR; DESAI, 2020). Mor et al. (2016) point out that these practices are not only good for sustainability but also good for business value. Jabbour et al. (2013) conclude that the implementation of the EMS, the more frequent practice in the studies, can have positive impacts in various areas on organization performance.

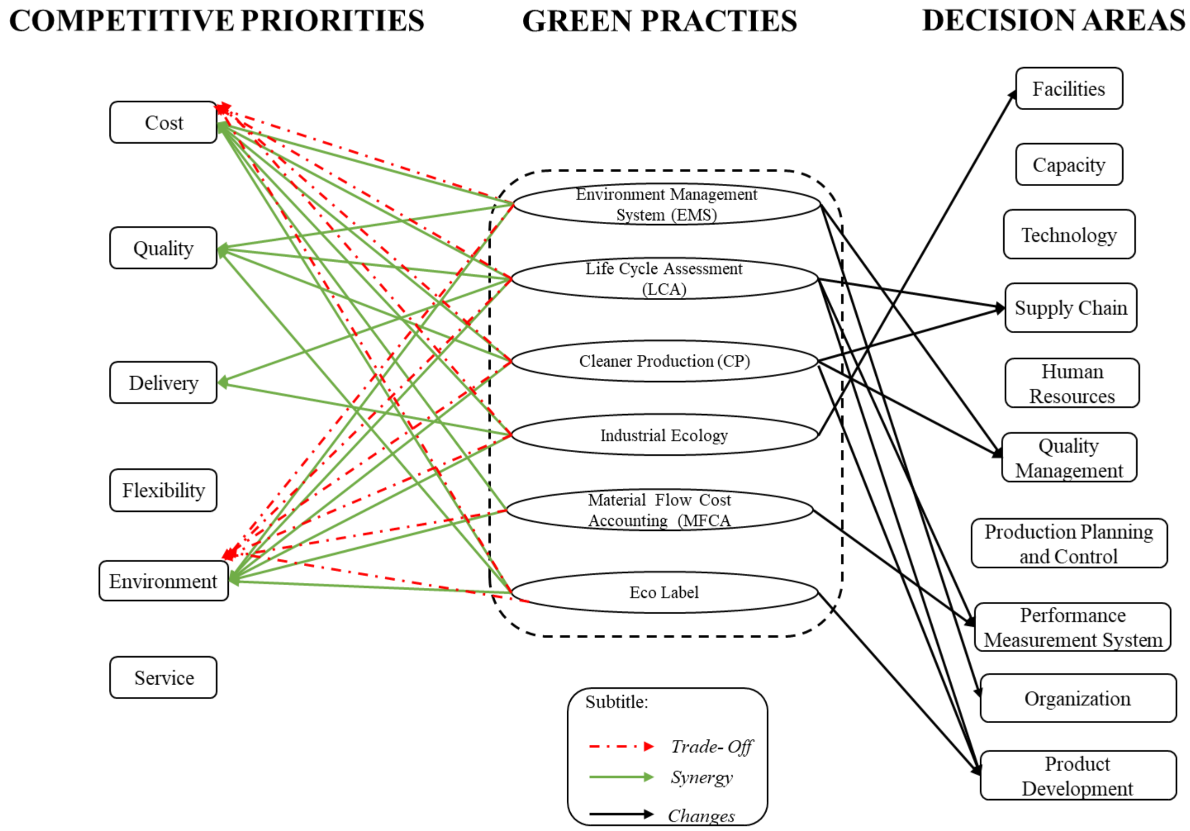


Figure 7 - GP and OS

(Figura 23 - Práticas Green e Estratégia de Operações.)

Source: created by the authors.

Lastly, it is important to present the practice Material Flow Accounting (MFCA), a method to measure the environmental performance by an accounting approach for estimating the output-input ratio and material flow using physical and monetary units (FU; GUO; ZHANWEN, 2017). Additionally, Dües et al. (2013) argue that GP have a positive influence on LP.

Although several studies argue that there are cost savings with the implementation of GP, it is possible to have certain trade-offs. These conflicts happen when the green improvement means an increase in cost or needs a huge investment. For example, when the results from an LCA or an improvement from an EMS identify that it is necessary to buy less harmful or more efficient equipment, the financial return on investment can be negative. Other example is related to the supply chain, when to reduce the CO_2 emission the load is consolidate, trying to transport with the least number of deliveries as possible, resulting in fewer emissions and fuel consumption. Thus, it can generate an increase in delivery lead time because some loads would have to wait to fill up the load.

4.2.3 Lean-Green Practices

This topic explains the LG Practices and it show the links with OS in Figure 8. They are described in more in all the details because they represent a consolidation of LG integration. These practices take the LP as a foundation and include the environment as a target of the improvements. This integration is one of the main steps for a LG and it helps to solve the trade-offs.

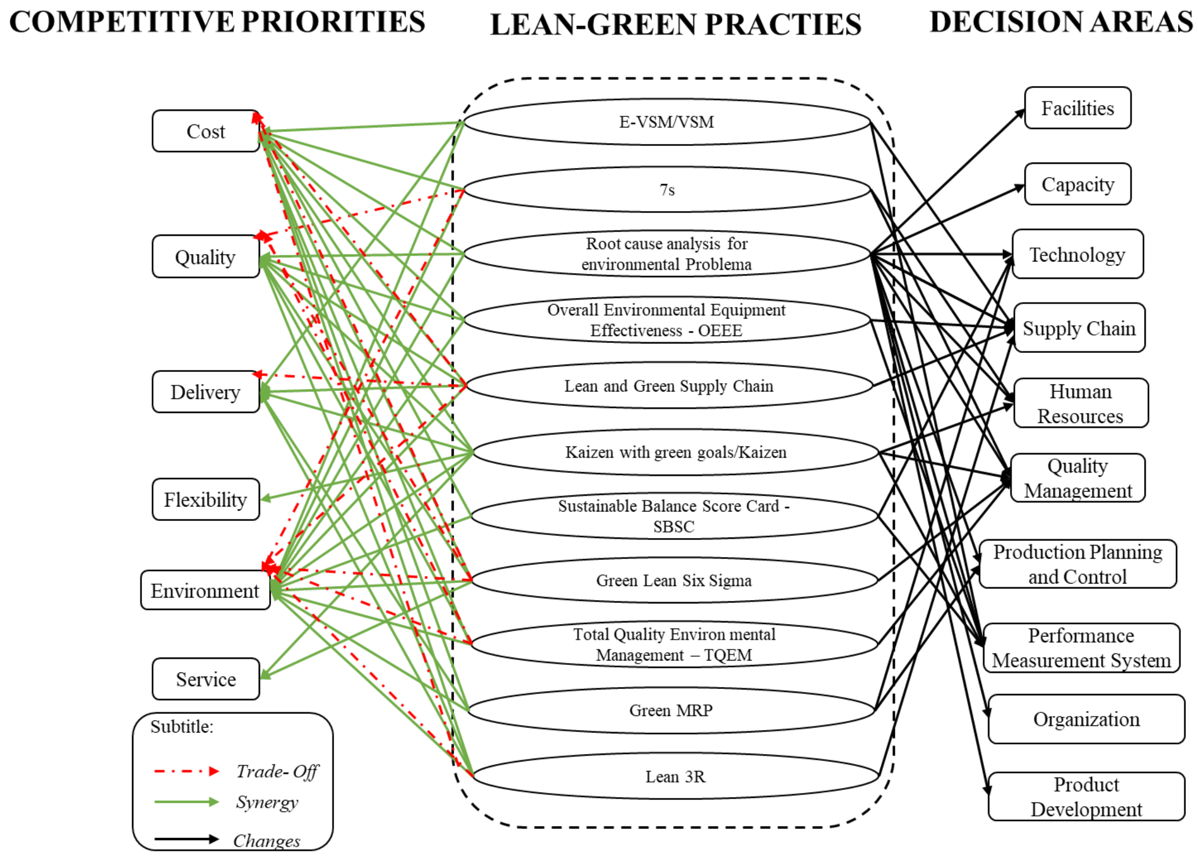


Figure 8- Lean-GP and OS.

(Figura 24 - Práticas Lean-Green e estratégia de Operações)

Source: created by the authors

4.2.3.1 E-VSM (Environmental Value Stream Map)

E-VSM practice, also called Green Value Stream Map, Extended Value Stream Map and Sustainable Value Stream Map was the most frequent LG practice in the studies analyzed. It aims to map the processes, present the main process indicators, and highlight the problems in the current state. This tool is based on Lean, specifically in VSM and it was created to guide improvement processes and facilitate communication between those involved. The environmental aspects, such as energy, water and materials consumption and emissions, are included in E-VSM and it helps to collect, and analyze these environmental data (AGUADO; ALVAREZ; DOMINGO, 2013; PAMPANELLI; FOUND; BERNARDES, 2014; SWARNAKAR *et al.*, 2020).

Regarding CP, this tool seeks to highlight performance indicators related to delivery, measuring lead-time of operations, quality, showing the rate of rework and defects in operations, and environment measuring environmental performance indicators such as consumption of materials, energy, water, emissions, among others. Cost is widely cited, since the general objective of an E-VSM is to reduce all types of waste, including environmental waste, seeking cost reduction or in some cases improving operational efficiency (BEN RUBEN; VINODH; ASOKAN, 2017; CHERRAFI *et al.*, 2017; SOUZA; ALVES, 2018). There is no trade-off observed with this practice; E-VSM has demonstrated a very synergic relationship with focusing on both Lean and Green.

In relation to the decision areas, this practice had a great impact on the decision area "performance measurement system". It is fundamental to measure and map the environmental impacts of the processes. The proposal is that sustainability indicators, raw material consumption, water consumption, energy consumption, waste generation, gas emissions, worker safety, ergonomic aspects and noise levels should be integrated in the traditional VSM, as exposed by Helleno et al. (2017) based on the proposal of (CALDERA; DESHA; DAWES, 2017; CHERRAFI *et al.*, 2017; FAULKNER; BADURDEEN, 2014; SULAIMAN *et al.*, 2019). In summary, as Faulkner and Badurdeen (2014) discuss, the E-VSM seeks to provide a wealth of information that can facilitate communication and management through Lean and Green indicators.

The Supply Chain is another area of decision, which is related to the E-VSM practice (Müller et al., 2014), since it can be used to obtain a global view of the entire chain (Caldera et al., 2017), from the extraction of the raw material to the final disposal, helping in the measurement, monitoring and visualization of possible improvements throughout the value chain. A point highlighted by Souza and Alves (2018) is the importance of integrating process information and understanding the client's value, i.e., capturing stakeholders' expectations following a life cycle perspective (Vinodh et al., 2016a). Therefore, when considering and integrating the entire value chain, it is essential to use LCA that contemplates product/service life cycle 'from cradle to grave', is the concept that is included in E-VSM to measure the environmental performance in the entire supply chain (LUCATO; VIEIRA; DA SILVA SANTOS, 2015).

4.2.3.2 7s

This practice is an extension of the 5s tool that includes safety in some cases, is called 6s and can be further expanded with one more s of sustainability. As far as priorities are concerned, this practice is used for cost reduction, quality and environmental improvement through waste reduction and environmental organization. Despite the presence of synergies to improve the cost, quality and environment, 7S may create trade-offs when increasing the consumption of cleaning products. Regarding the decision areas, it is noted that Quality Management in the improvement programs and Human Resources in the training are changed with inclusion of safety and environmental aspects.

In summary, the study presented by Anvari et al. (2011) shows that this program is the basis for improvement programs in the working environment. The study by Ho et al., 2015 states that the objective of this practice is to improve quality, increase sales, reduce cost and provide a quality environment. Duarte and Cruz Machado (2017) explain that this is a standardized work methodology used by organizations, which according to collaborate to achieve Green objectives.

4.2.3.3 Root cause analysis for environmental problems

According to Ben Ruben et al. (2017), the practice of root cause analysis can be extended to identify potential causes of environmental problems in processes, as already done for problems related to other competitive priorities.

Pinto and Mendes (2017) point out that this practice should be structured to allow the visualization of environmental problems and should be structured in cycles and improvement programs, such as PDCA and Kaizen. Galeazzo et al. (2014) complement that by adopting this approach together with quality managers it was possible to understand and question environmental problems and thus identify possible solutions. In summary, these studies infer that just like recurrent problems of quality or process inefficiency to reduce cost, environmental problems should be solved using the same reasoning as the others and can be included as variables for the cause of the other problems. Thus, it was found that these practices can change the way to solve the problems in Quality Management and support the achievement of cost, quality and environment.

4.2.3.4 OEEE

OEE is an abbreviation for the term Overall Equipment Effectiveness, which means the overall efficiency of the equipment in dealing with an indicator that monitors the efficiency of the manufacturing process. The OEEE, according to Domingo and Aguado, 2015, means Overall Environmental Equipment Effectiveness and incorporates the concept of sustainability based on the calculation of environmental impact in the life cycle. According to the authors, using this indicator can allow decision making by integrating sustainability and making comparative analysis of environmental impact when analyzing improvements implemented in the processes of the organization. Thus, it was observed that OEEE has a relationship with the area of Performance Measurement System and aims at efficiency improvements in which one monitors the performance in productivity and quality that imply cost reduction.

Also, this hybrid indicator is linked and can change the LP TPM and SMED. The first practice TPM (Total Productive Maintenance) is a set of techniques to ensure the reliability and productivity of all machines in the production process (FELD, 2000). The SMED (Single-minute Exchange of Dies) or Quick Tool Change has as principle to perform setup in less time, allowing increased flexibility and/or availability of the machine in the production flow.

*4.2.3.*5 *Lean and Green Supply Chain*

This practice, presented in the study by Sant’Anna et al. (2017) was defined as the combination of the three approaches Lean, Green and Supply Chain seeking cooperation for cost reduction, consumer focus, quality and environmental management through the ISO9000 and ISO14001 standards and risk management. In addition, the authors emphasize that the integration of the three approaches must be done to meet legal requirements, since Lean may not be sufficient to achieve them, and environmental management can collaborate in this direction. Thus, this practice seeks to include environmental performance in the decision area of supply chain and quality, as well as the objective of cost, quality and environmental performance (RUIZ-BENITEZ; LÓPEZ; REAL, 2017). Also, this practice involves supplier selection, procurement, third-party logistics and transportation that aim to minimize environmental impact of the product (MOLLENKOPF *et al.*, 2010).

One practice that is widely used to improve the delivery and reduce cost in supply chain is the JIT. As we cited before, this practice can present trade-offs between the competitive priority “delivery” and “environment”, because the studies show that to be better in delivery is necessary to increase the consumption of fuels and then increase the emissions for the environment (LONGONI; CAGLIANO, 2015a; MOLLENKOPF *et al.*, 2010; SALVADOR; PIEKARSKI; FRANCISCO, 2017; SARTAL; MARTINEZ-SENRA; CRUZ-MACHADO, 2018) Furthermore, it is important to highlight that LCA is a widely-used practice to measure environmental impacts in the supply chain. Thus, the decision area “Supply Chain” is modified by the practices Green Supply Chain, JIT and LCA and has to start to consider the trade-offs between delivery and environment in the decisions.

4.2.3.6 Kaizen with green goals

Lean uses kaizen for improvement processes. In this search, studies have been identified that deal with kaizen integrated with GP. They show that kaizen can be integrated into ISO14001 continuous improvement cycles, which can help involve employees and find innovative solutions to the problems identified (CALDERA; DESHA; DAWES, 2017; SINGH, P., 2019).

Kaizen with Green goals can affect mainly, in a synergic way, cost, quality and environment because it includes environmental objectives that can reduce energy and material consumption. Thus, environmental metrics, such as energy consumption (analyzing monthly energy bills), and water consumption within a period, are used to determine costs

(PAMPANELLI; FOUND; BERNARDES, 2014). In summary, as US EPA, 2007 shows, Kaizen activities should be aimed at reducing environmental costs in addition to tracking them, and the tools used in the improvement cycle are mainly traditional Lean tools. Thus, this practice implies changes in improvement programs (Quality Management), training for human resources (Human Resources), more involvement of employees and inclusion of the environment as a priority in the implemented improvements, measuring through environmental performance indicators.

4.2.3.7 Lean with environmental Indicators

First, it is important to show the study by (ZHU, X. *et al.*, 2017) that shows an adaptation in the BSC strategic planning tool including sustainability in financial, client, internal processes and learning and growth perspectives: SBSC - Sustainable Balanced Score Card. In summary, the BSC is about several interrelated indicators and indicators from these perspectives. According to the authors, including all these aspects in strategic planning can enable better performance management of the organization by senior management and can be a basic model to structure the integration of Lean and Green. The study of these authors highlights the inclusion of the social perspective, which is not the focus of this research, and the environmental perspective.

The authors stress the importance of performance measures and incentives for investments in information systems, coordination and autonomy for decision making. Thus, the use of this model for LG integration changes the system of performance measurement, information systems (technology) for measuring, recording and sharing information and seeks to monitor the results obtained in all competitive priorities and in the value chain from “Cradle to Grave”.

In addition, the most frequent indicators related to environmental priority are energy consumption (Kw/h), water consumption (m^3 consumed per period), kg of materials consumed, kg waste, kg of CO_2 emitted, among others. Several studies highlight the importance of including environmental performance indicators since this is what will allow integration with lean systems and monitoring of environmental gains (BEN RUBEN; VINODH; ASOKAN, 2017; CHERRAFI *et al.*, 2016; HELLENO *et al.*, 2017;

MOLLENKOPF *et al.*, 2010; PAMPANELLI; FOUND; BERNARDES, 2014; SREEDHARAN V; SANDHYA; RAJU, 2018).

*4.2.3.*8 *Lean 3R*

Lean 3R is related to the remanufacturing, recycling and reuse of products and/or materials used in the processes (DUARTE; CRUZ-MACHADO, 2019). It is defined as a product recovery process that uses energy and available resources and reduces the waste associated with the processes and therefore can increase the overall efficiency of the process. The advantages associated with it can include the reduction of lean waste such as overproduction, inventory, lead-time, unnecessary movement, waiting time and transportation (MAQBOOL *et al.*, 2019). So, there is a synergy between environment with cost. To be able to apply lean remanufacturing, this must be considered from product and process Design (VASANTHAKUMAR; VINODH; VISHAL, 2017). The GP Design for Environment and LCA are very useful with this practice (SALVADOR; PIEKARSKI; FRANCISCO, 2017).

*4.2.3.*9 *Green Lean Six Sigma*

This practice is a methodology that allows the search for environmental performance, applying robust tools for analysis and problem solving. Green Lean Six Sigma utilizes traditional aspects of Lean and Six Sigma while providing the tools needed to identify, implement and structure improvements that have a positive impact on the environment (SWARNAKAR *et al.*, 2020).

It is based on six pillars: leadership and people, Green and Lean six sigma tools, continuous improvement, strategic planning, interaction with stakeholders and results, and knowledge management Cherrafi et al. (2016). Kumar et al. (2016) highlight that this proposal has a great impact on product development, contributing to cost reduction, process optimization and enabling sustainability. Ruben et al. (2018) demonstrate that the Lean Six Sigma basis allows the reduction of process variations and thus helps in the reduction of defects and waste generation during the production process. In addition, the study by Sreedharan V et al. (2018) indicate that the use of these concepts contributes to the competitive priorities cost, quality and environment through reduction of environmental impacts and increases the level of service provided. Also, it is noted that this practice mainly modifies the following decision areas: Quality Management and Human Resources.

4.2.3.10 Total Quality Environmental Management - TQEM

This practice is a sub-development of the practice Total Quality Management- TQM, which extends the principles of quality management to include manufacturing practices and processes that affect environmental quality (CAMPOS; VAZQUEZ-BRUST, 2016; FLORIDA, 1996; PIL; ROTHENBERG, 2003; PRASAD; KHANDUJA; SHARMA, 2016; SALVADOR; PIEKARSKI; FRANCISCO, 2017). TQM can help increase quality (RAGHU KUMAR; AGARWAL; SHARMA, 2016) and reduce production defects, which consequently reduce the consumption of raw materials and energy use (BELHADI; TOURIKI; EL FEZAZI, 2018; SUNK *et al.*, 2017). However, trade-offs may arise when the production systems need more resources to improve the quality of the product (PIL; ROTHENBERG, 2003; ROTHENBERG; PIL; MAXWELL, 2001).

4.2.3.11 Green MRP

The Green MRP tool is essentially a conventional Material Requirements Planning system that has been modified to include environmental considerations, with the objective of minimizing the environmental impact of the generated waste, seeking to increase the planning potential for the components and process waste, i.e., optimize production planning in order to reduce possible problems related to the environment (MELNYK *et al.*, 2001).

This practice is directly related with the decision area “Production Planning and Control”. The production schedule and delivery schedule can help the environmental performance by minimizing net energy consumption and defining shorter delivery routes to reduce the emissions of CO2 (BALL, 2015). Thus, this tool aims to balance better production planning with cost and environmental performance. Therefore, this tool directly influences the decision area “Production Planning and Control”, “Capacity” and “Technology”.

4.2.3.12 Closing remarks from LG practices

The main aspects from the hybrid practices that integrate Lean and Green are that they focus on simultaneously considering the environmental performance and the other performance goals with the same degree of weighting in most cases, which helps to solve the trade-offs that can emerge in production systems. Because these tools make environmental indicators visible, train employees in environmental priorities, they make the environment an important variable in the process of continuous improvement and decision making.

Another important aspect from hybrid tools and LG integration is that simultaneous implementation of LG methods multiple performance parameters and this can result in significant cost reduction (MILLER; PAWLOSKI; STANDRIDGE, 2010). Furthermore, when Lean and Green are implemented together, they can create a more significant positive impact on organization than when implemented separately (Cherrafi et al., 2018; Dües et al., 2013)**.**

Finally, it is important to observe that the hybrid LG tools emerge from Lean. This feature can infer that Lean is used as a foundation for management of production systems to implement the OS. Furthermore, GP work as a complement of Lean to help to support the OS that the environment is a competitive priority. Also, Lean can be insufficient to be fully Green.

4.3 Summary and research agenda

Most of the studies found are empirical and focus on understanding the relationship between Lean and Green and how they can be integrated. Their results suggest that Lean and Green objectives are different in essence, i.e., while LP aim to reduce cost and lead time (delivery) and improve quality and flexibility, GP seek to reduce waste related to environmental impacts (CHERRAFI *et al.*, 2016, 2017; MILLER; PAWLOSKI; STANDRIDGE, 2010; MOR; SINGH; BHARDWAJ, 2016; ROTHENBERG; PIL; MAXWELL, 2001; SARTAL; MARTINEZ-SENRA; CRUZ-MACHADO, 2018; SUIFAN; ALAZAB; ALHYARI, 2019). Fahad et al. (2017) cite that Lean waste is different from Green Waste. Pinto and Mendes (2017) in agreement with Kleindorfer et al. (2005) point to the fact that Lean and Green objectives are different and generate different impacts on business performance. GP have the direct and clear objective of reducing the environmental impact of processes, while LP will directly impact on cost reduction, lead time and quality improvement and the improvement of environmental aspects can be achieved indirectly.

From these results it is possible to understand that Lean and Green are synergic in most of practices but some trade-offs exist. In this sense, it is important to have the OS well defined to support the strategy and the targets of the organization the environment is a CP, Lean can be insufficient to solve the trade-offs, thus it becomes necessary include GP directly in the decision areas. Also, when LP and GP are implemented together, it becomes possible to leverage the performance of an organization than when they are implemented separately. Moreover, these results reveal to us that there are many trade-offs that have not yet been explored, as well as synergy relationships that are often limited to waste reduction and efficient use of resources. Also, the strategic perspective of LG is still missing. Given these gaps, future research is suggested:

- Verifying the existence of unidentified trade-offs between the Lean and Green, as well as an understanding of how much and how the competitive priorities are affected and evaluating quantitatively the relationship between individual practices and the contribution for the competitive priorities.
- In-depth exploration of the changes and the contribution from LG implementation in the decision areas. Also, exploring the particularities of each practice to be implemented.
- Empirical studies asking how companies frame their competitive priorities and decision areas in different levels of Lean and Green implementation and in different industrial sectors. Also, the researchers in operations management should quantify the performance of the companies related with the operation strategy adopted.
- Quantifying the synergy between the LG empirically, exploring different industrial sectors as well as different operations strategies.
- Identifying and comparing the reasons for OS formulation and Lean-GP adoption and discussing their strategic role.
- In terms of research methods, based on theoretical propositions identified qualitatively by most of the researched literature quantitative approaches can be developed, as surveys and modeling, to confirm them.

5. Conclusions

The main intention of this work was to provide, from studies reported in the literature about LP and GP, an initial and holistic analysis of the adoption of such practices from the perspective of the OS, presenting synergies and trade-offs between competitive priorities, as well to discuss the main changes in decision areas from LG implementation.

The study of these links between the entire content of OS in LG literature is still recent and complex. The systematic review of the literature performed indicates that the analyzed articles do not cover the entire content of the OS and that the studies are still exploratory. As discussed, there is a tendency to favor a few practices, or a few competitive priorities, or only economic results and environmental impacts, namely in terms of cost reduction and energy consumption, waste generation and emissions resulting from the implementation of LG. Through this systematic literature review, it was possible to answer the proposed RQs. Content analysis was performed for 260 papers. This made possible an initial attempt, based on the SLR performed, to address the implementation of LG from the perspective of the content of the OS, consolidating the OS content with LG.

This work has some limitations. First, it is entirely theoretical, exploring articles published in three databases and only from journal publications. Second, it focuses only on the immediate links between the content of OS and LG, excluding the enabling and hindering variables of practices and OS adoption.

Finally, in an attempt to contribute to a theoretical discussion of the strategic roles of LG, this article proposes considering them as part (of the actions) of the OS and, thus, by promoting changes in the decision areas, they contribute to the achievement of competitive priorities. In addition, the results of this article have the potential to help managers and policymakers gain a holistic understanding of how they can implement integrated practices and learn about existing practices to improve the environmental impact of lean systems.

4. ESTUDO DE CASOS MÚLTIPLOS - LEAN AND GREEN MANUFACTURING : TRADE-OFFS FROM THE PERSPECTIVE OF OPERATIONS STRATEGY IN THE AUTOMOTIVE INDUSTRY

Neste capítulo, serão apresentados os resultados empíricos obtidos a partir da aplicação de estudos de casos. O Capítulo 4 será estruturado no formato de artigo.

Lean and Green Manufacturing : trade-offs from the perspective of operations strategy in the automotive industry

Abstract

Pressures from society, governments, investors, and customers have motivated organizations in the implementation of practices to reduce their environmental impact. Green practices were then implemented in production systems that had already implemented Lean practices as a way to meet this new demand. So, the production systems now must combine or integrate the two sets of practices and align them with their operations competitive priorities and with companies' competitive strategies. The literature has addressed the issue of practices integration, but few studies have focused on the alignment of practices and operations priorities. Thus, in this research, we carried out case studies in automotive sector companies to identify and discuss operations strategies that involve the implementation of Lean and Green practices. Different forms of operations strategies were found combining different levels of importance attributed to environment as an operations' competitive priority and different levels of implementation of Green practices. In addition to changes in structural decision areas - in product design and production processes - the movement to reduce environmental impacts and the attempt to integrate lean and green practices led companies to modify their infrastructural areas - mainly, performance measurement system, human resource and organization. Companies have also had to deal with trade-offs between the operations competitive priorities of cost and environment.

1. Introduction

Since the study published by Florida (1996), exploring how companies can integrate environmental issues in manufacturing by implementing Lean and Green practices, an increasing number of studies have being considering these practices, named “Lean-Green” approach or management paradigm, as a key to improve business competitiveness (BHATT; GHUMAN; DHIR, 2020; DUARTE; CRUZ-MACHADO, 2019; SIEGEL *et al.*, 2019). When recognizing environmental performance as a competitive priority, there is a tendency for companies to incorporate it into their operations strategies (GANDHI; THANKI; THAKKAR, 2018a; GARZA-REYES, 2015; LONGONI; CAGLIANO, 2015b). Thus, organizations and researchers began looking for solutions that would promote the integration and alignment of practices to improve the operational (Lean) and environmental (Green) dimensions (LEONG, W. D. *et al.*, 2020; THANKI, S.; THAKKAR, 2020).

Lean-Green literatures have been proposing some tools and frameworks for the LG integration (BEN RUBEN; VINODH; ASOKAN, 2017; PAMPANELLI; FOUND; BERNARDES, 2014; SOUZA; ALVES, 2018), presenting the results from implementation of them (CAMPOS; VAZQUEZ-BRUST, 2016; CHIARINI, 2014; GARZA-REYES *et al.*, 2018a), exploring and explaining synergies and trade-offs between competitive priorities when practices are implemented (HABIDIN, Nurul Fadly *et al.*, 2018; RESTA *et al.*, 2017; ROTHENBERG; PIL; MAXWELL, 2001; SUIFAN; ALAZAB; ALHYARI, 2019), and providing evidence about how cross-functional executive involvement and worker involvement in the formulation and implementation of the OS can support the strategic alignment of Lean and sustainability (Longoni; Cagliano (2015).

Although these studies discuss this range of aspects, highlighting the (potential) synergies between Lean and Green (Dües et al., 2013; Florida, 1996; Garza-Reyes et al., 2018a; King and Lenox, 2001), they do not provide guidelines on how Lean-Green should be integrated into production systems. To overcome this gap it is necessary to consider the operations strategy's content and the implementation process (LONGONI; CAGLIANO, 2015a). Moreover, holistic and empirical studies on the content of Operations Strategies (OS), in companies that implement Lean-Green, have not yet been published. Research on this topic is still needed to discuss in detail and in depth the trade-offs and synergies between competitive priorities and changes in decision areas when LG is implemented.

Most Lean and Green structures are developed in the automotive sector. Additionally, this industrial segment is representative in terms of benchmarking for Lean implementation (HOLWEG, 2007; KRAFCIK, 1988; OHNO, 1997; WOMACK, James; JONES, 2004). Thus, the automotive sector will be the focus of this research, as it can provide empirical data on operations strategies of companies that adopt the Lean and Green approaches.

We aim answering the following question *"What are the operations strategies contents of companies in automotive sector that implement Lean and Green practices?* Accordingly, the purpose of this study is to identify and analyze the OS of companies in the automotive sector that have implemented Lean and Green practices. Our focus is precisely on assessing operational competitive priorities and practices and changes in decision areas; evaluating possible stages of implementation of LG practices; describing the effect and the rationale of Lean-Green practices implementation in the organization's operations strategy;

and explaining the juxtaposition of Lean and Green Manufacturing practices from the perspective of operations strategy.

As such, identifying operations strategies will reveal which and in what level competitive priorities are addressed, identifying companies' intensions and achievements when lean and green practices are implemented. In other words: does LG implementation promote the priorities established in operations strategies? Does LG implementation cause trade-offs between operations priorities? What decision areas should be modified when LG practices are implemented? Studies with this aim can provide guidance on which practices must be implemented and combined when a company intends to improve certain competitive dimensions; especially when the environment (priority) is added to traditional competitive priorities.

To achieve these objectives, we carried out empirical exploratory case studies in six companies, in which four are Original Equipment Manufacturer (OEM) and two are suppliers. This set of studies can contribute to the field of operations management by presenting a broad perspective of Lean-Green literature and by providing empirical evidence on how companies can frame their operations strategies to achieve operational and environmental targets.

This paper is organized as follows: Section "Theoretical background and research model" states the main concepts from the LG and OS literature. Section "Research Method" details the scientific method. Section "Results" presents our findings in the cases. The "Discussion" is the section where we analyse the results and Section "Conclusion" presents the managerial implications and theoretical contributions by highlighting the limitations of the study and future research directions.

2. Theoretical background and research model

We present a conceptualization of OS and LG and a literature review on these topics to later expose an initial conceptual framework, based on the literature, which includes Lean-Green practices as part of the operations strategy content (competitive priorities and decision areas). This framework presents five theoretical prepositions analysed in the cases.

2.1Operations Strategy

The competitive or corporate strategy is the pattern of purposes and goals - and the main policies for achieving those goals - that define the business or businesses with which the company is involved and the kind of company it wishes to be (Andrews, 1988). Regarding the operations strategy, Skinner (1969) was the pioneer in highlighting and conceptualizing it, demonstrating the importance of incorporating and aligning the operational elements of the production function in the corporate strategy. According to this author, it should be considered as strategic and a source of competitive advantage.

OS can be defined as a sequence of decisions that over time enables a business unit to achieve a desired production structure and infrastructure and a specific set of resources, that is a consistent pattern of decision making in the production function, aligned to the business strategy (WHEELWRIGHT, 1984). There are two strands to the studies in OS: the content that represents the decisions made by the corporation for the effectiveness of the strategy and the strategy process that synergizes the stages of strategy formulation and implementation (KIM; ARNOLD, 1996). In this study we focus on the content of the OS. Figure 1 represents the content of OS based in Leong et al. (1990) and Wheelwright (1984).

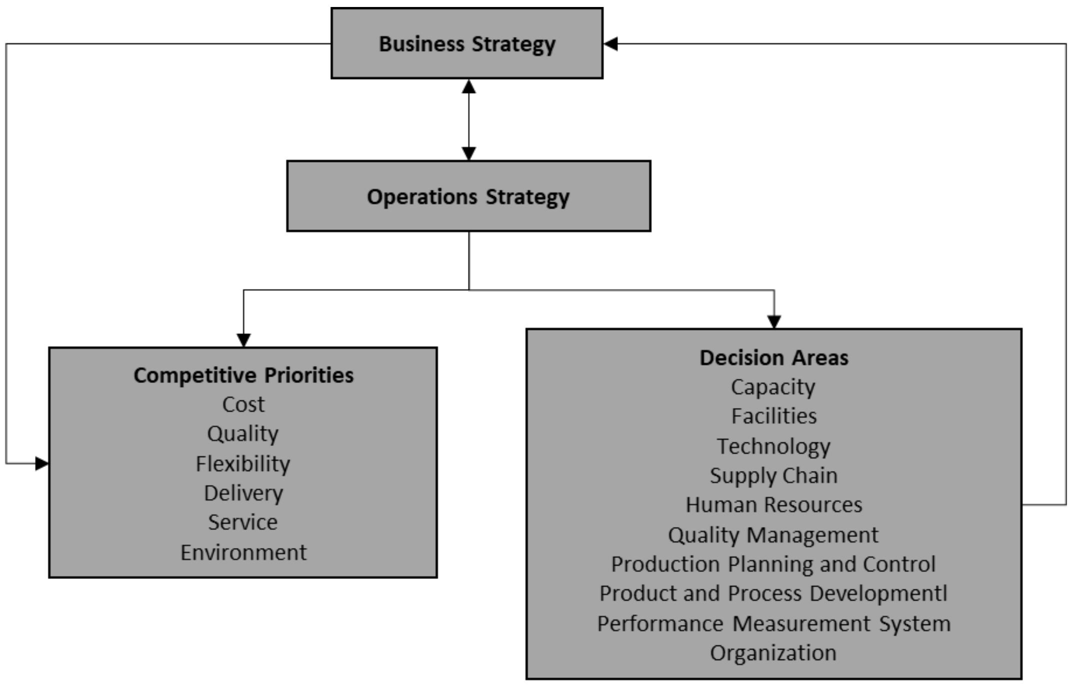


Figure 1 - OS content.

(Figura 25 - Conteúdo da Estratégia de Operações.)

Source: Based on (LEONG, G. K.; SNYDER; WARD, 1990; WHEELWRIGHT, 1984).

The competitive priorities are related to the performance objectives that the production function adopts to align with the company's competitive strategy (SKINNER, Wickham, 1969). The competitive priorities adopted in this paper were proposed by Garvin (1993): cost, quality, flexibility, delivery and service. Also, we have included the priority “environment” representing environmental performance, that has been considered as a new operation competitive priority (ANGELL; KLASSEN, 1999; DE MORAES, 2019; MARCUS; FREMETH, 2009). These competitive priorities are gotten through the decision areas (SKINNER, Wickham, 1969).

The main structural decisions influence project activities (e.g. technology, facilities, capacity), whereas the main infrastructure decisions are related to the workforce, planning, control, and improvement activities. The authors also point out that production needs to have an adequate infrastructure that guides the way to produce on a daily basis to ensure the functioning of improvements, high-cost technologies, and facilities (SLACK; LEWIS, 2011). This paper considers ten decision areas, listed below:

- Capacity: Operational capacity, number of units, variety of products (SLACK; LEWIS, 2011).
- Facilities: Plant size, layout, number and Location of facilities (MILTENBURG, 2005; SKINNER, Wickham, 1969).
- Technology: equipment, use of advanced technologies, systems, process type and maintenance practices (MILTENBURG, 2005; SKINNER, Wickham, 1996).
- Supply Chain: Degree of vertical integration and policies towards suppliers’ relationship (MILTENBURG, 2005; SLACK; LEWIS, 2011).
- Human Resources: policies about employees as skills, compensation system, incentives, training, degree of specialization required and performance appraisal. (MILTENBURG, 2005; SKINNER, Wickham, 1969).
- Quality Management: Quality policy and quality management system (HAYES *et al.*, 2007);
- Production Planning and Control: production scheduling, materials requirement planning, inventory and production control, planning input, planning strategy and planning horizon (HAYES *et al.*, 2007; MILTENBURG, 2005).
- Product and Process Development Product Design, Use of manufacturing engineering, technological risk and design stability (FINE; HAX, 1985; SKINNER, Wickham, 1969).

- Performance Measurement System: System of performance indicators(HAYES *et al.*, 2007).
- Organization: This decision area covers organizational hierarchy, culture, management style and organizational structure (MILTENBURG, 2005; SKINNER, Wickham, 1969).

Voss (2005, 1995) argues that the content of OS can be viewed as the strategic choices in process and infrastructure. Withal, these studies consider three paradigms that determine these choices: the company compete through manufacturing by aligning its operations capabilities with market requirements; strategic choices related to structure and infrastructure decisions (e.g. make or buy; manufacturing systems, logistics systems); and the third paradigm is related to the adoption of best practices (e.g. lean manufacturing, six sigma) to achieve competitive advantage. In this research, all will be addressed.

2.2Lean-Green

Shah and Ward (2007, p.791) conceptualize Lean Manufacturing as "an integrated socio-technical system whose main objective is to eliminate waste by concurrently reducing or minimizing supplier, customer, and internal variability". Also, LM is considered as a set of principles and practices to eliminate all forms of waste within an organization (MOSTAFA; DUMRAK; SOLTAN, 2013). More and more organizations from the most diverse sectors of the economy around the world are embracing LM practices (LOSONCI; DEMETER, 2013). These wastes are categorized into defects, inventory, inappropriate processing, overproduction, waiting, handling, transportation and talent (LIKER, 2005). The main Lean practices, among the most used are 5s, Kaizen, Value Stream Map (VSM), Just in Time (JIT), Single Minute Exchange of Die (SMED), Total Productive Maintenance (TPM), Kanban, Standardized Work, Visual Management, and 5 Why's (root cause analysis) and A3 report (SHAH; WARD, 2007).

The term Green Manufacturing came out in the 1990s as a philosophy and operational approach to reduce the negative environmental impacts of products, as well as to increase the environmental performance of processes as long as economic objectives are met (GARZA-REYES, 2015). Thus, several studies (DILIP MARUTHI; RASHMI, 2015; KLEINDORFER; SINGHAL; VAN WASSENHOVE, 2005; PATHAK; SINGH, 2017; SILVA; SILVA; OMETTO, 2015) summarize that Green Manufacturing is about the quest to reduce pollution, energy consumption and the generation of toxic substances through the development of new processes in the manufacturing phase. According to Pampanelli, Found, and Bernardes (2014) and Silva, Silva, and Ometto (2015), a Green company can apply different tools to reduce the environmental impacts generated by production processes, such as Cleaner production, Life Cycle Assessment (LCA), Environmental Management System, Circular Economy, Eco-design, Green Supply Chain, and 3R (Recycling, Remanufacturing and Reuse). It is important to highlight that GM has been through some changes, being the first implementations, around 1970’s, focused on the end of pipe approach with corrective actions only and, nowadays, since 2010’s, the GM is considered as a strategic approach with pro-active actions and green business strategies (KHAN, M. P.; TALIB; KOWANG, 2020).

LM and GM are considered compatible and synergic as they focus on the reductions of waste and efficient resources usage (GARZA-REYES, 2015). To refer to the integration of these approaches the term “Lean-Green” (DUARTE; CRUZ MACHADO, 2017) will be used. The LG literatures consider that this integration help the organizations achieve better results, as compared to implement LM and GM separately (CHERRAFI *et al.*, 2017). Moreover, previous evidence suggests that LP can help organizations to get environmental performance (DIESTE; PANIZZOLO; GARZA-REYES, 2020). However, some researchers, like the study of Rothenberg et al. (2001), argue that there are some conflicts as the environmental impact reduction is not yet the focus of Lean, provided that sometimes Lean improvements can increase environmental impacts. Regarding the OS and Lean-Green literature, the next section presents the main theoretical evidence found about them.

2.3OS content and LG Conceptual Framework

In the Lean-Green literature review (Queiroz et al., 2021, in press) congruities and trade-offs between Lean-Green practices were identified from the perspective of operations strategy. Based on the results from this review, the following five theoretical propositions were identified, as presented in Figure 1, and described as follows.

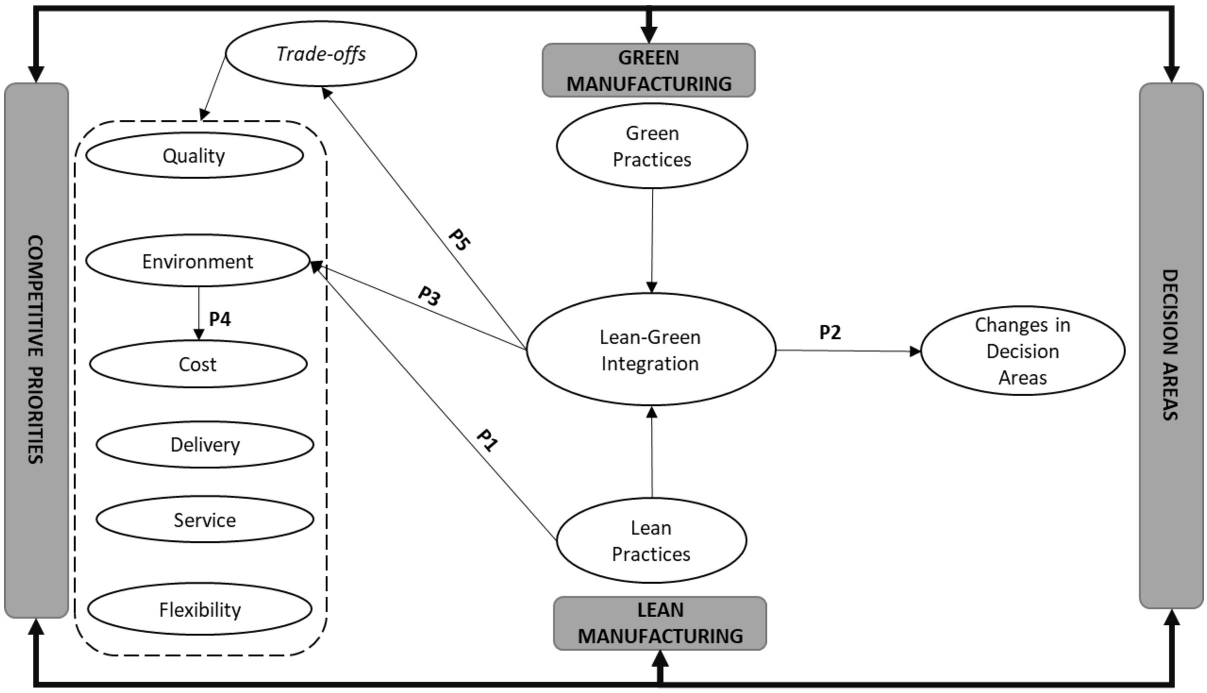


Figure 2 Conceptual Framework.

(Figura 26 - Modelo Conceitual.)

Source: Elaborated by the author.

Several studies, such as (DIESTE; PANIZZOLO; GARZA-REYES, 2020; VAIS *et al.*, 2006; VINODH; ARVIND; SOMANAATHAN, 2011), have demonstrated that Lean can bring environmental benefits and that this can be attributed to more efficient use of resources (such as water and other inputs). Similarly, Florida (1996), King and Lenox (2001), Dües, Tan, and Lim (2013), Chiarini (2014) and Garza-Reyes et al. (2018) argue that Lean practices implementation can offer significant advantages and synergies with the green performance of companies. This leads to Proposition 1:

P1: Lean can help reducing the environmental impacts from production process.

Although the literature shows that Lean can reduce the environmental impacts, there are studies arguing that, to achieve results in a sustainable way, some changes in decision areas are necessary. Firstly, Lean does not directly take the environmental impacts into consideration. Hence, organizations need to implement Green tools to fill this gap (Ng et al., 2015; Ruiz-Benitez et al., 2019). There are some frameworks to enable the synergies of Lean and Green, and some have proposed some adjustments in Lean tools to assist improvements in environmental performance (Garza-Reyes et al. 2018). These studies point out that to integrate Green in Lean explicitly is necessary, considering the environmental aspects in training, performance indicators and tools (BELHADI; TOURIKI; EL FEZAZI, 2018; BEN RUBEN; VINODH; ASOKAN, 2017; CHERRAFI *et al.*, 2016; DUARTE; CRUZ MACHADO, 2017; DÜES; TAN; LIM, 2013). Based on this, it was possible to infer the second theoretical proposition.

P2: Lean is not enough to be Green; it is necessary to implement Green Practices and change the decision areas.

The third proposition is related to the second one. Studies integrating Lean show that, besides aiming the improvement of cost, time and quality, it is necessary to integrate environmental aspects, such as energy, water and material consumption, reduction of emissions and waste generated by the processes (ALVES; ALVES, 2015; AZEVEDO, Susana G. *et al.*, 2012; BEN RUBEN; VINODH; ASOKAN, 2017; BRAGLIA *et al.*, 2020; GARZA-REYES, 2015; MINH; NGUYEN; CUONG, 2019; NG; LOW; SONG, 2015; SOUZA; ALVES, 2018; WONG, W. P.; WONG, 2014). This "environment" competitive priority was the most frequent in analyzed studies. Therefore, we can infer another theoretical proposition:

P3: The environment is a new competitive priority in companies that have already implemented Lean.

Regarding the "cost" priority, the second more frequent in these studies, it is important to highlight that cost is one of the most important motivation for organizations to reduce the environmental impacts. It is increasingly related to cost reduction of material, water and energy consumption, as well as waste disposal costs have dramatically increased over the past decade (GUPTA *et al.*, 2018). Furthermore, there are empirical studies that present the cost reduction through improvements in environmental aspects (CHERRAFI *et al.*, 2016; DE CARVALHO; GRANJA; DA SILVA, 2017; MILLER; PAWLOSKI; STANDRIDGE, 2010; PRASAD; KHANDUJA; SHARMA, 2016; TORIELLI *et al.*, 2010). In addition, improving the environment can lead to cost reductions from any punitive or restrictive measures that may be introduced through legislation (BALL, 2015). Thus, it is possible to reveal the fourth theoretical proposition:

P4: Prioritisation of the environment is dependent on investment and cost estimates and expected results.

Additionally regarding competitive priorities, it is important to highlight: literature shows that the implementation of Lean and Green practices can result in trade-offs (KLEINDORFER; SINGHAL; VAN WASSENHOVE, 2005; LONGONI; CAGLIANO, 2015a; PAMPANELLI; FOUND; BERNARDES, 2014; SALVADOR; PIEKARSKI; FRANCISCO, 2017). Longoni and Cagliano (2015a) argue that trade-offs might emerge when a business simultaneously pursues LM and environmental goals. Lean and Green share waste reduction, but differ in emphasis (DE CARVALHO; GRANJA; DA SILVA, 2017).While green initiatives aim to reducing pollution, Lean still does not have this as a priority (MOLLENKOPF *et al.*, 2010; PAMPANELLI; FOUND; BERNARDES, 2014) argue that the Lean is focused on manufacturing efficiency. Besides that, by introducing green practices into a Lean operating environment, companies will often have to make trade-offs between multiple targets that cannot be perfectly compatible.

One of the most frequent trade-offs cited in the literature refers to delivery and environment. Lean practices may negatively impact the environment, since the just-in-time (JIT) delivery process results in more deliveries, and therefore more emissions from the vehicles (AZEVEDO, Susana Garrido; CARVALHO; CRUZ-MACHADO, 2016; CAMPOS; VAZQUEZ-BRUST, 2016; LEE; PRABHU, 2016; LONGONI; CAGLIANO, 2015a; MOLLENKOPF *et al.*, 2010; SALVADOR; PIEKARSKI; FRANCISCO, 2017; WANG, Z. *et al.*, 2015). Other trade-off pointed out in the literature is related to environment and quality. Pil and Rothenberg (2003) exemplify that sometimes more consumption resources are necessary to maintain a good quality of the product. In addition, another trade-off found is related to flexibility and environment. Small batches allow more product variety of products, but they may increase the amount of setups (DÜES; TAN; LIM, 2013; SAWHNEY *et al.*, 2007). Based on these, it is possible to infer the fifth theoretical proposition:

P5: The Lean-Green integration can create trade-offs between the competitive priorities.

Based on the evidence found in the literature, the theoretical model presented in Figure 5 proposes that operations strategies can have different profiles according to the valuation of the priority environment, its alignment (compatibility or trade-offs) with the other competitive priorities and according to the implementation of lean and green practices, with consequent changes in decision areas. In summary, these propositions explain the possible configurations that operations strategies can assume when companies implement lean and green practices.

3. Research Method

This work has an exploratory character, which means that the variables are still unknown, and the phenomenon cannot be fully understood (Voss, Tsikriktsis, and Frohlich 2002). We employed a case study methodology, since, according to Eisenhardt (1989), building theory from case study research is most appropriate in the early stages of research. In addition, case study is a suitable methodology when research questions focus on contemporary events and when it is unnecessary to control behavior events or variables (Yin 2017). We studied multiple cases to explore the OS content of automotive companies that have implemented Lean and Green practices. The research steps are presented in Figure 3.

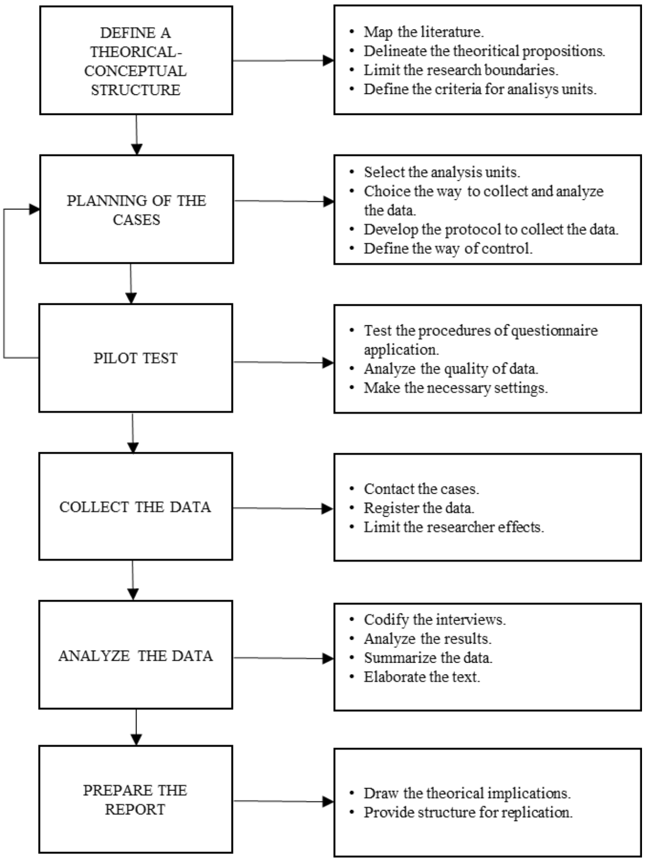


Figure 3 Research Phases.

(Figura 27 – Etapas da Pesquisa.)

Source: Based on Yin (2017).

The steps of the research were based on Yin (2017) and are elucidated in the follow sections.

3.1 Cases Selection

The automotive sector was chosen to be the focus of this research because, as shown in introduction, the Lean sector is where the approach was created and developed, and the sector where it is more advanced and widespread. The origin of Lean was in the Toyota Production system and today the automotive sector is a benchmarking for Lean implementation (HOLWEG, 2007; KRAFCIK, 1988; OHNO, 1997; WOMACK, James; JONES, 2004). Also, most of the empirical studies about Lean-Green have been performed in automotive industry. As shown in the study of Caldera and Dawes (2017), most of Lean and Green frameworks are developed in the automotive sector. Thus, the automotive sector will be the focus of this research, since it is a sector that can provide more empirical data of operations strategies concerning the adoption of Lean and Green approaches.

Table 1 Sample selected.

(Quadro 9 - Amostra selecionada para o estudo)

Company	Posiiton in Value Chain	Business unit number of workers	Business unit Location	Country of orign	Multinational Company	Respondent
A	OEM	More than 1000	Canada	Sweden	Yes	Manufacturer Manager and Sustainability projects manager
B	OEM	More than 1000	Brazil	Japan	Yes	Manufacturer Manager and Sustainability projects coordinator
C	OEM	More than 1000	Brazil	Japan	Yes	Manufacturer Manager and Facilities Manager
D	OEM	More than 1000	Brazil	Italy	Yes	Manufacturer Manager and Environmental Manager
E	Supplier Tier 1	More than 1000	Brazil	Germany	Yes	Manufacturer Manager and Enviromental Manager
F	Supplier Tier 1	More than 1000	Brazil	United States	Yes	Manufacturer Manager and Sustainability Director

Secondly, the research was intended to be developed in 2 countries: Brazil and Canada. These countries were chosen for a sample of convenience. Seeing that the research project involved researchers from both Brazil and Canada. In addition, a sample covering two countries has the objective of allowing the research to have an international scope with two countries that have different characteristics. These differences between them are related to different levels of technological development, with different economic indicators performance, different cultural aspects, different participation of each sector in the overall economy and they could eventually represent relevant points of observation which could lead to different results, and that could contribute to advance the understanding of different operations strategies, adopted practices and different levels of implementation of Lean and Green. Also, these countries have different levels in sustainability. Sachs et al. (2020) published the Sustainable Development Report (formerly the SDG – Sustainable Development Goals Index & Dashboards), that is a global assessment of countries' progress towards achieving the SDG. It is a complement to the official SDG indicators and a voluntary national review. According to this report, Canada and Brazil occupy different positions in the ranking as follow: 21th position for Canada, 53th position for Brazil. This may lead to an analysis that will allow the identification of companies in different contexts.

The field study focused on automotive sector, the sample composed by four OEMs and two suppliers for automakers, which meet the following criteria: they have implemented Lean Manufacturing and they have implemented Green practices or are still implementing them. After selecting the companies, an e-mail was sent to invite the employees that work in the selected companies to answer the questions.

3.2 Data collection and analysis

To carry out the research, on-line interviews were carried out with operations managers and the staff responsible for the environmental management. The first part was a structured questionnaire that the respondents answered before the semi-structured interview. Questions are related to the main characteristics of the company, the operations strategy content highlighting the competitive priorities and decision areas, the Lean and Green practices adoption, and the questions are about the integration of LG. For the data collection we developed a case study protocol, summarized in Table 2, to ensure the research design was complete and feasible (YIN, 2017).

Table 2 Case Study protocol Steps, based in Yin (2017).

(Quadro 10 - Etapas do Protocolo para estudo de caso.)

Case Study protocol steps
A. Introduction to the case study
1. Research questions
2. Conceptual Framework
B. Data collection procedures 1. Identification of the companies 2. Data collection Plan 3. Interview Guide *(A) Respondents profile - 3 questions;* *(B) Firm Characteristics - 11 questions;* *(C) Operations Strategy (competitive priorities and decision areas)- 10 questions;* *(D) Lean Manufacturing - 7 questions;* *(E) Green Manufacturing – 11 questions;* *(F) Lean Manufacturing and Green Manufacturing integration - 12 questions.* 4. Document Analysis C. Outline of case study report D. Data analysis Plan

The questions about operations strategy were based in Ward *et al.*, (1998), the Lean questions were based in Shah e Ward (2003) and the Green section was based in practices presented by Thanki Govindan e Thakkar (2016) e Silva, Silva e Ometto (2015).

After the pilot test, necessary adjustments were effectuated in this case study protocol before collecting data in other selected cases. For each case, the intention was to interview at least the operations director or manufacturing manager and the environmental manager for triangulation purpose. Yin (2017) argue that using triangulation of data adopting different sources of evidence in a case study is of the utmost importance to neutralize any points of view that may arise among respondents and to obtain complementary thoughts on the same phenomenon of the studied organization.

Data were collected through interview with structured and semi-structured questions. The structured questions to be able to have a measurement scale and allow a comparative analysis between the cases. The semi-structured questions have already related to the exploratory character of the research. The answers to these questions collaborated to analyze case by case in depth and capture the detailed perception of those involved in the research. Furthermore, data were obtained from documentary analysis, when authorized by the companies. Interviews were done on-line due to the COVID-19 pandemic. Also, it is important to highlight that the companies' name will be kept confidential, being coded as Company A, B, C, etc.

After the data collection, a content analysis was carried out. Data coding and content analysis will follow the recommendations of Krippendorff (2004), seeking to answer the research questions. To do so, the QDA Miner version 5 Software was used as a tool to facilitate the analysis process (individual cases and cross-cases). Codes are crucial to help identify relations and establish connections among the cases (GIBBS, 2009). The codification allowed the registration of all stages of analysis and facilitating the empirical proof of interpretations carried out in the analysis of the data. The content analysis method was performed following a codification process of the research constructs. The codebook used is in the supplementary material of this work.

4. OS and Lean-Green practices of companies

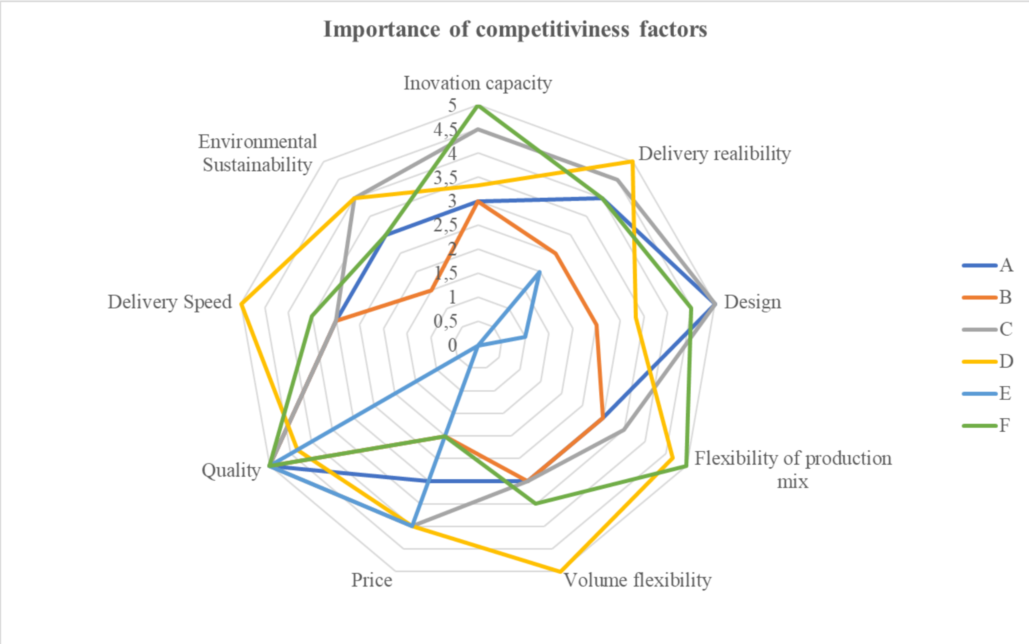
We present a comparative analysis of the OSs adopted by the six companies from the automotive sector. As shown in Table 1, there are four OEMs and two automotive suppliers, all of them being multinationals and only company A being based in Canada, as the others are based in Brazil. We began by identifying and analysing the competitive priorities of the six manufactures. We then discussed the main characteristics in the decision areas and presented the main actions implemented recently by the manufactures to attain strategic goals in their operations systems. Third, we showed the Lean and Green practices, presenting and explaining the juxtaposition of Lean and Green Manufacturing practices from the perspective of operations strategy. Finally, in section 4.4 we pointed similarities and differences in the OSs and Lean-Green Practices of the manufactures.

4.1 Operations Strategies

Before presenting and discussing the competitive priorities, it is important to present the competitive strategy and the competitive advantages of the organizations, since the OS focus on implementing the competitive strategy through the production function.

Regarding to competitive strategy that aims to stablish a lucrative position for the organizations, the spider chart in figure 3 shows the main factors of company's competitiveness. In five companies, "quality" is considered as the most important factor for the competitiveness, except in company D, where it is considered the second most important. An overall goal of OS relating with defects reduction converged with the competitive strategy presented as follows. The market requirements of products with a good quality standard were explained to the interviewees. Also, it is important to emphasize that Environmental sustainability is still not seen as the first most important factor of the competitive strategy. Company C and D consider Environment as the second, A and F as the third, B as the fourth and E do not consider it important for the competitive strategy.

Figure 4 Importance of competitiveness factors.



(Figura 28 - Importância dos fatores competitivos)

Source: Elaborated by the authors.

Second, we present what companies see as factors of competitive advantage over the competitors. Quality is considered the main competitive advantage in most of studied companies. Company D also includes service level, and company E considers Price as its first factor for competitive advantage. Moreover, only company A considers customization and service level as its main competitive advantage. Regarding competitive strategy, Quality being the main factor for the competitiveness converges with the main overall goals for the operations strategy of these companies: “defects reduction” and “cost reduction”. Table 2 summarize these points.

Table 3 Competitive strategy

(Quadro 11 - Estratégia competitiva das empresas.)

Company	Main factors for the competitiveness	Main Competitive Advantage	Overall goal of OS			
			Increase productivity	Reduce cost	Reduce defects	Reduce lead time
A	Quality and Design	Customization and Service Level	Very Important	Most Important	Most important	Important
B	Quality	Quality	Important	Farily Important	Most important	Very Important
C	Quality and Design	Quality	Very Important	Most Important	Most Important	Fairly Important
D	Delivery reliability and flexibility	Quality and Service Level	Very Important	Most Important	Fairly Important	Important
E	Quality	Quality and Price	Very Important	Most Important	Most important	Important
F	Quality, Innovation capacity and flexibility	Quality	Most Important	Most Important	Fairly Important	Very Important

These information show that there is an alignment between the competitive strategy, competitive advantage and the overall goal of the OS. In regard to ranking, the competitive strategy is presented in Table 3. This table demonstrates that in A, E and F Quality was considered as the most relevant among their priorities. For Companies C and D quality was seen as a second more important priority, and for company B quality was ranked as the third priority. Spite of Manufacturer B putting Quality after Delivery and Environment, it was argued that quality is the foundation of their operations ever since, therefore, nowadays it is necessary to focus on improvements in delivery and environment. The emphasis on quality can be originated from both external and internal factors to their plants. The external factors are the demands of the competitive strategies of their clients that require quality of products, that is related to the high level of security demanded for automobiles and their components. The market requires these plants to operate with a high-quality level, with needs a given standard of quality. Regarding the internal factor, it can be related to the management of the operations system itself. There is ISO 9001 certification in all of them.

Table 4 Competitive Priorities.

(Quadro 12 - Prioridades competitivas das empresas.)

Company	1st Priority	2nd Priority	3rd Priority	4th Priority	5th Priority
A	Cost/Quality	Flexibility/Service	Environment	-	-
B	Delivery	Environment	Quality	Service/Cost	Flexibility
C	Cost/Delivery	Quality	Environment	Service	Flexibility
D	Delivery	Quality/Service	Flexibility	Cost	Environment
E	Quality	Cost	Flexibility	Service/Delivery	Environment
F	Quality	Cost/Delivery	Environment/Flexibility	Service	-

Cost and Delivery are taken as important competitive priorities for these manufactures after quality. The prioritization of cost can be explained as per the market conditions, where in a state of economics crises, the companies needed to focus some actions on the cost reduction and on the use of production factors to reduce the effects on the financial results. Additionally, the efforts directed at cost cannot affect quality in its various dimensions, since the latter plays an important role in the automaker’s competitive strategy. In respect of priority delivery, the companies have worked with low stock level of both finished product and raw material. The first reason for that is because, with the Pandemic, the chain has suffered a rupture, with some missing inputs. That way, the companies are trying to fulfill the demand with a low lead time and obtain a higher capital turnover.

Regarding the Environment, it is not considered by any company as the most important priority. However, all companies studied have considered “environment” as a priority in their operations, since small actions to environmental impacts reductions to green practices structured in their production systems. In all companies, improving the environment was observed as a target. The section about LG practices will explain the practices and the level of adoption in each company.

Manufacture B considered the environment as a second operations’ competitive priority, but it also considered it as the last advantage competitive. It was disclosed that although the company takes several actions to reduce the environmental impact and include these issues in the management of operations, the factor that the company still has as a differential and is sought by its customers is quality. The environmental staff pointed out that now that the company has sought to publicize its actions related to the environment, in addition to the development of more sustainable products, to add value to the brand. Therefore, it is coherent that environmental sustainability is still a factor of little importance for competitiveness. Also, it is important to mention that this company considered environment ahead of cost. It was disclosed that improvement projects that can promote cost reduction are analysed for environmental specialists and in no case or in the face of any possibility is the project carried out if it generates any type of environmental impact.

When analysing companies, A, C and F, they have considered Environment as a third priority. First, in this case environmental sustainability, was seen at different levels of importance as a competitiveness factor. Company C was the only one that considered it as a second most important factor for the competitiveness, which aligns to what was mentioned by the respondents. Case A and F see the Environmental Sustainability as a third factor, as well as environmental priority, as it was mentioned in case A, that a good level of environmental integration with operations and the staff working together is considered as a management pillar of this company. In Company F, there is a program to motivate workers to carry out pollution-reduction projects, but it is still an isolated initiative, as it is not part of a daily management. And they understand the environment as an urgent factor to the companies, being said that environmental actions can be a determinant factor to remain in the market, especially when it comes to global markets.

Company D and E considered the environment as a last operation's competitive priority, where for E, Environment Sustainability is not considered as an important factor for its competitiveness. As for case D, the competitive priority, and the level of importance for the competitiveness is divergent. It was observed that environment factors are integrated with their production systems, but it was argued that the management has currently focused more on projects to reduce lead time and quality.

Flexibility and Service are of lesser importance, as the classification proposed by Hill (2000), they can be considered performance objective qualifiers. As presented, the companies adopt competitive priorities in reason of a wide and varied set of factors, but with the objective to implement actions and practices in decision areas to promote fit with the market conditions or competitive strategy requirements. Also, in all companies, some trade-offs between cost and environment were identified when environmental projects need investment. In cases C, D, E and F, it was mentioned that the project to be approved needs to have a fast investment return of least two years. Furthermore, it was discussed that cost reduction projects that can increase the environmental impact are not approved.

We compared the decision areas contribution for the competitiveness, demonstrated in the spider chart, Figure 4. According to the results, the main decision area to implement the

OS of the companies is the Quality Management, followed by Capacity, Development of new products/materials and Supply Chain.

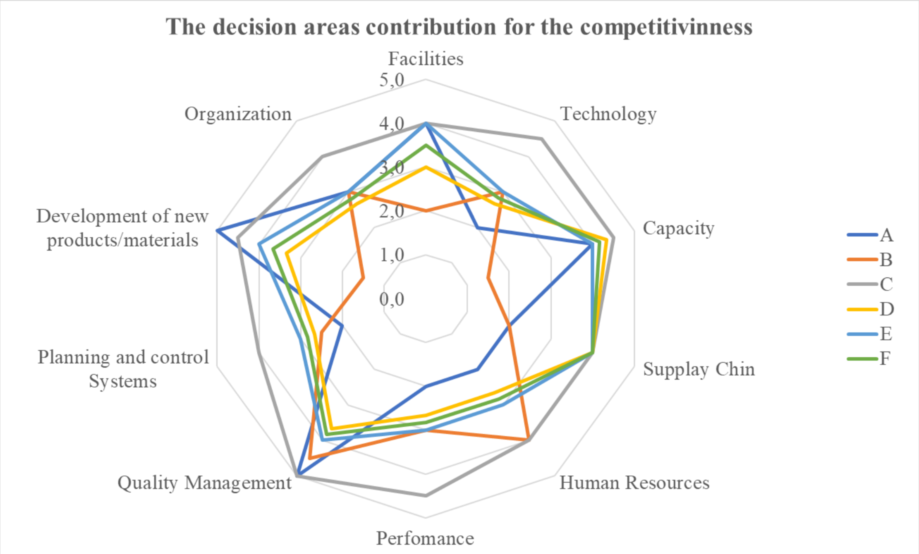


Figura 29 – Contribuição das áreas de decisão para a competitividade

Figure 5 The decision areas contribution for the competitiveness

The fact that Quality Management contributes more than others is related to the company's competitive strategy focused on priority Quality. Furthermore, it is important to observe, in Table 5, the main changes identified in the decision areas when priority Environment is considered as a competitive priority and Green practices are included in production systems.

No changes related to the capacity were observed and no increase or reduction in productivity capacity because of Green Practices was identified. Furthermore, no change in Production, Planning and Control was mentioned. All companies include some aspects in Quality Management, Human Resources, Performance Measurement System and Organization. The inclusion of environmental performance in training and in the indicators were the main actions highlighted in the results.

Table 5 Changes in Decision Areas

Quadro 13 – Mudanças nas áreas de decisão.

Company	**Changes in Decision Areas**
A	*Facilities:* Improvements in the in the lighting of factory facilities. *Technology: S*earch for cleaner technologies that result in less environmental impact. *Human Resources:* Inclusion of environmental aspects in the training as well as quality and efficiency aspect. *Quality Management:* Inclusion of ISO14000 environmental management certification. *Product Development:* Development of more sustainable products, such as electric vehicles. *Performance Measurement System:* Inclusion of environmental performance indicators in the production system. Strategic environmental targets for 2050. *Organization:* Lean Management disseminated to all, one leader but everyone has a little responsibility. There is an integration in the structure of the organization, from the decision-making process and direction to achievement of goals. The lean and green results are reported to the same leader.
B	*Facilities:* Design of the facilities considering environmental aspects, such as lighting design for lower energy consumption. *Technology:* Switching the energy matrix of transportation equipment to electricity. *Supply Chain:* Integration and training of suppliers to improve the environmental performance of their operations and implementation of an environmental purchasing guide. *Human Resources:* Inclusion of environmental aspects in the training and Quality Circles (QC) as well as quality and efficiency aspect. Also, activities for the engagement of all employees in Lean and Green, such as suggestion programs and awards for improvement initiatives. *Quality Management:* Inclusion of ISO14000 environmental management certification. *Product Development:* Development of more sustainable products, such as electric cars. *Performance Measurement System:* Environment in the factory floor KPIs, such as electricity consumption, waste overall per assembly line and KPI's per vehicle: kg of co2 per vehicle. Strategic environmental targets for 2050. Use of Hoshin Kanri for deployment of strategic goals to operations. *Organization:* Focus on team integration for Kaizens, integration and validation of environmental specialists for any project. Integrated organizational structure but with a specialized corporate environmental department.
C	*Supply Chain:* Alignment with suppliers for the packaging of components to go beyond the possibility of recycling and seek alternatives for reuse. *Human Resources:* Training of the environmental team to make the leaders aware of the common responsibility of everyone for environmental performance. Alignment with suppliers for the packaging of components to go beyond the possibility of recycling and seek alternatives for reuse. *Quality Management:* Inclusion of ISO14000 environmental management certification. *Product Development:* Development of projects for reuse of component packaging. *Performance Measurement System:* Environmental performance indicators included in the company's management system not directly integrated with Lean but under the same management Aggressive targets for recycling and emissions. *Organization:* Environmental specialists under the management of maintenance and utilities. Environment and operations under the same directorate in the organizational structure.
D	*Facilities:* Design of the facilities considering environmental aspects, such as lighting design for lower energy consumption *Technology:* Design of equipment to reduce emissions. Project decisions weigh aspects of green, water and energy consumption for the acquisition of new equipment. *Human Resources:* Training for all employees on all management pillars and the environment is included. Employees are motivated to think about improvements to reduce environmental impact. *Quality Management:* Inclusion of ISO14000 environmental management certification. *Product Development:* Development of more sustainable products, such as electric cars. *Performance Measurement System:* Environmental performance indicators for operations. There is the deployment of the global strategy to the operations. *Organization:* Management based on technical pillars (safety (occupational safety), cost of deployment, focused improvement, autonomous maintenance, quality control, logistics and customer service, early equipment management people development, environment and energy, for all changes. The improvement projects occur in an integrated way and considering all technical pillars.

Company	Changes in Decision Areas
E	*Technology:* Equipment acquisition projects focused on emission reduction, water and energy consumption. *Supply Chain:* Integration with suppliers for compliance with product safety and environmental performance requirements. *Human Resources:* Development of training for the integration of everyone involved, such as the presentation of the VSM with the flow and possibilities for improvement. There is an incipient work to include the environment in the improvement initiatives. *Quality Management:* Inclusion of ISO14000 environmental management certification. *Product Development:* Development of more sustainable products, such as products that can be recycled and in case of incineration emit fewer toxic gases. *Performance Measurement System:* Beginning of the deployment of strategic goals to achieve the sustainability objectives for 2050 through Hoshin Kanri that seeks to deploy these targets to performance measures of the operations. *Organization:* Inclusion in the management system a corporate policy for environment, safety, and health protection but there are not actions for integration with practices Lean.
F	*Technology:* Projects to reduce energy consumption and emissions of equipment. *Supply Chain:* Integration with suppliers and customers for sharing information about the environmental impacts of operations. *Human Resources:* Individual initiatives to suggest improvements. *Quality Management:* Inclusion of ISO14000 environmental management certification. *Product Development:* Focuses on innovation and has formalized Life Cycle Management as it incorporates environmental, health, and safety considerations into new product development. *Performance Measurement System:* Adoption of indicators at the basic level, includes safety indicators in daily management, but still no environmental performance indicators for operations, only sustainability indicators at the corporate level. In addition, a report is made to the automakers on the environmental performance of emissions. *Organization:* Structure by certifications that follow the levels of implementation of Lean practices by areas. The aspects and practices for sustainability are still based on isolated initiatives and with very specific people, departmentalized and disintegrated into the production system.

4.2 Lean-Green Practices

The companies have implemented Lean since 1990 and the cost reduction and quality improvement are the primary motivations to adopt Lean practices, what converge with the competitive advantage, operational goals, and competitive priorities.

Table 6 Lean in Companies.

(Quadro 14 - Lean nas empresas.)

Company	Period of Implementation	Lean Responsible	Motivation to implement Lean
A	Between 1990 and 2000	Lean coordinator	Cost reduction and quality improvement
B	Between 1990 and 2000	Operations Management	Cost reduction and quality improvement
C	Between 1990 and 2000	Operations Management	Cost reduction ,Market Competition, and Business Strategy
D	Between 1990 and 2000	Operations Director	Cost reduction , Quality improvement, Market competition and Business strategy.
E	Between 2006 and 2010	Lean coordinator	Cost reduction, Quality improvement and Market competition
F	Between 2011 and 2015	Lean coordinator	Cost reduction, Quality improvement, Market competition, Process standardization across different locations and leadership sees value to implement.

In Table 7 we present some Lean Practices (LP) and the Level of adoption in the companies. The practices, Kaizen and 5S (Five S) are fully implemented in all the companies. Kanban and JIT were the less implemented in the companies. Company B is the only one that follows almost all the practices implemented, only TPM is still partially deployed. Also, it includes the Karakuri practice, that is a low-cost automation, and QCC - quality control circle where a group of workers identify, analyze and solve problems.

There is a good level of Lean practices implementation in all the companies. Company F has around 45 % of fully implemented Lean practices, the others are partially implemented, and it includes the Tier meetings (daily meeting leaderships) in the production system. Company C has approximately 55% LP fully implemented ant it is trying to improve in the JIT that has an incipient implementation, justifying the Delivery to be one of the main competitive priorities. Company D is at the same level, being also in the beginning of implementation of JIT and Cellular Manufacturing. Company A presents 45% LP fully implemented and considers that Standardized Work and Total Productive Maintenance are still incipient. Company E has 55% LP fully implemented, but JIT is not implemented and Pull production is still in “project” level but not yet implemented. The level of these two practices in company E can be explained as the strategy adopted, so they focus more on practices that can help improve the performance on quality.

Table 7 Lean Practices.

(Quadro 15 - Práticas Lean)

Company	Kaizen	5s (five S)	Visual Management	5 why / Ishikawa (fishbone) diagram	Poka-Yoke (error-proofing system)	Cellular Manufacturing	Standartized work	Value Stream Mapping (VSM)	Total Productive Maintenance (TPM)	Pull Prodcution/ Kanban	Just-in-Time (JIT)	Other Lean practices	Score of Lean implementation Level
B	4	4	4	4	4	4	4	4	3	4	4	Karakuri, Quality Circles (QC)	**43**
C	4	4	4	4	3	4	4	3	3	3	2		**38**
F	4	4	3	4	3	4	4	3	3	3	3	Tier Meetings - daily leadership meetings	**38**
D	4	4	4	3	3	2	4	4	4	3	2		**37**
A	4	4	4	4	3	4	2	3	2	3	3	Skills matrices, leadership	**36**
E	4	4	4	4	4	3	3	4	3	1	0		**34**
Poontuation of Practices	**24**	**24**	**23**	**23**	**20**	**21**	**21**	**21**	**18**	**17**	**14**		

LEGEND	
Nothing has been done	0
Currently at the "project" level but not yet implemented	1
Incipient implementation	2
Partially deployed	3
Fully deployed and tracked	4

From these findings, it is possible to understand that B has the most advanced level in Lean practices implementation, followed by C, F, D, A and E. In general, companies have not yet the majority of consolidated practices, and these practices are aligned with their strategy. It was emphasized for the respondents that companies take Lean focusing on waste reduction in the value stream, aiming the improvement of their performance. In Table 8, the Lean Performance Metrics were used.

Table 8 Lean Performance Metrics

(Quadro 16 - Indicadores de Desempenho Lean).

Lean Performance Metrics	**Company**					
	A	**B**	**C**	**D**	**E**	**F**
Average Cycle Time (days/hours)		✔	✔	✔	✔	✔
First Time Through FTT = (Units processed - Units rejected)/(Units processed)	✔	✔	✔	✔		✔
On Time In Full (OTIF)	✔	✔	✔	✔	✔	✔
Percentage of defects or non-conforming parts	✔	✔	✔	✔	✔	✔
Percentage of value-added time (%TAV)			✔	✔		
Productivity	✔	✔	✔	✔	✔	✔
Takt Time (Available Minutes for Production / Required Units of Production)	✔	✔	✔	✔	✔	✔
Health and safety	✔					
% Absenteeism	✔					
OEE - Overall equipment effectiveness	✔	✔	✔	✔	✔	✔

The FTT indicators, Percentage of defects or non-conforming parts, OTIF, Productivity, Takt Time and OEE are frequent in all the cases. They aim to measure aspects of quality, efficiency, and delivery respectively, aligned with the main competitive priorities considered by the companies of quality, cost, and delivery.

Regarding to Green Practices, in Table 9, it is presented the period when the first Green practice was implemented. It was noted in the interviews that some green practices occurred first than Green because of compliance with environmental legal requirements, as possible to see that legislation is one of the main motivations to implement Green, except that in A, Corporate Strategy is the main reason for that. Also, market competition, cost reduction and customer’s requirement were mentioned.

Table 9 Green in companies.

(Quadro 17 - Green nas empresas.)

Company	Period of Implementation	Green Responsible	Motivation to implement Green
A	Between 1990 and 2000	Operations manager	Corporate strategy
B	Between 1990 and 2000	Environment Engineer	Corporate strategy, cost reduction, quality improvement, legislation and market competition.
C	Between 2001 and 2005	Environment Engineer	Corporate strategy, cost reduction, Customer's requirement, legislation and market competition.
D	From 2016	Environment coordinator	Corporate strategy,Customer's requirement, legislation, market competition and creating environmentally sustainable culture
E	Between 2001 and 2005	Environment coordinator	Corporate strategy, legislation and market competition.
F	Before 1990	Environment coordinator	Corporate strategy, cost reduction, legislation and market competition.

Regarding the Green Practices implemented in companies shown in Table 9. All companies have Environmental Management, Waste Management, Recycling Program, Publication of reports with environmental information and Effluent treatment fully implemented. It was mentioned in the interviews and in the sustainability reports that all of them are trying to implement the concept of circularity focusing in doing more with the same resources and consider all the product life cycle. Also, no company has implemented all the green practices questioned. What might infer is that the Lean maturity is larger than Green in those companies. Environmental accreditation of suppliers, Environmental Education Programs and Inter-process resource sharing programs are the less implemented.

In Table 10, Company C has obtained the highest score in Green implementation. It can be justified as the company has a Green Global program. Level Company B and C have 71% of the practices fully implemented, B are implementing the Life cycle analysis and C has this practice partially implemented. Furthermore, Reverse Logistics is sill in project phase in B and Partially deployed in C. The company F has 64% of the green implemented practices, showing the Environmental accreditation aspect as the only one that has not been yet implemented and Environmental education and Inter-process resource sharing program are still incipient. It is important to highlight that this company was a pioneer in cleaner production program, but this program refers to isolated initiatives and it still not fully integrated with the production system.

Company A and D have 57% of green implemented practices, while A does not implement environmental accreditation of suppliers and Environmental education program, D has an incipient implementation of them, also A is incipient in inter-process resource sharing programs and D does nothing. At last, we have observed the company E with 43% of the green practices fully deployed and 57% that are incipient. According to the interviews and reports, this company is aiming to structure their actions and processes to improve their environment aspect.

Table 10 - Green Practices

(Quadro 18 - Práticas Green nas empresas.)

Company	Environmental Management 1an	. Waste Management Policy	Recycling program	Effluent Treatment	Publication of reports with environmental information	Water consumption reduction program	Energy conservation program	Program to reduce material consumption	Product life cycle analysis	Cleaner production program	Reverse logistics	Inter-process resource sharing programs	Environmental education programs for the community	Environmental accreditation of sup1iers	Score of Green implementation Level
C	4	4	4	4	4	4	4	4	3	4	3	3	3	4	**52**
B	4	4	4	4	4	4	4	4	2	1	1	4	4	3	**47**
F	4	4	4	4	3	4	4	4	4	4	3	2	2	0	**46**
D	4	4	4	4	4	4	4	2	4	2	3	0	2	2	**43**
A	4	4	4	4	4	4	4	3	2	4	2	2	0	0	**41**
E	4	4	4	4	4	2	2	4	2	2	2	2	2	2	**40**
Score of Practices implementation	**24**	**24**	**24**	**24**	**23**	**22**	**22**	**21**	**17**	**17**	**14**	**13**	**13**	**11**	

Moreover, all businesses have mentioned the intention of developing actions around circular economy. Another important result from the cases is the strategic alignment related to the sustainability targets. All companies have mentioned strategic targets for the long term and targets for operations in the short term. It was observed that they have deployed these targets for the short term and all companies have the operational targets to short term, being that company B, C and E have used the *Hoshin Kanri* concept to do that. Also, a same strategic target of carbon neutrality until 2050 was observed, being a commitment of organisations at a global level. Company E for example has had its actions changed in operations because of that. In Table 11, it is possible to observe the Green Performance Metrics used in the companies, where some of them are integrated in the Lean system.

Table 11 Green Performance Metrics

(Quadro 19 - Indicadores de Desempenho Lean).

Green Performance Metrics	Company					
	A	B	C	D	E	F
Amount of waste generated	✔	✔	✔*	✔*	✔*	✔*
Emissions (greenhouse gases, NOx, SOx)	✔	✔	✔	✔*	✔	✔
Energy consumption	✔*	✔*	✔*	✔*	✔*	✔
Materials utilization (weight and volume)	✔	✔	✔	✔*	✔	✔*
Utilization (consumption) of toxic substances (materials)	✔	✔				✔
Water consumption	✔	✔*	✔*	✔*	✔*	✔
Metal scrap	✔					
Spills	✔*					

**metric that is considered in Lean system of the company*

The amount of waste generated, emissions, energy consumption, materials utilization and water consumption metrics are used in all companies. Company D considers all green metrics in its production system. The performance of energy, waste and water are the greenest metrics used in Lean. As presented before, the inclusion of Green metrics in Performance Measurement System is of extreme importance in order to have the Environment as a competitive priority.

5. Discussion

5.1 Cross case analysis

Based on the described OSs, including the adopted practices, it is possible to explain and compare them by using four different basic OS configurations, Figure & that are different mainly in terms of the importance attributed to priority Environment, the level of adoption of Lean and Green practices and the corresponding changes in Decision Areas, and how Lean and Green are integrated. The Environment priority was the second priority for company B, while companies A, C e F put in a third position, and D and E consider it as the last priority. Considering changes in decision areas, company B has performed more changes in their structure. As represented in Figure 6, the companies are in different stages of Lean and Green Implementation. Regarding Lean practices implemented through of the answers obtained in the questionnaires, the companies are not at huge different Lean levels. Company C and F are on the same, D and A are very close. Company E is slightly below, which can be attributed to the lack of implementation of pulled production and JIT. In respect to Green practices, it is possible to observe that C is the first, following by company B, D, A and E. Also, company C and E present the the greatest difference, which makes sense in terms of the environmental priority order, as well as the fact that green initiatives are starting in company E.

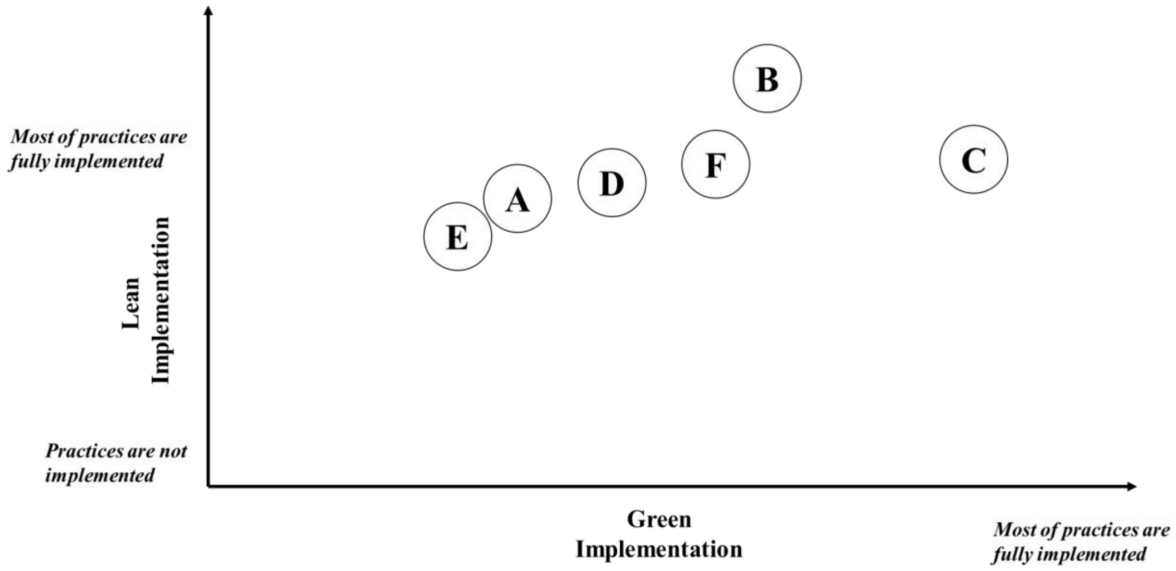


Figura 30 - Nível de implantação Lean e Green.

Figure 6 Lean versus Green Implementation.

Besides the magnitude of changes in the decision areas and the different levels of practices implementation, it is important to point that LG integration in these companies occur in different ways. Company A has Lean and Green coordination working side by side in the same office, discussing and integrating their metrics and targets. The most important aspect on A is that Lean and Green are related to operational excellence strategies, and the initiatives and long-term objectives are analyzed on how to put them into practice. An attempt of interviewees integrating their projects is observed, as the integration of Lean and Green requirements is essential from the starting point of implementing something new. In A, Lean and Green are under the same and the main organizational structure, where similar patterns on their reports demonstrate an operations strategy alignment at a same level of importance.

Company B presents a high level of LG integration in their operations. It was observed that environmental gains are attained, whatever the objective of the kaizen is. Moreover, integrated teams are planning, analyzing and approving the kaizens considering the environmental aspects. Another example of integration are green performance indicators in the production system and their use of Lean tools in Green problem-solving processes. In Company C, the LG integration was not observed. the training including Green for Lean teams is focused only in of greater impact critical processes. However, the fact of the Company C present the highest green level can be attributed to the fact that they have a global green programme, but the green initiatives happen in projects disconnected from the lean management system.

In the case of Company D, the environment is integrated as one of the pillars of the D management system. The improvements, focused on losses reduction, also include energy, water, waste, and material. Also, the green indicators are analysed side by side with lean indicators, and the environmental specialists are integrated in every improvement project.

In Company E, Green indicators are still under the responsibility of the environmental area. As an illustration, the variable remuneration for the environmental targets is only established to the environmental specialists. There are incipient actions to include environment on the production's system training programs. At last, Company F does not present elements that show initiatives of LG integration.

It is accountable to compare companies B and E, which show the biggest difference between the levels of implementation of green practices. As presented before, company E, a first tier manufacturer for the automotive sector, started considering the environment as a competitive priority and beyond the regulatory issues in a short period of time. In general, comparing all companies, the levels of Lean are slightly different, as comparing with Green. Based on these results, a summary of the different OS configurations is shown in Figure 7.

What can be inferred form that comparison is that the level of integration of LG practices can be directly related to the prioritization of the environment as operations' competitive priority, and the changes in the decision areas in the respective operations strategies. The results indicate that there is no relationship between the level of implementation of Green practices with the Green integration in Lean systems. Those with the lowest level of Lean and Green implementation have the lowest level of integration, however, one can have the green initiative implemented in an isolated way to solve a specific problem but not being inserted into the company's management system.

In relation to the integration of Green practices in Lean management, it was observed and questioned about the inclusion of environmental performance indicators in Lean systems and integration in the organizational structure of the two areas, as well as the changes and actions in the decision areas. The results evidenced that this integration occurs by means of different actions and changes in the decision areas. At a lower level, observed in company E and F. At company E, it was observed that due to the need for strategy deployment, efforts are made to include environmental indicators in operations. While in company F, as already mentioned, it has a global level program for pollution reduction, however, the program deals with isolated and punctual initiatives that use Green practices and may, punctually, be related to process improvement programs that involve Lean, such as actions for energy consumption reduction. But regarding to indicators in the daily management of operations, this company only links material consumption. But there are no elements in the structure and daily management indicating that the two areas integrate.

Company (s)	CP Environment	Trade-offs	Changes in Decision Areas: Capacity	Facilities	Tecnology	Supply Chain	Human Resources	Quality Management	PCP	Product and Process Development	Performance Measurement System	Organization	Lean Practices	Green Practices	Integration of LG
B	2nd Priority, Environment ahead of cost	Enviroment and Cost	No	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	HIgh	High	High
A	3rd Priority, Cost ahead of Environment	Enviroment and Cost	No	Yes	Yes	No	Yes	Yes	No	No	Yes	Yes	Medium	High	Medum
D	Last Priority, Cost ahead of environment	Enviroment and Cost	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes	Yes	High	Medium	Medium
C	3rd Priority, Cost ahead of Environment	Enviroment and Cost	No	No	No	Yes	Yes, very incipient	Yes	No	Yes	Yes	Yes	Medium	High	Very Low
F	3rd Priority, Cost ahead of Environment	Enviroment and Cost	No	No	Yes	Yes	Yes, very incipient	Yes	No	Yes	No	No, only isolated initiatives.	Medium	Medium	Very Low, Isolated Initiatives
E	Last Priority Cost ahead of environment	Enviroment and Cost	No	No	Yes	Yes	Yes	Yes	No	Yes	Yes	No	Medium	Low	Very Low, Isolated Initiatives

*Figure 7 - OSs configurati*ons (*Figura 31 - Configurações das Estratégias de Operações)*

Case C presents an integration in project analysis and in the performance management system. However, the integration in the organizational structure as well as the training directed to the collaborators occurs in a punctual way and according to the need of specific projects. In cases B, A and D it was observed that the environment is systematically included in the pillars of operations management. There is an integration in the organizational structures, from decision making and project analysis in an integrated manner, to shop floor indicators and training for employees. Company B presented more integration actions as regards the suppliers' actions.

5.1 Conceptual Framework discussion

As shown in Table X, we find a possible cluster of three configurations of operations strategy, that can be identified when Lean and Green practices are implemented**.** Besides that, the results found explain the relations of Lean and Green with the OS, as presented in Conceptual Framework (Figure 1). In that way, it is possible to understand as per found results, from the analysis of the theoretical propositions.

P1: Lean has the potential to reduce the environmental impacts.

The literature (Dües, Tan, and Lim (2013), Chiarini (2014) and Garza-Reyes et al. (2018)) argue that Lean can improve the environment. The results from all companies show that Lean practices and culture can contribute to the enviroment. Company C show that the Lean standartization colaborate to reduction of problems and improve the envinonment aspects control of the process. Company D, E and F mentioned that Lean can significatively reduce the environmental impacts by cause of the culture to waste reduction. Also, Company A claimed that although most of the time Lean collaborates positively, Green complex projects do not need Lean practices to achieve their goals, thus, it is possible to improve on Green without Lean. They argue that in order to achieve Green, in most cases, innovation processes and the inclusion of green practices in decision areas are necessary.

P2: Lean is not enough to be Green; it is necessary to implement Green Practices and change the decision areas.

As Lean is not Green in its essence, literature suggest that it is necessary to implement Green tools to achieve a better environmental performance ((Ng et al., 2015; Ruiz-Benitez et al., 2019) and consider environmental aspects explicitly in the production system (Belhadi et al., 2018; Ben Ruben et al., 2017; Cherrafi et al., 2016; Duarte and Cruz Machado, 2017; Dües et al., 201..). The cases studied support that, as shown in table "decision aeras", some changes in the decision areas, on facilities, techinology, Supply Chain, human resources, Quality Management, Product Development, Performance Measurament System and Organizaiton are required. The foundation of these changes, as indicated in case A and B is the integration of the areas in decision making, including green variables on training and performance indicators as indicated in all cases. As an example, there is an integration of areas since the organizational structure in case A, B and C.

P3: The environment is a new competitive priority in companies that have already implemented Lean.

It was possible to notice on the results that "Environment" is considered as a competitive priority of OS in all cases but on different levels of prioritization. Additionally, all of them measure the environmental performance in their performance measurement system, as the necessity of integrating environment aspects in the production systems is shown in literature (Ben Ruben et al., 2017; Braglia et al., 2020; Garza-Reyes, 2015; Minh et al., 2019). This is motivated by reasons such as corporate strategy, cost reduction, market requirement, legislation, and customer's requirement. However, it was perceived that the first Green practice was implemented after some Lean Practice only in company C and D. It was observed that in Company A, B, E and F, the Green Practice starts with legislation requirements, which is one of the reasons for having green practices. To this extent, it was not possible to infer a relation between green or lean deployment sequence and the environment prioritization.

P4: The prioritization of environment is dependent of costs and investments.

In Case B, C, D and F the cost reduction was one of the motivations for the adoption of Lean Practices. Those cases argued that improvements in the environment can help reducing the waste, improving the efficiency process and issues regarding environmental regulation fines. These points converge with the studies (CHERRAFI *et al.*, 2016; DE CARVALHO; GRANJA; DA SILVA, 2017; MILLER; PAWLOSKI; STANDRIDGE, 2010; PRASAD;

KHANDUJA; SHARMA, 2016; TORIELLI *et al.*, 2010) that show cost reduction through environmental improvements. Companies also emphasize that environment projects have to be analyzed from the financial return aspect, where an investment return time being set to more than three years represents a long-term investment that cannot be adopted. For example, Company E pointed out that the top management needs to have a financial value in the solutions. Also, it was possible to observe that in all companies, the cost is prioritized ahead of the environment, except for company B, which infers that most times companies can focus on the environment only when being assisted on costs.

P5: The Lean-Green integration creates trade-offs between the competitive priorities.

Based on the presented cases, this preposition should be changed to "*P5: The Lean and Green integration creates trade-off between cost and environment".* Despite the literature pointing out the trade-offs between delivery and environment (Azevedo et al., 2016; Campos and Vazquez-Brust, 2016; Lee and Prabhu, 2016; Longoni and Cagliano, 2015b; Mollenkopf et al., 2010; Salvador et al., 2017; Wang et al., 2015b), environment and quality (Pil; Rothenberg,2003), flexibility and environment (DÜES; TAN; LIM, 2013; SAWHNEY *et al.*, 2007), the results from the cases studied demonstrated that when deciding to or implementing improvements related to environment, the cost is taken into consideration.

6. Conclusion, limitations, and directions for future research

Our study shows that the examined companies here somehow include - at different levels of importance, and explicitly or implicitly - the Environment priority among their competitive priorities and implement practices to achieve it. In a context where Lean practices were also adopted, the literature suggests that being Lean is not enough to be Green. Lean companies, in addition to including Environment in their competitive operations priorities, must also implement Green practices and promote the necessary changes in structural and infrastructural decision areas.

Another important observation is that the companies include environmental performance indicators in their performance measurement systems, making it possible to monitor improvements and eventual trade-offs among competitive priorities. Additionally, companies that prioritize Environment adopt the training programs for their Human Resources on the environmental aspects and the integration of the Lean and Green areas in the organizational structure.

Regarding the theoretical propositions, the cases represented illustrations of them. A new aspect is seen only seen on the proposition 1, regarding the fact that Green improvements can be independent of Lean and also on proposition 5, because we only find trade-offs between the cost and environment priority, while in literature is pointed out another kind of trade-off is pointed out.

This study can help operations managers in the duty of integrating green practices into their production systems. From the perspective of the operations strategy, this integration must seek alignment with the company's competitive strategy, which requires considering the Environment as a competitive priority, the assessment of potential compatibilities or tradeoffs - such as between environment and cost - between competitive priorities, and the implementation of appropriate changes in decision areas - including the implementation of new practices.

Furthermore, this study can contribute to academic knowledge by presenting a preliminary discussion of Lean and Green from the perspective of the literature on OS and based on empirical cases of companies that implement these approaches. These results extend the discussion about LG, confirming that Lean can help improving the environment, but Green cannot rely on Lean to perform well. In addition, it points out to the need of analyzes, considering the pressures of the environment and the company's strategy, the tradeoffs between cost and the environment (not only in the short term), since the financial value remains the most important objective for organizations.

Lastly, the main point is that Lean is not enough for a company to be considered Green. The results suggest that the level of implementation of Lean cannot influence the level of Green and, to achieve environmental performance in their operations, some changes are necessary while implementing Green practices in structural and infrastructural decision areas. Thus, this article seeks to examine how an organization, which (at some level) already adopts Lean as a means of implementing its operations strategy, can harmoniously incorporate the Environment as a new competitive criterion and the necessary changes for the corresponding adoption of the Green approach.

However, this research suffers from some limitations that calls for the need of future research. The small number of cases and convenient sampling method do not permit a broad generalization. Also, because of COVID-19, it was not possible to physically visit the companies. However, the focus of this exploratory study was not a statistical generalization

(YIN, R. K., 2017). The sample selection was done with criteria to identify representative cases and, a qualitative approach was very important to understand the context of the research problem and mitigate the impact of the sample size. Another limitation is related with the depth of the assessment of practices and decision areas, as the aim of the study was to be more comprehensive to allow a holistic view.

Future research might explore in quantitative study with a large sample to understand the level of integration between Lean and Green practices in the decision areas and the results in the competitive priorities. Also, we suggest studies to analyze these propositions in bigger sample and another industrial sector.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could appear to influence the work reported in this paper.

Acknowledgments

This research was supported by the Coordination for Improvement of Personnel and Higher Education (CAPES).

Ethical approval

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional (Université de Sherbrooke, Ethics Approval Number: 2020-2730 and Federal University of Sao Carlos, CAAE 39924720.40000.5504).

5. CONSIDERAÇÕES FINAIS

Esta pesquisa teve como objetivo principal identificar e analisar estratégias de operações de empresas do setor automotivo que adotam as abordagens *Lean* e *Green*. Foi realizada uma revisão sistemática da literatura e, também, seis estudos de casos em empresas do setor.

Na primeira etapa deste estudo, com a realização de uma revisão sistemática da literatura, 260 artigos foram selecionados, pois continham ou tratavam de pelo menos uma prática *Lean e Green*, bem como de ao menos um elemento do conteúdo da estratégia de operações. Foram identificados então sinergias ou *trade-offs* entre prioridades competitivas quando práticas *Lean-Green* são implementadas. Muitos dos autores indicaram que a integração *Lean-Green* promove sinergias entre prioridades competitivas e, assim, a implementação dessas práticas pode ser considerada uma maneira adequada de formação de uma estratégia de operações em que o ambiente é colocado dentre as prioridades competitivas e de uma maneira, portanto, de promover a sustentabilidade nas operações.

Contudo, diversos autores identificaram práticas que geram *trade-offs* entre algumas prioridades competitivas. O *trade-off* mais frequentemente mencionado ocorre entre as prioridades custo e ambiente. Em certos casos, portanto, a adoção de práticas *Green* pode fazer com que custos aumentem e, desse modo, o custo pode ser um limitante para adoção de tecnologias mais limpas. Além disso, foram apresentados trabalhos que discutiram *trade-offs* entre qualidade e ambiente, flexibilidade e ambiente ou entrega e ambiente. Como o caso da prática *Just in Time* que pode aumentar a geração de emissões, ou o caso em que, para garantir a qualidade do produto, é necessário aumentar o consumo de insumos.

Do mesmo modo, foram identificados modelos e ferramentas propondo a integração entre as abordagens Lean e Green. Nestas propostas, o *Lean Manufacturing* é utilizado como base e são então incluídas práticas Green – e adotados indicadores (ou variáveis) de desempenho ambiental –, como o caso da ferramenta *Environmental Value Stream Mapping (*Mapeamento de Fluxo de Valor ambiental). Assim o *Lean* é apontado como uma base para a gestão dos sistemas de produção, e as práticas Green trabalham como complemento e para sustentar a inclusão do ambiente como prioridade competitiva.

Os Estudos de Casos realizados na segunda etapa da pesquisa forneceram ilustrações de como são as estratégias de operações em empresas do setor automotivo que implantam práticas *Lean* e práticas *Green.* Em cada um desses estudos foram identificadas prioridades competitivas, mudanças nas áreas de decisão, práticas implementadas e ações no sentido de integrar *Lean* e *Green*.

Com relação às prioridades competitivas de produção, fator determinante da estratégia, foi possível observar que as empresas atribuem níveis diferentes de importância à prioridade ambiente, ao mesmo tempo em que, na maioria dos casos, não consideram a sustentabilidade ambiental como fator de grande importância para a competividade. Qualidade foi apontada como um dos principais fatores da estratégia competitiva e também como uma das principais vantagens competitiva das empresas, e como consequência foi ordenada entre as principais prioridades competitivas de produção. Isso ocorre, segundo os entrevistados, por ser a qualidade uma forte exigência de mercado.

Esses resultados mostraram que as empresas, embora atribuam níveis de importância diferentes à prioridade ambiente, que fica atrás principalmente das prioridades custo e qualidade, com exceção do caso B, a consideram como estratégica e estão, ainda que de maneira incipiente, procurando implementar mudanças e práticas correspondentes nas operações.

Com relação aos *trade-offs*, nos estudos de casos estes foram apontados apenas entre custo e ambiente, ilustrando o que sugere a literatura: a adoção de uma tecnologia mais limpa depende do investimento e do retorno financeiro para a empresa. Por outro lado, observou-se que medidas para redução de custo que podem trazer impactos negativos ao meio ambiente, não vêm sendo mais adotadas pelas empresas. Em todos os casos foi relatado que todo e qualquer projeto que resultasse em impacto ambiental não são aprovados. Por exemplo, o caso B expôs uma situação em que uma melhoria de processo resultaria em redução de custo, mas aumentaria o impacto ambiental. Segundo relatado, nesta situação a equipe, que contou com a participação de um profissional de meio ambiente, optou por analisar outras alternativas de projeto.

No que diz respeito a mudanças nas áreas de decisão, verificou-se que as empresas que mais priorizam o ambiente em suas ações apresentaram mais alterações nas áreas de decisão, incluindo a implementação de práticas e ações *Green* nas instalações, em tecnologia, cadeia de suprimentos, gestão da qualidade, sistema de medição de desempenho, recursos humanos, projeto do produto e organização. Tais mudanças, em sua maioria, estão relacionadas à necessidade de incorporação, ao lado das prioridades tradicionais, da prioridade Ambiente e dos correspondentes indicadores nos sistemas de gestão e, além disso, da adoção de práticas *Green* em sistemas de produção com práticas *Lean* já implementadas. Foi demonstrada principalmente a inclusão de indicadores operacionais para medição do desempenho ambiental, como consumo de energia, materiais, água e geração de emissão, assim como treinamento e conscientização dos funcionários para a preservação do meio ambiente e motivação na realização de iniciativas *Green.*

Os níveis de implantação das práticas, pelas percepções dos entrevistados, são diferentes entre as empresas, tanto com relação às práticas Lean quanto às práticas Green. Comparando os níveis de implantação de práticas Lean, apenas a empresa B pode ser considerada como tendo um nível alto de implantação, uma vez que apenas duas práticas foram consideradas como parcialmente implantadas, enquanto as demais estão completamente implantadas. Já o restante dos casos apresenta uma implantação em nível médio, uma vez que foi apontada uma média de metade das práticas já totalmente implantadas e as demais estariam implantadas parcialmente ou em fase de implantação, e poucas delas em fase de projeto.

Com relação às práticas *Green*, foi relatado que, apesar do Caso C ter um nível de implantação menor em *Lean*, possui mais práticas Green implementadas. No entanto, com base nos resultados dos casos, não foi possível identificar nenhuma relação entre os níveis de implantação de práticas Lean e os níveis de implantação de práticas Green. No entanto, verificou-se que, no Caso B, em que houve maior integração nas ações Lean e Green, a prioridade ambiente está à frente da prioridade custo.

Ainda, os resultados empíricos ilustraram diferentes configurações de estratégias de operações nas empresas, tendo sido possível agrupá-las em quatro configurações que se diferenciam pelos níveis de priorização do ambiente e de integração entre *Lean e Green.*

É importante destacar também que o cruzamento dos resultados teóricos com os resultados empíricos reforça as proposições teóricas indicadas nesta tese. Todas as proposições indicadas a partir da revisão sistemática da literatura foram ilustradas nos casos estudados e complementadas com algumas questões. Confirmou-se que Lean pode contribuir para a redução de impactos ambientais, principalmente no que tange ao consumo de recursos. No entanto, o caso A expôs exemplos de projetos que envolvem mudança técnica de processo ou nova tecnologia para redução de impacto ambiental, não tendo sido adotadas práticas Lean; as práticas Green foram, na opinião do entrevistado, suficientes.

Os casos ilustraram *trade-offs* entre as prioridades ambiente e custo, mas não foram apontados nas entrevistas *trade-offs* envolvendo as prioridades qualidade e entrega, como indicado na revisão sistemática de literatura. Além disso, nos resultados empíricos, nota-se ainda uma superficialidade e dificuldade das empresas em mensurar detalhadamente os resultados de desempenho ambiental provocados pelas práticas Lean, o que pode justificar a dificuldade em apontar *trade-offs* do ambiente com as outras prioridades.

Por fim, com base nas evidências encontradas na literatura e, também, nos casos, mesmo que em uma pequena amostra, a abordagem *Lean-Green* nas operações pode ser uma maneira de operacionalizar a inclusão da prioridade ambiente entre as prioridades competitivas de produção. Além disso, as práticas podem ser adotadas e implementadas, com adaptações se necessário, de modo que promovam a melhoria das prioridades competitivas de produção escolhidas. Diante desses resultados, considera-se que foram alcançados os objetivos propostos inicialmente nesta tese. Com base na fundamentação teórica, nas evidências da revisão sistemática da literatura exposta no capítulo 3 e nas evidências empíricas dos casos relatadas no capítulo 4, elaborou -se a Figura 17 a seguir, em um esforço de síntese do trabalho, destacando os pontos em que foram identificadas as proposições (P1 à P5).

Foi possível identificar, considerando-se desde a estratégia de negócios, que são traçadas metas de longo prazo buscando gerar vantagens competitivas para a organização e baseadas nas necessidades dos *stakeholders.* Seu desdobramento, na estratégia de operações, alvo desta pesquisa, envolve as decisões para o alcance de uma estrutura e infraestrutura e recursos de produção alinhada à estratégia de negócios. Pois como destacado, as operações têm um papel decisivo no desdobramento e implementação da estratégia. Isto é alinhado ao que é exposto nos estudos de Skinner (1969), Alves Filho, Nogueira e Bento (2015) e Dangayach e Deshmukh (2001).

Os resultados desta pesquisa podem ainda ilustrar um dos três paradigmas discutidos por Voss (1995, 2005): aquele em que "escolhas estratégicas determinam decisões estruturais e infraestruturais" –, pois para a inclusão da prioridade ambiente nos sistemas *Lean,* são necessárias mudanças nas áreas de decisão. Dentre as áreas mais afetadas e apontadas nos casos estão as áreas de Recursos Humanos, Sistema de Medição de Desempenho e Organização.

Observou-se ainda que práticas *Lean* são tratadas como fundamentais para a competitividade das empresas na busca pela redução dos desperdícios. Empresas do setor automotivo – setor de origem e visto como benchmarking destas práticas – vêm adotando tais práticas para a redução de custos e de lead-time, bem como para melhoria nos níveis de qualidade. Assim como adotam práticas Green, para obterem melhorias no desempenho ambiental das operações, motivadas principalmente pela redução de custos, estratégia, legislação e requisitos do mercado. Neste sentido, a literatura e os casos sugerem que a integração dessas abordagens pode ser promovida para a o alcance alinhado e concomitante de metas de desempenho ambiental e de desempenho operacionais.

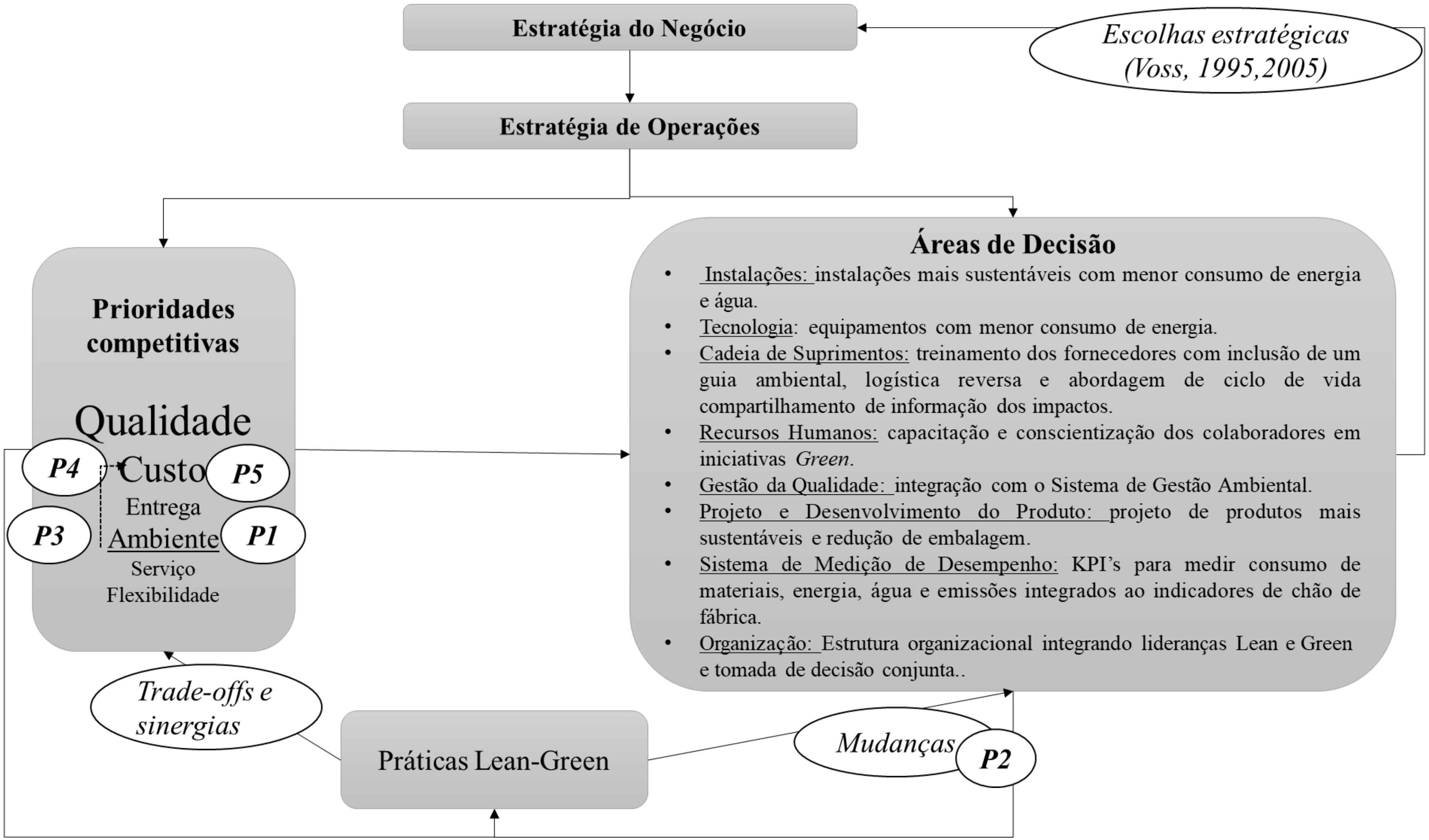


Figura 32 – Síntese do Trabalho.

Não tendo sido encontrado, no levantamento bibliográfico realizado, um artigo que examinasse as abordagens *Lean* e *Green* sob uma perspectiva estratégica, procurou-se neste trabalho iniciar o preenchimento de tal lacuna. Como afirmado no capítulo introdutório, apesar de vários estudos abordarem a integração das abordagens *Lean* e *Green*, não há trabalhos que explorem relações entre práticas de promoção da sustentabilidade (que visem à redução de impactos ambientais) e a estratégia de operações (em sistemas de produção que já têm práticas Lean implementadas).

Assim, neste trabalho procurou-se identificar e discutir conteúdos de estratégias de operações – prioridades competitivas e áreas de decisão –, propiciando uma visão, por meio de uma revisão sistemática da literatura e de um conjunto de estudos de casos no setor automotivo, de como abordagens *Lean* e *Green* podem ser tratadas na gestão de operações. A análise de conteúdo de 260 artigos tornou possível, de maneira inicial, consolidar o estado da arte sobre o conteúdo da estratégia de operações e as respectivas relações com as práticas Lean-Green, apresentando as principais (compatibilidades) sinergias e os principais *trade-offs* entre as prioridades competitivas e mudanças nas áreas de decisão. Além disso, com base na literatura foi possível propor um conjunto de proposições teóricas que foram reforçadas empiricamente e colaboraram para ampliar a literatura neste campo de pesquisa.

Já com relação às contribuições gerenciais, este trabalho, como demostrado na Figura 17, espera proporcionar uma base para que as organizações possam realizar um alinhamento estratégico de suas ações no sistema de produção com suas metas de longo prazo para as operações e para a empresa. Por exemplo, práticas *Lean* e Práticas *Green* podem ser selecionadas e implementadas de modo que a empresa venha a reduzir impactos ambientais e a melhorar seu desempenho nas dimensões das prioridades competitivas definidas em sua estratégia de operações. Além disso, esta pesquisa indica as mudanças necessárias, identificadas tanto na literatura quando nos casos estudados, nas áreas de decisão, quando o ambiente é considerado uma prioridade competitiva e almeja-se integrar práticas Green nos sistemas produtivos.

Cabe aqui indicar também as principais limitações deste trabalho. Primeiro, no que se refere ao estudo empírico, foi utilizada uma amostra pequena e que impede generalizações. Outro aspecto, foi a impossibilidade de realização de visitas *in-loco* na condução dos casos, pois a pesquisa foi realizada durante a pandemia do COVID-19, além da dificuldade para contar com a adesão de mais empresas em participarem da pesquisa. Além disso, nesta tese foram feitas algumas escolhas para delimitação da pesquisa no que tange ao setor estudado, que em pesquisas futuras podem ser modificadas. Deste modo, torna-se necessário o desenvolvimento de mais pesquisas nesta temática.

De forma geral, verifica-se a necessidade de mais pesquisas empíricas que possam “mensurar” os *trade-offs* e sinergias entre as práticas *Lean* e *Green* e os impactos nas prioridades competitivas. Ainda, pesquisas que identifiquem quais são os fatores facilitadores e as barreiras para a integração e implantação da abordagem *Lean-Green* nas áreas de decisão. Do mesmo modo, é relevante que sejam realizadas investigações científicas que busquem analisar de maneira profunda, a partir da implantação das práticas Lean-Green, como cada área de decisão colabora e quais são seus impactos nas prioridades competitivas. Além disso, estudos em outros setores podem proporcionar uma visão abrangente de configurações de estratégias de operações quando práticas Lean e Green são implementadas. Por fim, recomenda-se a realização de estudos que contemplem a perspectiva social, na perspectiva de se considerar o tripé da sustentabilidade em pesquisas sobre a estratégia de operações.

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APÊNDICE A – MATERIAL SUPLEMENTAR RBS

SLR SUPPLEMENTARY MATERIAL

A. SLR Protocol

1 Question Formulation

1.1 Research Problem

There are many studies that highlight the importance of operations strategy and the reduction of negative environmental impacts from products and process. Furthermore there are studies that point positive results of improvements in environmental aspects caused by the implementation of lean production practices. However, it is missing studies that address the environmental issues embedded in the operation strategy, as well as how the content of operations strategy, competitive priorities and decision areas, is related with Lean-Green practices.

1.2 Research Question

Firstly, we established the SLR research questions needed to achieve the aim of the project, which was to identify how do the Lean-Green practices relate to content of OS. As a result, this aim was broken down into three research questions (RQs) as follows:

> *RQ1. Do the implementation of Lean-Green practices affect operations' competitive priorities causing synergies or trade-offs?*
>
> *RQ2. What decision area(s) are modified with the implementation of each practice?*

1.3 Objective

Explain how the Lean-Green literature addresses the relationship between the content of operations strategy and Lean-Green practices.

1.4 Primary references

Articles with the highest number of citations in the databases used were used as primary references, in addition to publications by members of the group, specialists in the areas of interest.

Primary references	
Operations Strategy	(CHATHA; BUTT, 2015; SKINNER, Wickham, 1969; SLACK; LEWIS, 2011; WHEELWRIGHT, 1984).
Lean Manufacturing	(KRAFCIK, 1988; LIKER, 2005; WOMACK, James; JONES, 2004)
Green	(GAVRONSKI, 2012; GIMENEZ; SIERRA; RODON, 2012; KLEINDORFER; SINGHAL; VAN WASSENHOVE, 2005; PATHAK; SINGH, 2017).

1.5 Keywords:

After a preliminary review on operations strategy, Lean Manufacturing and Green Manufacturing, some keywords were identified among the three themes, the construction of the strings was performed from the combination between the terms linked to the three thematic groups as presented in the following Chart.

Thematic Groups	**Keywords**
1 – Operations Strategy	*operation* strategy; manufacturing strategy; production strategy*
2- Lean Manufacturing	*Lean Manufacturing: lean manufactur* (manufacture, manufacturing); lean thinking; lean production; lean system* (system, systems); toyota production system* (system, systems).*
3 – Green Manufacturing	*green manufacturing; clean* (clean/cleaner) production; pollution prevention; resource efficient/efficiency (production, manufacturing, methods); environmental manufacturing; Sustainable operations; Environmentally Responsible Manufacturing.*

Consulting the primary references the most commonly used key words to refer to the areas of interest were selected. These keywords do not represent synonyms, but are capable of obtaining results within the area of interest when combined.

○Operations strategy,

<table>
<tr><td>Opeation Strategy</td><td colspan="2">Operation Strategy
Manufacturing Strategy
Production Strategy</td></tr>
<tr><td>Competitive priority</td><td colspan="2">Competitive priority
Operation priority
Performance objective
Flexibility
Quality
Delivery
Speed
Dependability
Cost
Service</td></tr>
<tr><td>Decision Areas
Facility
Capacity
Technology
Vertical Integration
Workforce
Quality
Planning and control
Organization</td><td>Facility
Localization
Capacity
Layout
Mix of product
Technology
Equipment
Machine
System
Vertical Integration
Purchase strategy
Supplier relationship
Workforce
Quality
Planning and control
Organization
Improvement practices
Performance indicators
Design of product</td><td>Decision Areas
Facility
Localization
Geography
Capacity
Layout
Mix of product
Product group
Variety of product
Technology
Equipment
Machine
System
Vertical Integration
Supply chain
Value chain
Supply network
Purchase strategy
Make or buy
Workforce
Labor
Human resource
Quality management
Planning and control
Organization
Improvement practices
Performance indicators
Performance measurement system
Design of product
Product development</td></tr>
</table>

○Lean Manufacturing

Lean	Lean; Toyota production system; Just in time.

○Green manufacturing

Green	Green; Cleaner; Pollution prevention; Resource efficiency; Environment; Responsible; Sustainability; Social;

In addition, the words “manufacturing’ and “Industry” were added to direct the search only to manufacturing sectors. Below are listed the search strings composed of these words used in each database.

2 Selection of databases

This section describes the procedure and criteria for the selection of the databases to be used for the systematic review.

2.1 Databases

The criterion for selection of databases was based on international reach and recognition. The databases selected were: Web of Science, Scopus and EBSCO.

2.2 Search Strings definition

The search method consists in using strings defined in a way that returns results that simultaneously contain at least one keyword related to production strategy, lean and green manufacturing in the search fields: title, abstract or keywords. In order to amplify the results, the number of articles found, it was sought to use the synonyms of the key words in English. The strings definition is adequate to each researched database, once the search mechanisms are different in each base. The strings used in this research can be seen in the table below.

There was no year limited and the search was conducted on 14/01/2019, as well as the importation of the libraries to the StArt software. In 01/11/2020 was done a search update. It is noteworthy that we chose a more detailed string seeking the widest possible range of articles, especially regarding the content of the production strategy, due to the possibility of having an article addressing only one competitive priority or a single decision area. Following are the search strings used in each database.

Web of science

TS=((operation* strateg* OR manufactur* strateg* OR production* strateg* OR competitive priorit* OR operation* priorit* OR performance objective* OR cost OR quality OR delivery OR speed OR velocity OR flexibility OR dependability OR decision area* OR strateg* decision* OR infrastructural decision OR structural decision OR facilit* OR localization OR location OR locality OR geography OR layout OR plant design OR capacity OR size OR mix of product OR product group OR variety of product OR product range OR technology OR equipment OR machine OR system OR vertical integration OR supply chain OR value chain OR supply network OR supplier* OR make or buy OR purchase strategy OR workforce OR labor OR human resource OR wage OR reward system OR compensation system OR skill* OR abilit* OR competence* OR quality management OR planning and control OR demand forecasting OR inventory OR organization* OR leadership OR guidance OR management OR improvement practice* OR continuous improvement OR performance indicators OR performance measurement system OR design of product OR product development OR innovation) AND (lean OR toyota production system OR Just in time) AND (green OR cleaner OR pollution prevention OR Resource efficiency OR environment* OR responsible OR sustainab* OR social) AND (industry* OR manufactur*))

SCOPUS

TITLE-ABS-KEY ("operation* strateg*" OR "manufactur* strateg*" OR "production* strateg*" OR "competitive priorit*" OR "operation* priorit*" OR "performance objective*" OR "cost" OR "quality" OR "delivery" OR "speed" OR "velocity" OR "flexibility" OR "dependability" OR "decision area*" OR "strateg* decision*" OR "infrastructural decision" OR "structural decision" OR "facilit*" OR "localization" OR "location" OR "locality" OR "geography" OR "layout" OR "plant design" OR "capacity" OR "size" OR "mix of product" OR "product group" OR "variety of product" OR "product range" OR "technology" OR "equipment" OR "machine" OR "system" OR "vertical integration" OR "supply chain" OR "value chain" OR "supply network" OR "supplier*" OR "make or buy" OR "purchase strategy" OR "workforce" OR "labor" OR "human resource" OR "wage" OR "reward system" OR "compensation system" OR "skill*" OR "abilit*" OR "competence*" OR "quality management" OR "planning and control" OR "demand forecasting" OR "inventory" OR "organization*" OR "leadership" OR "guidance" OR "management" OR "improvement practice*" OR "continuous improvement" OR "performance indicators" OR "performance measurement system" OR "design of product" OR "product development" OR "innovation") AND TITLE-ABS-KEY ("lean" OR "toyota production system" OR "Just in time") AND TITLE-ABS-KEY ("green" OR "cleaner" OR "pollution prevention" OR "Resource efficiency" OR "environment*" OR "responsible" OR "sustainab*" OR "social") AND ABS ("industr*" OR "manufactur*")

EBSCO

((operation* strateg* OR manufactur* strateg* OR production* strateg* OR competitive priorit* OR operation* priorit* OR performance objective* OR cost OR quality OR delivery OR speed OR velocity OR flexibility OR dependability OR decision area* OR strateg* decision* OR infrastructural decision OR structural decision OR facilit* OR localization OR location OR locality OR geography OR layout OR plant design OR capacity OR size OR mix of product OR product group OR variety of product OR product range OR technology OR equipment OR machine OR system OR vertical integration OR supply chain OR value chain OR supply network OR supplier* OR make or buy OR purchase strategy OR workforce OR labor OR human resource OR wage OR reward system OR compensation system OR skill* OR abilit* OR competence* OR quality management OR planning and control OR demand forecasting OR inventory OR organization* OR leadership OR guidance OR management OR improvement practice* OR continuous improvement OR performance indicators OR performance measurement system OR design of product OR product development OR innovation) AND (lean OR toyota production system OR Just in time) AND (green OR cleaner OR pollution prevention OR Resource efficiency OR environment* OR responsible OR sustainab* OR social) AND (industry* OR manufactur*))

The results brought many articles in common between the databases which implies that the databases converge among themselves, thus, this evidences that if new databases were included the results would probably return the same.

2.3 Criteria for articles selection

- Language: English and Portuguese
- Period: from the earliest to the present date
- Only articles from periodicals will be accepted

2.4 Methods and tools

This stage involved defining the steps for conducting searches, defining filters, tools used and databases. Searches were conducted using strings, which were presented in topic 1.3 of this protocol and were defined so as to return results that simultaneously contained at least one keyword referring to the three themes.

The filters were separated in 1, 2 and 3, which will be described in detail in topic 3. The tools used to store the results obtained were the StArt and Microsoft Excel and QDA Miner to content analysis.

3 Processing

In this stage the database searches took place from October 2018 to November 2018 using the strings previously defined. The results of the searches were exported and converted as files from the StArt program and used during Filter 1 and Microsoft Excel, used during filters 2 and 3. In the sequence, the inclusion and exclusion criteria are described and subsequently how each filter was performed are presented in detail.

3.1 Criteria for inclusion and exclusion of articles

In this step it is defined if the studies should or should not be selected for the Systematic Review. The criteria for inclusion and exclusion of articles are of great importance, since when performing searches it is likely that one will find a large number of studies that do not answer the research questions. Thus, the following inclusion and exclusion criteria were determined:

Inclusion:
- Be in the English or Portuguese language;
- Address the areas of interest: production strategy, lean manufacturing and green manufacturing;

Exclusion:
- Duplicate studies; Articles that use the term sustainability or similar terms in the sense of durability/permanence;
- Studies that had fenced access to the full content of their text and were not available for download.
- Articles that only cited the areas of interest but did not answer at least one research question.

3.2 Filter 1

Filter 1 consists of reading the title and abstract of each study found in the search, eliminating studies that meet the inclusion and exclusion criteria and duplicate studies. The results found are shown in the table below.

Studies found with the search strings	
Web of Science	1.488
SCOPUS	1682
EBSCO	1467
Gross total	4.637
Duplicate studies	1002
Total	3635
Studies selected Filter 1	345
Studies selected Filter 2	222
Studies selected Filter 3	165
Results from search update	
Web of Science	508
SCOPUS	450
EBSCO	350
Gross total	1308
Duplicate studies	315
Total	993
Studies selected Filter 1	180
Studies selected Filter 2	168
Studies selected Filter 3	95
Total of studies analysed	**260**

This gross total refers to all articles found using the search strings in the databases used.

3.3 Filter 2

In Filter 2, the introduction and conclusion of the selected studies are read, and the qualification is started. This filter will be performed because in filter 1 the studies that were kept were doubtful as to their relevance to the areas of interest. If after reading the introduction and conclusion the study proves not to be pertinent, it will be excluded.

Inclusion and exclusion criteria applied:

- Relevance: Main topic related to the two areas of interest.
  - Yes
  - No

3.4 Filter 3

Filter 3 is the reading of the entire text and aims to extract specific information from the studies related to the research topic. In this filter, qualification criteria will be used in order to classify the selected studies and evaluate their importance for the research:

- Research Method, for example:
  - Theoretical-conceptual
  - Simulation
  - Survey

  - Case Study
  - Action Research
  - Experiment
  - Systematic Review
- Sector in which the study was developed: The classification according to sector will indicate for which sector the study was developed, the answer is an open question, examples are: automotive sector, aeronautics, civil construction, among others.
- Country where the study was developed and the institution of the first author of the study.
- Size of the companies where the empirical studies were conducted.
- Lean, Green and lean-green practices addressed.
- Decision area and competitive priority of the operation strategy considered.
- In addition to these points were extracted the points of trade-offs and synergies between the practices found.

In the next section of this supplementary material it is presented all the studies analysed in the filter 3.

B. Studies

1. Number correspondent, author, title and Journal.

Number of study	Author	Title	Journal
1	(MILLER; PAWLOSKI; STANDRIDGE, 2010)	A case study of lean, sustainable manufacturing	International Journal Of Industrial Engineering And Management
2	(LERMEN *et al.*, 2018)	A framework for selecting lean practices in sustainable product development The case study of a Brazilian agroindustry.	Journal Of Cleaner Production
3	(CHERRAFI *et al.*, 2016)	A framework for the integration of Green and Lean Six Sigma for superior sustainability performance	International Journal Of Production Rese
4	(PAMPANELLI; FOUND; BERNARDES, 2014)	A Lean e Green Model for a production cell	Journal Of Cleaner Production
5	(KLOTZ; HORMAN; BODENSCHATZ, 2007)	A Lean Modeling Protocol for Evaluating Green	Lean Construction Journal
6	(MÜLLER; STOCK; SCHILLIG, 2014)	A method to generate energy value-streams in production and logistics in respect of time- and energy-consumption	Production Management
7	(GARZA-REYES *et al.*, 2018a)	A PDCA-based approach to Environmental Value Stream Mapping (E-VSM)	Journal Of Cleaner Production
8	(DE CARVALHO; GRANJA; DA SILVA, 2017)	A systematic literature review on integrative lean and sustainability synergies over a building's lifecycle	Sustainability
9	(PRASAD; KHANDUJA;	An empirical study on applicability of lean and green practices in the foundry industry	Journal Of Manufacturing Technology Management

	SHARMA, 2016)		
10	Paranitharan et al. (2017)	An empirical validation of integrated manufacturing business excellence model	The International Journal Of Advanced Manufacturing Technology
11	Thanki, Govindan e Thakkar (2016)	An investigation on lean-green implementation practices in Indian	Journal Of Cleaner Production
12	(HO; MOHD HASHIM; MOHD IDRIS, 2015)	Applicability of SIRIM Green 5-S Model for productivity & business growth in Malaysia	The Tqm Journal
13	(VASANTHAKUMAR; VINODH; VISHAL, 2017)	Application of analytical network process for analysis of product design	Clean Technologies And Environmental Policy
14	(VINODH; RAMESH; ARUN, 2016)	Application of interpretive structural modelling for analysing the factors influencing integrated lean sustainable system	Clean Technologies And Environmental Policy
15	(AZFAR, 2017)	Application of Lean Agile Resilient Green Paradigm Framework on China Pakistan Economic Corridor A Case Study	Journal Of Engineering & Technology
16	(FU; GUO; ZHANWEN, 2017)	Applying the green Embedded lean production model in developing countries A case study of China	Environmenr Development
17	(SALVADOR; PIEKARSKI; FRANCISCO, 2017)	Approach of the Two-way Influence Between Lean and Green Manufacturing and its Connection to Related Organisational Areas	International Journal Of Production Management And Engineering
18	(DIAZ-ELSAYED *et al.*, 2013)	Assessment of lean and green strategies by simulation of manufacturing systems in discrete production environments	Manufacturing Technology
19	(KUMAR, Sanjay *et al.*, 2016)	Barriers in green lean six sigma product development process an ISM approach	Production Planning And Control
20	(BELHADI; TOURIKI; EL FEZAZI, 2018)	Benefits of adopting lean production on green performance of SMEs a case study	Production Planning And Control
21	(MAXWELL *et al.*, 1998)	Case study Honda of America manufacturing, Can lean production practices increase environmental performance	Environmental Quality Management
22	(KHAN, Z., 2008)	Cleaner production an economical option for ISO certification in	Journal Of Cleaner Production

23	(SULAIMAN *et al.*, 2019)	Cleaner production implementation in an E-Waste recovery plant by using the Value Stream Mapping	Journal Of Advanced Manufacturing Technology
24	(VERRIER *et al.*, 2014)	Combining organizational performance with sustainable development issues the Lean and Green project benchmarking repository	Journal Of Cleaner Production
25	(WANG, Z. *et al.*, 2015)	Composite sustainable manufacturing practice and performance framework Chinese auto-parts suppliers' perspective	International Jounal Of Production Economics
26	(REBELO; SANTOS; SILVA, 2014)	Conception of a flexible integrator and lean model for integrated management systems	Total Quality Management & Business Excellence
27	(BESSERIS; KREMMYDAS, 2014)	Concurrent multi-response optimization of austenitic stainless steel surface roughness driven by embedded lean and green indicators	Journal Of Cleaner Production
28	(BOLTIĆ *et al.*, 2016)	Continuous improvement concepts as a link between quality assurance and implementation of cleaner production - case study in the generic pharmaceutical industry	Chemical Industry & Chemical Engineering Quarterly
29	(CHAPLIN; O'ROURKE, 2018)	Could lean and green be the driver to integrate business improvement throughout the organisation_	International Journal Of Productivity And Performance Management
30	(LEME *et al.*, 2018)	Creating value with less impact Lean, green and eco-efficiency in a metal working industry towards a cleaner production	Journal Of Cleaner Production
31	(LONGONI; CAGLIANO, 2015a)	Cross-functional executive involvement and worker involvement in lean manufacturing and sustainability alignment	International Journal Of Operations & Production Management
32	(KARAULOVA; BASHKITE, 2016)	Decision-making framework for used industrial equipment	Inzinerine Ekonomika-Engineering Economics
33	(WU, P.; PIENAAR; O'BRIEN, 2013)	Developing a lean benchmarking process to monitor the carbon efficiency in precast concrete factories—a case study in Singapore	Journal Of Green Building
34	(GOTI *et al.*, 2018)	Development and application of an assessment complement for production system audits based on data quality, IT infrastructure, and sustainability	Sustainability

35	(LEONG, W. D. *et al.*, 2018)	Development of multivariate framework for lean and green process	Chemical Engineering Transactions
36	(SUNK *et al.*, 2017)	Developments of traditional value stream mapping to enhance personal and organisational system and methods competencies	International Journal Of Production Research
37	(ALVANDI *et al.*, 2016)	Economic and environmental value stream map (E2VSM) simulation for multi-product manufacturing systems	International Journal Of Sustainable Engineering
38	(LUCATO; VIEIRA; DA SILVA SANTOS, 2015)	Eco-Six Sigma integration of environmental variables into the Six Sigma technique	Production Planning And Control
39	(MKHAIMER; ARAFEH; SAKHRIEH, 2017)	Effective implementation of ISO 50001 energy management system Applying Lean Six Sigma approach	International Journal Of Engineering Business Management
40	(ERDIL; AKTAS; ARANI, 2018)	Embedding sustainability in lean six sigma efforts	Journal Of Cleaner Production
41	(FAHAD *et al.*, 2017)	Energy Management in a Manufacturing Industry through Layout Design	Procedia Manufacturing
42	(SAWHNEY *et al.*, 2007)	En-Lean a framework to align lean and green manufacturing in the metal cutting supply chain	International Journal Enterprise Network Management
43	(MANIKAS; KROES, 2018)	Environment is free, but its not a gift	International Journal Of Lean Six Sigma
44	(RUIZ-BENITEZ; LÓPEZ; REAL, 2017)	Environmental benefits of lean, green and resilient supply chain management The case of the aerospace sector	Journal Of Cleaner Production
45	(FERRONE, 1996)	Environmental business management practices for a new age	Total Quality Environmental Management
46	(JABBOUR, C. J. C. *et al.*, 2013)	Environmental management and operational performance in automotive companies in Brazil the role of human resource management and lean manufacturing	Journal Of Cleaner Production
47	(PIL; ROTHENBERG, 2003)	Environmental performance as a driver of superior quality	Production And Operations Management
48	(ANVARI; ZULKIFLI; YUSUFF, 2011)	Evaluation of Approaches to Safety in Lean Manufacturing and Safety Management	World Applied Sciences Journal

49	(CALDERA; DESHA; DAWES, 2017)	Exploring the role of lean thinking in sustainable business practice	Journal Of Cleaner Production
50	(DUARTE; CRUZ MACHADO, 2017)	Green and lean implementation an assessment in the automotive industry	International Journal Of Lean Six Sigma
51	(DÜES; TAN; LIM, 2013)	Green as the new Lean how to use Lean practices as a catalyst to greening your supply chain	Journal Of Cleaner Production
52	(MELNYK *et al.*, 2001)	Green MRP Identifying the material and environmental	International Journal Of Production Research
53	(OLSON; BRADY, 2009)	Green Sigma and the technology of transformation for environmental stewardship	Ibm Journal Of Research And Development
54	(MOLLENKOPF *et al.*, 2010)	Green, lean, and global supply chains	International Journal Of Physical Distribution & Logistics Management
55	(AMANI *et al.*, 2015)	Green-Lean Synergy - Root-Cause Analysis in Food Waste Prevention	International Journal On Food System Dynamics
56	(WU, P.; FENG, 2014)	Identification of non-value adding activities in precast concrete production to achieve low-carbon production	Architectural Science Review
57	(GREEN *et al.*, 2019)	Impact of JIT, TQM and green supply chain practices on environmental sustainability	Journal Of Manufacturing Technology Management
58	(YANG; HONG; MODI, 2011)	Impact of lean manufacturing and environmental management on business performance: An empirical study of manufacturing firm	International Journal Of Production Economics
59	(SANT'ANNA *et al.*, 2017)	Implementation of Lean and Green practices a supplier-oriented assessment method	Production Engineering
60	(RAJ *et al.*, 2017)	Implementation of lean production and environmental sustainability in the Indian apparel manufacturing industry a way to reach the triple bottom line	International Journal Of Fashion Design, Technology And Education
61	(BEN RUBEN; VINODH; ASOKAN, 2017)	Implementation of Lean Six Sigma framework with environmental considerations in an Indian automotive component manufacturing firm a case study	Production, Planning And Control
62	(CHEUNG; LEONG; VICHARE, 2017)	Incorporating lean thinking and life cycle assessment to reduce environmental impacts of plastic injection moulded products	Journal Of Cleaner Production

63	(IOPPOLO *et al.*, 2014)	Industrial ecology and environmental lean management Lights and shadows	Sustainability
64	(AZEVEDO, Susana G. *et al.*, 2012)	Influence of Green and Lean Upstream Supply Chain Management Practices on Business Sustainability	Ieee Transactions On Engineering Management
65	(NG; LOW; SONG, 2015)	Integrating and implementing Lean and Green practices based on proposition of Carbon-Value Efficiency metric	Journal Of Cleaner Production
66	(HALLAM; CONTRERAS, 2016)	Integrating lean and green management	Management Decision
67	(JOHNSON; SUN; JOHNSON, 2007)	Integrating multiple manufacturing initiatives Challenge for automotive suppliers	Measuring Business Excellence
68	(HELLENO *et al.*, 2017)	Integrating sustainability indicators and Lean Manufacturing to assess	Journal Of Cleaner Production
69	(PUVANASVARAN *et al.*, 2012)	Integration model of ISO 14001 with lean principles	American Journal Of Applied Sciences
70	(WIRKUS; CHMIELARZ, 2018)	Integration of lean management with ISO management systems in enterprise	Management And Production Engineering Review
71	(BEN RUBEN; VINODH; ASOKAN, 2018)	ISM and Fuzzy MICMAC application for analysis of Lean Six Sigma barriers with environmental considerations	International Journal Of Lean Six Sigma
72	(KLASSEN, 2000)	Just-in-time manufacturing and pollution prevention generate mutual benefits in the furniture industry Klassen	Interfaces
73	(PIL; ROTHENBERG, 2003)	Knowledge content and worker participation in environmental management at NUMMI	Journal Of Management Studies
74	(AZEVEDO, Susana Garrido; CARVALHO; CRUZ-MACHADO, 2016)	LARG index A benchmarking tool for improving the leanness, agility, resilience and greenness of the automotive supply chain	Benchmarking: An International Journal
75	(FLORIDA, 1996)	Lean and Green the move to environmentally conscious manufacturing	California Management Review

76	(VAIS *et al.*, 2006)	Lean and Green at a Romanian secondary tissue paper and board mill - Putting theory into practice	Resources, Conservation And Recycling
77	(INMAN; GREEN, 2018)	Lean and green combine to impact environmental and operational performance	International Journal Of Production Research
78	(GALEAZZO; FURLAN; VINELLI, 2014)	Lean and green in action interdependencies and performance of pollution prevention projects	Journal Of Cleaner Production
79	(KURDVE *et al.*, 2014)	Lean and green integration into production system models – experiences from Swedish industry	Journal Of Cleaner Production
80	(VERRIER; ROSE; CAILLAUD, 2016)	Lean and Green strategy the Lean and Green House and maturity deployment model	Journal Of Cleaner Production
81	(COLICCHIA; CREAZZA; DALLARI, 2017)	Lean and green supply chain management through intermodal transport insights from the fast moving consumer goods industry	Production, Planning E Control
82	(MASON; NIEUWENHUIS; SIMONS, 2008)	Lean and green supply chain mapping adapting	Progress In Industrial Ecology: An International Journal
83	(CAMPOS; VAZQUEZ-BRUST, 2016)	Lean and green synergies in supply chain management	Supply Chain Management: An International Journal
84	(SONG; LIANG, 2011)	Lean construction implementation and its implication on sustainability a contractor's case study	Canadian Journal Of Civil Engineering
85	(RAGHU KUMAR; AGARWAL; SHARMA, 2016)	Lean management – a step towards sustainable green supply chain	Competitiveness Review
86	(WU, P.; LOW, 2012)	Lean management and low carbon emissions in precast concrete factories in Singapore	Journal Of Architectural Engineering
87	(HAJMOHAMMAD *et al.*, 2013a)	Lean management and supply management their role in green practices and performance	Journal Of Cleaner Production
88	(HABIDIN, Nurul Fadly *et al.*, 2018)	Lean manufacturing practices ISO 14001 and environmental performance in Malaysian automotive suppliers	Journal Of Management Science And Engineering Management
89	(LETENS, 2015)	Lean Product Development—Faster, Better, Cleaner	Frontiers Of Engineering Management

90	(PENG; PHENG, 2011)	Lean production, value chain and sustainability in precast concrete factory-A case study in Singapore	Lean Construction Journal
91	(POWELL *et al.*, 2017)	Lean Six Sigma and environmental sustainability the of Norwegian	International Journal Of Lean Six Sigma
92	(SO; SUN, 2015)	Lean thinking as organisational practice in enabling supply chain sustainability	International Journal Of Environmental Technology And Management
93	(UGARTE; GOLDEN; DOOLEY, 2016)	Lean versus green The impact of lean logistics on greenhouse gas emissions in consumer goods supply chains	Journal Of Purchasing & Supply Management
94	(CHERRAFI *et al.*, 2018)	Lean, green practices and process innovation A model for green supply chain performance	International Journal Of Production Economics
95	(ROTHENBERG; PIL; MAXWELL, 2001)	Lean, green, and the quest for superior environmental performance	Production And Operations Management
96	(BELAYUTHAM; GONZÁLEZ; YIU, 2017)	Lean-based clean earthworks operation	Journal Of Cleaner Production
97	(FERCOQ; LAMOURI; CARBONE, 2016)	Lean-Green integration focused on waste reduction techniques	Journal Of Cleaner Production
98	(GHOBAKHLOO; AZAR; FATHI, 2018)	Lean-green manufacturing the enabling role of information technology resource	Journal Of Manufacturing Technology Management
99	Souza e Alves (2018)	(SOUZA; ALVES, 2018)	Journal Of Cleaner Production
100	(MOR; SINGH; BHARDWAJ, 2016)	Learning on Lean Production A Review of Opinion and Research within Environmental Constraints	Operations And Supply Chain Management
101	(VINODH; BEN RUBEN; ASOKAN, 2016)	Life cycle assessment integrated value stream mapping	Clean Techn Environ Policy
102	(RATNAYAKE; CHAUDRY, 2017)	Maintaining sustainable performance in operating petroleum assets via a lean-six-sigma approach A case study from engineering support services	International Journal Of Lean Six Sigma

103	(DAVIES; VAN DER MERWE, 2016)	Methodology to produce a water and energy stream map (WESM) in the South African manufacturing industry	South African Journal Of Industrial Engineering
104	(AGUADO; ALVAREZ; DOMINGO, 2013)	Model of efficient and sustainable improvements in a lean production system through processes of environmental innovation	Journal Of Cleaner Production
105	(PINTO; MENDES, 2017)	Operational Practices of Lean Manufacturing Potentiating Environmental Improvements	Journal Of Industrial Engineering And Management
106	(RUBIO; COROMINAS, 2008)	Optimal manufacturing-remanufacturing policies in a lean production environment	Computers & Industrial Engineering
107	(NUJOOM; WANG; MOHAMMED, 2018)	Optimisation of a sustainable manufacturing system design using the multi-objective approach	The International Journal Of Advanced Manufacturing Technology
108	(WEE; CHUNG, 2009)	Optimising replenishment policy for an integrated production inventory deteriorating model considering green component-value design and remanufacturing	International Journal Of Production Research
109	(DOMINGO; AGUADO, 2015)	Overall environmental equipment effectiveness as a metric of a lean and green manufacturing system	Sustainability
110	(RUBEN; ASOKAN; VINODH, 2017)	Performance evaluation of lean sustainable systems using adaptive neuro fuzzy inference system a case study	International Journal Of Sustainable Engineering
111	(ALVES; ALVES, 2015)	Production management model integrating the principles of lean manufacturing and sustainability supported by the cultural transformation of a company	International Journal Of Production Research
112	(GANDHI; THANKI; THAKKAR, 2018b)	Ranking of drivers for integrated lean-green manufacturing for Indian manufacturing SMEs 2	Journal Of Cleaner Production
113	(LYON; QUESADA-PINEDA; CRAWFORD, 2014)	Reducing Electrical Consumption in the Forest Products Industry Using Lean Thinking	Bioresources
114	(HEGEDIC; GUDLIN;	Relationship between lean and green management in Croatian manufacturing companies	Interdisciplinary Description Of Complex Systems

	�TEFANI�, 2018)		
115	(HAJMOHAMMAD *et al.*, 2013b)	Reprint of Lean management and supply management	Journal Of Cleaner Production
116	(OGLETHORPE; HERON, 2010)	Sensible operational choices for the climate change agenda	The International Journal Of Logistics Management
117	(DALLASEGA; RAUCH, 2017)	Sustainable Construction Supply Chains through Synchronized Production Planning and Control in Engineer-to-Order Enterprises	Sustainability
118	(TSENG *et al.*, 2013)	Sustainable consumption and production for Asia sustainability through green design and practice	Journal Of Cleaner Production
119	(TAYYAB; SARKAR; ULLAH, 2018)	Sustainable lot size in a multistage lean-green manufacturing process under uncertainty	Mathematics
120	(CHIARINI, 2014)	Sustainable manufacturing-greening processes using specific Lean	Journal Of Cleaner Production
121	(BROWN, A.; AMUNDSON; BADURDEEN, 2014)	Sustainable value stream mapping (Sus-VSM) in different manufacturing system configurations application case studies	Journal Of Cleaner Production
122	(BROWN, A.; AMUNDSON; BADURDEEN, 2014)	Sustainable Value Stream Mapping (Sus-VSM) methodology to visualize and assess manufacturing sustainability performance	Journal Of Cleaner Production
123	(MAIA; ALVES; LEÃO, 2013)	Sustainable Work Environment with Lean Production in Textile	International Journal Of Industrial Engineering And Management
124	(JAMALI *et al.*, 2017)	SWOT-AHP Approach for Sustainable Manufacturing Strategy Selection A Case of Indian SME	Global Business Review
125	(MARUDHAMUTHU; MARIMUTHU, 2011)	The development of green environment through lean implementation in a garment industry	Journal Of Engineering And Applied Sciences
126	(GARZA-REYES *et al.*, 2018c)	The effect of lean methods and tools on the environmental performance of manufacturing organisations	International Journal Of Production Economics

127	(WU, L. *et al.*, 2015)	The Impact of Integrated Practices of Lean, Green, and Social Management Systems on Firm Sustainability	Sustainability
128	(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	Journal Of Cleaner Production
129	(BAJJOU *et al.*, 2017)	The Practical Relationships between Lean Construction Tools and Sustainable Development A literature review.	Journal Of Engineering Sc Ience And Technology Review
130	(MANIKAS; KROES, 2018)	The relationship between lean manufacturing, environmental damage, and firm performance	Letters In Spatial And Resource Sciences
131	(PIERCY; RICH, 2015)	The relationship between lean operations and sustainable operations	International Journal Of Operations & Production Management
132	(VINODH; ARVIND; SOMANAATHAN, 2011)	Tools and techniques for enabling sustainability through lean initiatives	Clean Technologies And Environmental Policy
133	(SIMPSON; POWER, 2005)	Use the supply relationship to develop lean and green suppliers	Supply Chain Management: An International Journal
134	(TORIELLI *et al.*, 2010)	Using lean methodologies for economically and environmentally sustainable foundries	China Foundry
135	(THANKI, S. J.; THAKKAR, 2016a)	Value–value load diagram a graphical tool for lean–green performance assessment	Production Planning & Control
136	(KURDVE *et al.*, 2015)	Waste flow mapping to improve sustainability of waste management a case study approach	Journal Of Cleaner Production
137	(SAJAN *et al.*, 2017)	Lean manufacturing practices in Indian manufacturing SMEs and their effect on sustainability performance	Journal Of Manufacturing Technology Management
138	(RAMOS *et al.*, 2018)	A lean and cleaner production benchmarking method for sustainability assessment	Journal Of Cleaner Production
139	(ZHU, X. *et al.*, 2017)	An economic model of integration framework of lean production and green manufacturing based on sustainability balanced scorecard	Boletín Técnico
140	(SREEDHARAN V; SANDHYA; RAJU, 2018)	Development of a green lean six sigma model for public sectors	International Journal Of Lean Six Sigma

141	(YIN, L. *et al.*, 2016)	Energy-Efficient Scheduling Problem Using an Effective Hybrid Multi-Objective Evolutionary Algorithm	Sustainability
142	(MAGNUSSON; BERGGREN, 2001)	Environmental innovation in auto development - managing technological uncertainty within strict time limits	International Journal Of Vehicle Design
143	(WIENGARTEN; FYNES; ONOFREI, 2013)	Exploring synergetic effects between investments in environmental and quality lean practices in supply chains	Supply Chain Management: An International Journal
144	(ABD RAHMAN; ISMAIL; ARIFFIN, 2016)	From Green to Lean Firms' Waste Management Practices and Their Impacts on Business Performance.	Social Sciences & Humanities
145	(WONG, C. W. Y.; WONG; BOON-ITT, 2018)	How Does Sustainable Development of Supply Chains	Business Strategy And The Environment
146	(RESTA *et al.*, 2017)	How Lean Manufacturing Affects the Creation of Sustainable Value An Integrated Model	International Journal Of Automation Techonology
147	(STRZELCZAK, 2017)	Integrated Assessment of 'Green–Lean' Production	International Journal Of Automation Technology
148	(THANKI, S. J.; THAKKAR, 2018)	Interdependence analysis of lean-green implementation challenges a caseof Indian SMEs	Journal Of Manufacturing Technology Management
149	Lee, Vittaldas e Prabhu (2016)	Just-in-time delivery for green fleets A feedback control approach	Transportation Research Part D: Transport And Environment
150	(OLIVEIRA; TAN; GUEDES, 2018)	Lean and green approach An evaluation tool for new product development focused on small and medium enterprises	International Journal Of Production Economics
151	(ZHU, Qingyun; JOHNSON; SARKIS, 2018)	Lean six sigma and environmental sustainability hospital perspective	Supply Chain Forum: An International Journal
152	(RUBEN; VINODH; ASOKAN, 2018)	Lean Six Sigma with environmental focus review and framework	International Journal Of Advanced Manufacturing
153	(MITTAL; SINDHWANI; KAPUR, 2016)	Two-way assessment of barriers to Lean–Green Manufacturing System insights from India	International Journal Of Systems Assurance Engineering Management

154	(SANTOS *et al.*, 2019)	Using problem-oriented monitoring to simultaneously improve productivity and environmental performance in manufacturing companies	International Journal Of Computer Integrated Manufacturing
155	(SARTAL; MARTINEZ-SENRA; CRUZ-MACHADO, 2018)	Are all lean principles equally eco-friendly A panel data study	Journal Of Cleaner Production
156	(FATEMI; FRANCHETTI, 2016)	An application of sustainable lean and green strategy with a Six Sigma approach on a manufacturing system	International Journal Of Six Sigma And Competitive Advantage
157	(WHITE; JAMES, 2014)	Extension of process mapping to identify “green waste”	Benchmarking: An International Journal
158	(DE FREITAS; COSTA; FERRAZ, 2017)	Impacts of Lean Six Sigma over organizational sustainability A survey study	Journal Of Cleaner Production
159	(GUPTA *et al.*, 2018)	Implementation of sustainable manufacturing practices in Indian manufacturing companies	Benchmarking: An International Journal
160	(GECEVSKA; ANISIC; STOJANOVA, 2013)	Lean product lifecycle management approach	International Journal Of Industrial Engineering And Management
161	(BALL, 2015)	Low energy production impact on lean flow	Journal Of Manufacturing Technology Management
162	(HABIDIN, N. F.; YUSOF, 2012)	Relationship between lean six sigma, environmental management systems, and organizational performance in the Malaysian automotive industry	International Journal Of Automotive Technology
163	(WONG, W. P.; WONG, 2014)	Synergizing an ecosphere of lean for sustainable operations	Journal Of Cleaner Production
164	(KING; LENOX, 2001)	Lean and green? An empirical examination of the relationship between lean production and environmental performance	Production And Operations Management
165	(GARZA-REYES, 2015)	Lean and green a systematic review of the state of the art literature	Journal Of Cleaner Production
166	(UDOKPORO, C.; ANOSIKE; LIM,	A decision-support framework for Lean, Agile and Green practices in product life cycle stages	Journal Of Cleaner Production

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167	(ORJI; LIU, 2020)	A dynamic perspective on the key drivers of innovation-led lean approaches to achieve sustainability in manufacturing supply chain	International Journal Of Production Economics
168	(DEHDASHT *et al.*, 2020)	A hybrid approach using entropy and TOPSIS to select key drivers for a successful and sustainable lean construction	Plos One
169	(PATTANAIK; BAUG; KOTESWARAPAVAN, 2019)	A hybrid ELECTRE based prioritization of conjoint tools for lean and sustainable manufacturing	Production Management
170	(RAFIQUE *et al.*, 2020)	A Lean Agile Resilient Green Implementation and Technology Utilization A New Vision in Technology Adoption	Journal Of Engineering And Technology
171	(SWARNAKAR *et al.*, 2020)	A multiple integrated approach for modelling critical success factors in sustainable LSS implementation	Computers And Industrial Engineering
172	(LI *et al.*, 2020)	A new framework of industrialized construction in China Towards on-site industrialization.	Journal Of Cleaner Production
173	(AMJAD *et al.*, 2020)	A new vision of LARG Manufacturing — A trail towards Industry 4.0	Cirp Journal Of Manufacturing Science And Technology
174	(BAYSAN *et al.*, 2019)	A simulation-based methodology for the analysis of the effect of lean tools on energy efficiency An application in power distribution industry	Journal Of Cleaner Production
175	(TIWARI; SADEGHI; ESEONU, 2020)	A sustainable lean production framework with a case implementation Practice-based view theory.	Journal Of Cleaner Production
176	(RAMIREZ-PEÑA *et al.*, 2020)	Achieving a sustainable shipbuilding supply chain under I4.0 perspective.	Journal Of Cleaner Production
177	(RUIZ-BENITEZ; LÓPEZ; REAL, 2019)	Achieving sustainability through the lean and resilient management of the supply chain	International Journal Of Physical Distribution \& Logistics Management
178	(LEONG, W. D. *et al.*, 2019)	Adaptive analytical approach to lean and green operations	Benchmarking
179	(FARIAS *et al.*, 2019a)	An ANP-based approach for lean and green performance assessment	Resources, Conservation & Recycling

180	(LIU; LIAO; ZHANG, 2019)	An enhanced MOPSO algorithm for energy-efficient single-machine production scheduling	Sustainability
181	(MAQBOOL *et al.*, 2019)	An Implementation Framework to Attain 6R-Based Sustainable Lean Implementation-A Case Study	Ieee Access
182	(PANDITHAWATTA; ZAINUDEEN; PERERA, 2020)	An integrated approach of Lean-Green construction Sri Lankan perspective	Built Environment Project And Asset Management
183	(CHOUDHARY *et al.*, 2019b)	An integrated lean and green approach for improving sustainability performance a case study of a packaging manufacturing SME in the U.K.	Production Planning \& Control
184	(GAIKWAD; SUNNAPWAR, 2020)	An integrated Lean, Green and Six Sigma strategies A systematic literature review and directions for future research	TQM Journal
185	(THANKI, S.; THAKKAR, 2020)	An investigation on lean–green performance of Indian manufacturing SMEs	International Journal Of Productivity And Performance Management
186	(ZHU, X. Y.; ZHANG; JIANG, 2020)	Application of green-modified value stream mapping to integrate and implement lean and green practices A case study	International Journal Of Computer Integrated Manufacturing
187	(BEN RUBEN; VINODH; ASOKAN, 2019)	Application of multi-grade fuzzy and ANFIS	Benchmarking
188	(MINH; NGUYEN; CUONG, 2019)	Applying lean tools and principles to reduce cost of waste management an empirical research in Vietnam	Management And Production Engineering Review
189	(MELLADO; LOU, 2020)	Building Information Modelling, Lean and Sustainability An integration	Business Strategy And The Environment
190	(SULAIMAN *et al.*, 2019)	Cleaner production value stream mapping at a chromium plating plant A case study	International Journal Of Agile Systems And Management
191	(NIÑEROLA; FERRER-RULLAN; VIDAL-SUÑÉ, 2020)	Climate change mitigation Application of management production philosophies for energy saving in industrial	Sustainability
192	(ZHU, X. Y.; ZHANG, 2020)	Construction of lean-green coordinated development model from the perspective of personnel integration in	Proceedings Of The Institution Of Mechanical Engineers Part B-Journal Of engineering

			Manufacture
193	(FARIAS *et al.*, 2019b)	Criteria and practices for lean and green performance assessment Systematic review and conceptual framework	Journal Of Cleaner Production
194	(GAIKWAD; SUNNAPWAR, 2021)	Development of an integrated framework of LGSS strategies for Indian manufacturing firms to improve business performance an empirical study	TQM Journal
195	(R; VINODH; P, 2020)	Development of structural equation model for Lean Six Sigma system incorporated with sustainability considerations	International Journal Of Lean Six Sigma
196	(MISHRA *et al.*, 2020)	Development of sustainable value stream mapping	International Journal Of Lean Six Sigma
197	(JAMIL *et al.*, 2020)	DMAIC-based approach to sustainable value	Economic Research-Ekonomska Istrazivanja
198	(NUJOOM; MOHAMMED; WANG, 2019)	Drafting a cost-effective approach towards a sustainable manufacturing	Computers And Industrial Engineering
199	(LEITÃO; DE BRITO; CUBICO, 2019)	Eco-Innovation Influencers Unveiling the Role of Lean Management Principles Adoption	Sustainability
200	(BRAGLIA *et al.*, 2020)	Energy Cost Deployment (ECD) A novel lean approach to tackling	Journal Of Cleaner Production
201	(PILATI *et al.*, 2019)	Enhancing stock efficiency and environmental sustainability goals in direct distribution logistic networks	International Journal Of Advanced Operations Management
202	(LEONG, W. D. *et al.*, 2020)	Enhancing the adaptability: Lean and green strategy towards the Industry Revolution 4.0	Journal Of Cleaner Production
203	(CALDERA; DESHA; DAWES, 2019)	Evaluating the enablers and barriers for successful implementation of sustainable business practice in Lean SMES	Journal Of Cleaner Production
204	(DIESTE; PANIZZOLO; GARZA-REYES, 2020)	Evaluating the impact of lean practices on environmental performance evidences from five manufacturing companies	Production Planning \& Control

205	(LOGESH; BALAJI, 2021)	Experimental Investigations to Deploy Green Manufacturing	International Journal Of Precision Engineering And Manufacturing-Greentechnology
206	(AGYABENG-MENSAH *et al.*, 2021)	Exploring the mediating influences of total quality management and just in time between green supply chain practice	Journal Of Manufacturing Technology Management
207	(CHERRAFI *et al.*, 2019)	Green and lean a Gemba Kaizen model for sustainability enhancement	Production Planning \& Control
208	(DUARTE; CRUZ-MACHADO, 2019)	Green and lean supply-chain transformation a roadmap	Production Planning \& Control
209	(KASWAN; RATHI, 2020)	Green Lean Six Sigma for sustainable development Integration and	International Journal Of Sustainable Engineering
210	(SONY; NAIK, 2020)	Green Lean Six Sigma implementation framework a case of reducing graphite and dust pollution	International Journal Of Sustainable Engineering
211	(OGLETHORPE; HERON, 2010)	Green or lean A supply chain approach to sustainable performance	Journal Of Cleaner Production
212	(DESHMUKH; BORADE, 2019)	Green practices in the supply chain and their impact on its performance: In perspective of Indian plastic processing industry	International Journal Of Innovative Technology And Exploring Engineering
213	(MUÑOZ-VILLAMIZAR, Andrés *et al.*, 2019)	Green value stream mapping approach to improving productivity and	International Journal Of Productivity And Performance Management
214	(BASHA *et al.*, 2020)	Green and Lean Industrial Engineering Practices in Selected Manufacturing Units in Andhra Pradesh: Statistical Analysis	International Journal Of Emerging Trends In Engineering Research
215	(GARDAS; RAUT; NARKHEDE, 2019)	Identifying critical success factors to facilitate reusable plastic packaging	Journal Of Environmental Management
216	(GREEN *et al.*, 2019)	Impact of JIT, TQM and green supply chain practices on environmental sustainability	Journal Of Manufacturing Technology Management
217	(IRANMANESH *et al.*, 2019)	Impact of lean manufacturing practices on firms' sustainable performance Lean culture as a moderator	Sustainability
218	(SINGH, J.; SINGH; KUMAR, 2020)	Impact of lean practices on organizational sustainability through green supply chain management – an empirical investigation	International Journal Of Lean Six Sigma

219	(UDOKPORO, C. K. *et al.*, 2020)	Impact of Lean, Agile and Green (LAG)- Pre print	Resources, Conservation & Recycling
220	(ALI *et al.*, 2020)	Impact of Lean, Six Sigma and environmental sustainability on the performance of SMEs	International Journal Of Productivity And Performance Management
221	(JERMSITTIPARSERT; NAMDEJ; SRIYAKUL, 2019)	Impact of quality management techniques and system effectiveness on the green supply chain management practices	International Journal Of Supply Chain Management
222	(KAMBLE; GUNASEKARAN; DHONE, 2020)	Industry 4.0 and lean manufacturing practices for sustainable organisational performance in Indian manufacturing companies	International Journal Of Production Research
223	(YU *et al.*, 2020)	Innovativeness and lean practices for triple bottom line testing off it-as-mediation versus fit-as-moderation models	International Journal Of Operations \& Production Management
224	(SIEGEL *et al.*, 2019)	Integrated green lean approach and sustainability for SMEs From	Journal Of Cleaner Production
225	(TĂUCEAN *et al.*, 2019)	Integrating Sustainability and Lean SLIM Method and Enterprise Game Proposed	Sustainability
226	(SAGNAK *et al.*, 2020)	Integration of Lean Approach with Energy Efficiency: Application in Kitchenware Manufacturing Company	International Journal Of Mathematical, Engineering And Management Sciences
227	(BAI; SATIR; SARKIS, 2019)	Investing in lean manufacturing practices an environmental and operational perspective	International Journal Of Production Research
228	(VASCONCELOS; VIANA; NETO, 2017)	Lean and Green the contribution of lean production and environmental management to the waste	Brazilian Journal Of Management
229	(SINGH, P., 2019)	Lean in healthcare organization an opportunity for environmental sustainability	Benchmarkin An International Journal
230	(WANG, C. H.; CHEN; TAN, 2019)	Lean Six Sigma applied to process performance	Production Planning \& Control
231	(BHATTACHARYA; NAND; CASTKA, 2019)	Lean-green integration and its impact on sustainability performance	Journal Of Cleaner Production
232	(HARTINI *et al.*, 2020)	Manufacturing sustainability assessment using a lean manufacturing tool A case study in the Indonesian wooden	International Journal Of Lean Six Sigma

233	(SINDHWANI *et al.*, 2019)	Modelling and analysis of barriers affecting the implementation of lean green	Benchmarkin An International Journal
234	(KUMAR, N.; MATHIYAZHAGAN; MATHIVATHANAN, 2020)	Modelling the interrelationship between factors for adoption ofs ustainable lean manufacturing a business case from the Indian automobile industry	International Journal Of Sustainable Engineering
235	(SCHULZ; BUSCHER; SHEN, 2020)	Multi-objective hybrid flow shop scheduling with variable discrete production speed levels and time-of-use energy	Journal Of Business Economics
236	(TAFAZZOLI; MOUSAVI; KERMANSHACHI, 2020)	Opportunities and Challenges of Green-Lean An Integrated System for Sustainable Construction	Sustainability
237	(DE GIOVANNI; CARIOLA, 2020)	Process innovation through industry 4.0 technologies, lean practices and green supply chains	Research In Transportation Economics
238	(LU; DIAZ; HASAN, 2019)	Proposing a “lean and green” framework for equipment cost	Rontiers Of Engineering Management
239	(ZAINUDDIN *et al.*, 2019)	Quality green energy supply chain management practices in Malaysian Automotive Companies	Benchmarking
240	(PARMAR; DESAI, 2020)	Ranking the solutions of Sustainable Lean Six Sigma implementation in Indian manufacturing organization to overcome its barriers	Journal Of Business Economics
241	(BAUMER-CARDOSO *et al.*, 2020)	Simulation-based analysis of catalyzers and trade-offs in Lean & Green manufacturing	Journal Of Cleaner Production
242	(CHOUDHARY *et al.*, 2019b)	SI-TBL an integrated lean and green approach for improving	Production Planning \& Control
243	(TASDEMIR; GAZO; QUESADA, 2020)	Sustainability benchmarking tool (SBT) theoretical	Environment Development And Sustainability
244	(CHEN *et al.*, 2019)	Sustainable manufacturing Exploring antecedents and influence of Total Productive Maintenance and lean manufacturing	Advances In Mechanical Engineering

245	(BALIGA; RAUT; KAMBLE, 2020)	Sustainable supply chain management practices and performance An integrated perspective from a developing economy	Management Of Environmental Quality
246	(KUMAR, M.; RODRIGUES, 2020)	Synergetic Effect of Lean and Green on Innovation A Resource-based perspective	International Journal Of Production Economics
247	(SANCHEZ RODRIGUES; KUMAR, 2019)	Synergies and misalignments in lean and green practices a logistics industry perspective	Production Planning \& Control
248	(PIYATHANAVONG *et al.*, 2019)	The adoption of operational environmental sustainability approaches in the Thai manufacturing sector	Journal Of Cleaner Production
249	(ALLAWI; MIJBIL; SALLOOMI, 2019)	The compatibility between lean accounting and cleaner production for achieving competitive advantage	Polish Journal Of Management Studies
250	(DEY *et al.*, 2020)	The Impact of Lean Management Practices and Sustainably-Oriented Innovation on Sustainability Performance of Small	British Journal Of Management
251	(SHASHI *et al.*, 2019)	The impact of leanness and innovativeness on environmental and financial performance Insights from Indian SMEs	International Journal Of Production Economics
252	(PIERCY; RICH, 2015)	The relationship between lean and environmental performance	Journal Of Cleaner Production
253	(MUÑOZ-VILLAMIZAR, A. *et al.*, 2020)	Toolkit for simultaneously improving production and environmental efficiencies	Central European Journal Of Operations Research
254	(CAIADO *et al.*, 2019)	Towards sustainability by aligning operational programmes and sustainable performance measures	Production Planning \& Control
255	(SUIFAN; ALAZAB; ALHYARI, 2019)	Trade-off among lean, agile, resilient and green paradigms an empirical study on pharmaceutical industry in Jordan using a TOPSIS-entropy method	International Journal Of Advanced Operations Management
256	(WOLFF *et al.*, 2020)	Transforming automotive companies into sustainability leaders	Journal Of Cleaner Production
257	(SANTOS *et al.*, 2019)	Using problem-oriented monitoring to simultaneously improve productivity and environmental performance in manufacturing companies	International Journal Of Computer Integrated Manufacturing
258	(BAIT; DI PIETRO; SCHIRALDI, 2020)	Waste Reduction in Production Processes through Simulation and VSM	Sustainability

259	(PURUSHOTHAMAN; SEADON; MOORE, 2020)	Waste reduction using lean tools in a multicultural environment	Journal Of Cleaner Production
260	(KALYAR; SHAFIQUE; ABID, 2019)	Role of lean manufacturing and environmental management practices in eliciting environmental and financial performance: the contingent effect of institutional pressures	Environmental Science And Pollution Research

2. *Main focus of the research and Studies correspondents.*

Main Focus of the research	Studies	Total studies
Link between lean and green (synergies and trade-offs)	8; 11; 14; 17; 37; 43; 44; 45; 46; 47; 48; 51; 54; 55; 57; 58; 60; 63; 70; 72; 75; 77; 83; 87; 88; 89; 90; 91; 95; 98; 105; 114; 116; 125; 130; 131; 133; 137; 143; 144; 146; 148; 150; 151; 155; 158; 162; 164; 177; 184; 195; 199; 204; 206; 211; 212; 214; 216; 217; 218; 219; 220; 221; 222; 223; 234; 236; 247; 248; 249; 250; 251; 252; 254; 255.	75
Framework to integrate Lean and Green	2; 3; 4; 5; 10; 15; 16; 19; 20; 22; 24; 26; 29; 30; 35; 39; 40; 42; 53; 61; 62; 64; 65; 66; 69; 74; 79; 85; 92; 94; 97; 99; 107; 108; 110; 111; 122; 123; 124; 126; 128; 134; 135; 138; 139; 140; 152; 153; 159; 160; 163; 170; 172; 173; 175; 176; 178; 181; 192; 193; 194; 202; 203; 208; 209; 210; 224; 225; 226; 239; 240; 243; 253.	73
Results from implementation of Lean-GP	1; 18; 21; 25; 28; 31; 33; 34; 36; 38; 56; 67; 71; 73; 76; 78; 81; 84; 86; 93; 96; 102; 104; 113; 118; 119; 120; 129; 142; 145; 149; 154; 156; 161; 174; 180; 183; 185; 186; 188; 191; 205; 228; 229; 230; 235; 241; 244; 260.	49
Integrated LG Tools	6; 7; 9; 12; 23; 27; 32; 41; 52; 68; 80; 82; 101; 103; 106; 109; 115; 117; 121; 127; 132; 136; 141; 157; 182; 189; 190; 196; 197; 200; 201; 207; 213; 215; 233; 237; 242; 245; 246; 256; 257; 258; 259.	43
Method to evaluate the integration level	13; 50; 59; 147; 187.	5
Framework for practices selection	166; 168; 169; 227; 238.	5
State of the art of the literature about Lean and Green	49; 100; 165; 231.	4
Drivers to LG integration	112; 167; 171.	3
LG index	179; 232.	2
Lean and Green variable optimization model	198.	1

C. Codebook SLR's Content Analysis

1. The process of code definition

The first step it was to find the main constructs of the three areas based in the preliminary review of the literature for the inductive process.

a. Operations Strategy: competitive priorities and decision areas
b. Lean Manufacturing: lean practices
c. Green Manufacturing: green practices

2. Operations Strategy

2.1. Competitive priorities

Code	Competitive Priority	Focus	Author
Cost	Cost	Reduce production cost and price for customers	(SLACK; LEWIS, 2011)
		Produce and distribute products at a low price	(LEONG, G. K.; SNYDER; WARD, 1990)
		Product acquisition cost	(GARVIN, 1993)
		Production cost and productivity of capital	(FINE; HAX, 1985)
Quality	Quality	Produce products according to specifications	(SLACK; LEWIS, 2011)
		Perceived Quality	(GARVIN, 1993)
		Produce products with high quality and performance standards	(LEONG, G. K.; SNYDER; WARD, 1990)
Flexibility	Flexibility	Ability to react to changes in product mix and volume and production schedule	(Garvin, 1993, Slack and Lewis, 2011)
		Variation in the mix and volume of products produced	(GARVIN, 1993; LEONG, G. K.; SNYDER; WARD, 1990)
Delivery	Delivery	Reduce the lead-time between the beginning and the end of the operations	(SLACK; LEWIS, 2011)
		Have the product available and deliver it faster	(GARVIN, 1993; LEONG, G. K.; SNYDER; WARD, 1990)
		Fulfill the agreed product delivery deadline	(SLACK; LEWIS, 2011)
Service	Service	Support in customer service	(GARVIN, 1993; LEONG, G. K.; SNYDER; WARD, 1990)
		Provision of information to the customer	(GARVIN, 1993)
Environment	Environment	Reduce the environmental impacts	(GARZA-REYES, 2015; KLEINDORFER; SINGHAL; VAN WASSENHOVE, 2005; LONGONI; CAGLIANO, 2015b)
Social	Social	Corruption risk	(GOVINDAN *et al.*, 2015)

		Impacts on human resources	(CHERRAFI *et al.*, 2016)
		Working conditions and products security	(VELDHUIZEN *et al.*, 2015)

2.2. Decision areas

Code	Decision Area	Focus	Author
Facilities	Facilities	Location and Layout.	(HAYES *et al.*, 2007; JABBOUR, A. B. L. de S.; ALVES FILHO, 2009; SLACK; LEWIS, 2011)
		Plant size and Location	(SKINNER, Wickham, 1969)Skinner (1969)
		Location, product group, process type	(FINE; HAX, 1985)
Capacity	Capacity	Quantity to be produced, form of production	(HAYES *et al.*, 2007; JABBOUR, A. B. L. de S.; ALVES FILHO, 2009)
		Production volume	(FINE; HAX, 1985)
		Operational capacity, number of units, variety of products	(SLACK; LEWIS, 2011)
Technology	Technology	Equipment, systems and process type	(HAYES *et al.*, 2007; JABBOUR, A. B. L. de S.; ALVES FILHO, 2009; SKINNER, Wickham, 1969)
		Type of Process	(FINE; HAX, 1985)
		Definition of process technologies to be used	(SLACK; CHAMBERS; JOHNSTON, 2010)
		Type of process, technologies used in processes, equipment, machines and systems.	(SLACK; LEWIS, 2011)
Supply Chain	Supply Chain	Decision to make or buy; relationship with suppliers	(HAYES *et al.*, 2007; JABBOUR, A. B. L. de S.; ALVES FILHO, 2009)
		Degree of vertical integration	(SLACK; LEWIS, 2011)
		Degree of reliability with the supplier	(FINE; HAX, 1985)

		Design of the supply network involving make or buy decisions, supplier development, allocation of activities per facility and supplier relationships.	(SLACK; CHAMBERS; JOHNSTON, 2010)
		Purchasing strategy, supplier relationship, supply chain risks	(SLACK; LEWIS, 2011)
Humano Resources	Human Reoursce/ Workforce	Define the skills needed for human resources,	(HAYES *et al.*, 2007; JABBOUR, A. B. L. de S.; ALVES FILHO, 2009)
		Compensation system, incentives, and degree of specialization required for human resources.	(SKINNER, Wickham, 1969)
		Human resource management involving incentive policies, compensation system, and job design	(FINE; HAX, 1985)
		Definition of the functions that people should perform in the operation and the skills that should be developed.	(SLACK; CHAMBERS; JOHNSTON, 2010)
Quality Management	Quality Management	Quality policy and quality management system	(HAYES *et al.*, 2007; JABBOUR, A. B. L. de S.; ALVES FILHO, 2009)
		Quality management and performance measurement systems	(FINE; HAX, 1985)
		Finding ways to avoid and deal with failures in operations	(SLACK; CHAMBERS; JOHNSTON, 2010)
Production Planning and Control	Production Planning and Control	Production resource forecasting and scheduling	(HAYES *et al.*, 2007; JABBOUR, A. B. L. de S.; ALVES FILHO, 2009)
		Planning, inventory, and quality control	(SKINNER, Wickham, 1969)
		Demand forecasting and monitoring, demand response, planning and control systems, resource allocation decisions, and inventory sizing and control	(SLACK; CHAMBERS; JOHNSTON, 2010)
Product and Process Development	Product and Process Development	Decide what to buy externally and seek innovation.	(HAYES *et al.*, 2007)
		Product variety, design stability, process technology, development policy	(JABBOUR, A. B. L. de S.; ALVES FILHO, 2009)
		Product Design	(FINE; HAX, 1985)
		Definition of products to be developed and management of the development process	(SLACK; CHAMBERS; JOHNSTON, 2010))
		Use of manufacturing engineering, technological risk and design	(SKINNER, Wickham, 1969)

		stability.	
Performance Measurement System	Performance Measurement System	Related to process improvement, defining performance measurement system.	(SLACK; CHAMBERS; JOHNSTON, 2010)
		System of performance indicators,	(HAYES *et al.*, 2007)
Organization	Organization	Leadership	(HAYES *et al.*, 2007)
		Management style and organizational structure.	(SKINNER, Wickham, 1969)

3. Lean Manufacturing
3.1. Lean Practices codes

Lean Manufacturing practices defined through an inductive process guided by the literature review work of Godinho Filho and Fernandes (2004) and Shah and Ward (2003) about the state for art of Lean.

Code	**Lean Practice**	**Focus**	**Author (s)**
Value Stream Mapping	Value Stream Mapping	Represent the value stream, understanding the flow of materials, people and information and presenting the necessary steps for the production of a product, which goes from the consumer to the supplier.	(Mostafa et al., 2013; Rother et al., 1999)
5s	5s	Organizations of the work environment.	(Gurumurthy and Kodali, 2009)
Kaizen	Kaizen	Short term project, in event format, focusing on process improvement, cost reduction and waste elimination.	(Rother et al., 1999)
Visual Management	Visual Management	Boards with the workflow, process performance, problems and opportunities for improvement visible to all employees.	(Henderson and Jorge, 1999)
Standartization	Standartization	Definition of standard, specific and precise work procedures for each operator activity in a production process	(Spear and Bowen, 1999)
Just in Time (JIT)	*Just in Time (JIT)*	Controlling production so that everything is produced and delivered only in the quantity required and when needed	(Shingo, 2007)

Kanban	Kanban	Signal or "card" is a visual information system that, based on the pull system, signals the control of production or transport flows in a company.	(Liker, 2005; Ohno, 1988)
Poka yoke (Error-proof system)	Poka yoke (Error-proof system)	Methods to avoid mistakes during the execution of the task, in manufacturing processes and/or in the use of products.	(Feld, 2000)
Autonomation (*Jidoka)*	Autonomation (*Jidoka)*	It seeeks to provide equipment with the ability to differentiate good parts from bad parts automatically, eliminating the need for continuous monitoring of operators.	(Ohno, 1988)
Total productive maintenance (TPM)	Total productive maintenance (TPM)	Set of techniques to ensure the reliability and productivity of all machines in the production process.	(Feld, 2000)
SMED (Single Minute Exchange of Die)	SMED (Single Minute Exchange of Die)	The method to do the setup and chageover in less time, allowing increased flexibility and/or machine availability in the production flow.	(Feld, 2000)
Cellular Manufacturing	Cellular Manufacturing	Allocate equipment and workstations to similar products in a sequence that allows the continuous flow of materials and components through the process, with minimal transport or delay.	(Rother and Harris, 2001)
Heijunka	Heijunka	goal of distributing production volume evenly over the time horizon.	(Feld, 2000)
Continuos Flow	Continuos Flow	Continuous flow, without stops, waits and work in progress between the steps of the production process.	(Womack and Jones, 2004)
A3 Report	A3 Report	It is a complete report that documents a production or improvement process that one wants to develop in the company	(Liker, 2005)
Root cause analysis	Root cause analysis	A method to find the deeper and systematic causes of a problem	(Liker, 2005; Ohno, 1988)
Pulled Production	Pulled Production	Focus on producing only the quantities requested by the customer.	(Womack and Jones, 2004)
Continuous Improvement*	Continuous Improvement*	Strive for perfection by continuously eliminating waste.	(Womack and Jones, 2004)
		It is the ongoing improvement of products, services or processes through incremental and breakthrough improvements	American Society for Quality (ASQ)

TQM (Total Quality Management) *	TQM (Total Quality Management) *	Is a set of management practices to help companies increase their quality and productivity.	American Society for Quality (ASQ)
Gemba Walk *	Gemba Walk *	The tour of the shop-flor.	(CHERRAFI *et al.*, 2016)
Supply Chain Management *	Supply Chain Management *	The planning and management of all activities involved in sourcing and procurement, conversion, and all Logistics Management activities. It also includes coordination and collaboration with channel partners, In essence, Supply Chain Management integrates supply and demand management within and across companies.	(BALLOU, 2007)
Spaguetti Diagram*	Spaguetti Diagram*	A study to identify ways to shorten the walking time from one activity to another for frequently performed tasks.	(American Society for Quality, n.d.)
Statistical Process Control (SPC)*	Statistical Process Control (SPC)*	Consists of a powerful set of tools used in achieving process stability and improving capability through the reduction of variability.	(Montgomery, 2009)
Value Engineering*	Value Engineering*	The reduction of unnecessary functions to improve performance, as one of the most important items in this methodology.	(Santis SH et al., 2016)
Quality circles*	Quality circles*	A small group of employees of the same work area, doing similar work that meets voluntarily and regularly to identify, analyse and resolve work related problems.	(Koneru, 2018)
Hoshin Kanri*	Hoshin Kanri*	A systematic system of performance evaluation, developed to guide the day-to-day actions are aligned with the strategic vision of the company, so that they are effective and achieve the desired results .	(Cowley and Domb, 1997)

* This practices were selected through the deductive process, which attempted to identify in the articles selected in the SLR other Lean practices that could emerge.

4. Green Manufacturing

4.1. Green Practices

The Green Practices was based in the practices presented in the (GUPTA *et al.*, 2018; SILVA; SILVA; OMETTO, 2015).

Code	Gree Practice	Focus	Author (s)
EMS	Environmental Management System (EMS)	Processes, policies and audit protocols directed at operations that cause waste of materials or emissions of pollutants and focus on providing tools to companies to allow the reduction of damage to the environment, but in a way that the benefits of this system exceed the costs of its implementation	(MATTHEWS, 2003)
LCA	Life Cycle Assessmet - LCA	Analyze the environmental aspects and impacts of products and processes and identify points for improvement throughout the product life cycle.	(LOPES SILVA *et al.*, 2018)
GSCM	Green Supply Chain Management	The inclusion of the environmental variable to the chain management seeks to consider the impact of the value chain activities and its influence on nature	(KUMAR, Sameer; TEICHMAN; TIMPERNAGEL, 2012)
3R	3R*	The activities to Reduce, Reuse, Recycle	Campos and Vzquez-Brust (2016)
Cleaner Procuction	Cleaner Production (Pollution Prevention)	Continuous application of a preventive environmental strategy integrated into processes and products in order to reduce risks to humans and the environment.	(UNIDO, 2004)
Ecodesign	Ecodesign/Design for Environment	Product design that seeks to minimize the environmental impact of the product during all stages of its life cycle, without compromising other essential criteria such as cost, quality, functionality and aesthetics	(JOHANSSON, 2002)
Reverse Logistics	Reverse Logistics	Logistics in recycling, waste disposal and hazardous material management; a broader perspective includes a relationship to the logistics activities performed in source reduction, recycling, substitution, material reuse and disposal.	(NETO *et al.*, 2018)
Industrial Ecology	Industrial Ecology	The concept requires that an industrial system be viewed not in isolation from its surrounding systems, but in concert with them. It is a systems view in which one seeks to optimise the total materials cycle from virgin material, to finished material, to component, to product, to obsolete product, and to ultimate disposal. Factors to be optimized include resources, energy and capital.	(GRAEDEL; ALLENBY, 1995)
Material Flow Cost Accounting (MFCA)*	Material Flow Cost Accounting (MFCA)*	The tool-like material flow cost accounting (MFCA) is able to assess the environmental performance through physical and monetary evaluation of material flow within the production system	(THANKI, S. J.; THAKKAR, 2016b)

Eco-Label*	Eco-Label*	The practice of marking products with a distinctive label to show that their manufacture conforms to recognized environmental standards	(PRASAD; KHANDUJA; SHARMA, 2016)Prasad, Khanduja and Sharma (2016)

* This practices were selected through the deductive process, which attempted to identify in the articles selected in the SLR other Lean practices that could arise.

5. Lean-Green Practices

The Lean-Green Practices was defined from a deductive process from this SLR. The practices that originated from Lean or Green and it had using an integrate way.

Code	**Lean-Green Practices**	**Focus**	**Author (S)**
E-VSM	Environmetal Value Stream Mapping	VSM with environmental aspects.	(AGUADO; ALVAREZ; DOMINGO, 2013)
7s	7s/Green 5s	5s with S (safety) and S (susntainability).	(ANVARI; ZULKIFLI; YUSUFF, 2011)
Root cause analysis for environmental problems	Root cause analysis for environmental problems	The practice of root cause analysis can be extended to identify potential causes of environmental problems in processes.	(BEN RUBEN; VINODH; ASOKAN, 2017)
OEEE	Overall Environmental Equipment Effectiveness - OEEE	To incorporate the concept of sustainability based on the calculation of environmental impact in the life cycle.	(DOMINGO; AGUADO, 2015)
Lean and Green Supply Chain	Lean and Green Supply Chain	To combine the three approaches Lean, Green and Supply Chain seeking cooperation for cost reduction, consumer focus, quality and environmental management.	(SANT’ANNA *et al.*, 2017)
Kaizen with green goals	Kaizen with green goals	Kaizen activities should be aimed at reducing environmental costs	(CALDERA; DESHA; DAWES, 2017)
SBSC	SBSC - Sustainable Balanced Score Card	An adaptation in the BSC strategic planning tool including sustainability in financial, client, internal processes and learning and growth perspectives.	(ZHU, X. *et al.*, 2017)
Lean 3R	Lean 3R	Recycling and reuse of products and/or materials used in the processes as one of focus of Lean.	(FERCOQ; LAMOURI; CARBONE, 2016)
Green Lean six sigma	Green Lean Six sigma	Integrate environmental aspects in Lean Six Sigma	(CHERRAFI *et al.*, 2016)

TQEM	Total Quality Environmental Management - TQEM	Practice which extends the principles of quality management to include manufacturing practices and processes that affect environmental quality.	(CAMPOS; VAZQUEZ-BRUST, 2016)
Green MRP	Green MRP	MRP modified to include environmental considerations with the objective of minimizing the environmental impact of the generated waste, seeking to increase the planning potential for the components and process waste.	(MELNYK *et al.*, 2001)

D. Codes in Studies

1. Competitive Priorities

Operations Strategy		**Studies**	**Total of Studies**
Competitive Priorities	**Cost**	1; 2; 3; 4; 5; 6; 7; 8; 9; 10; 11; 12; 13; 14; 15; 16; 17; 18; 19; 20; 21; 22; 24; 25; 26; 27; 28; 29; 30; 31; 32; 33; 34; 35; 36; 37; 38; 40; 41; 43; 44; 45; 46; 47; 48; 49; 50; 51; 52; 53; 54; 55; 57; 58; 59; 60; 61; 63; 64; 66; 67; 68; 69; 72; 74; 75; 76; 77; 79; 81; 82; 83; 84; 85; 88; 89; 90; 93; 95; 96; 98; 99; 100; 101; 102; 103; 104; 105; 106; 108; 109; 110; 111; 112; 113; 116; 119; 122; 125; 126; 128; 129; 130; 131; 133; 134; 135; 136; 137; 138; 139; 140; 141; 143; 144; 145; 146; 147; 148; 149; 151; 152; 153; 154; 155; 156; 157; 158; 159; 161; 163; 164; 166; 167; 169; 170; 172; 174; 175; 176; 177; 178; 180; 181; 182; 183; 184; 185; 186; 187; 189; 190; 192; 194; 195; 196; 197; 198; 199; 200; 201; 202; 204; 205; 205; 206; 207; 208; 210; 211; 212; 213; 214; 215; 216; 217; 218; 219; 220; 225; 226; 227; 228; 229; 230; 231; 232; 234; 235; 236; 238; 240; 243; 246; 247; 248; 249; 250; 251; 253; 254; 255; 258; 259.	205
	Envinronment	; 1; 2; 3; 4; 5; 7; 8; 9; 10; 11; 12; 13; 14; 15; 16; 17; 18; 19; 20; 21; 22; 23; 24; 25; 26; 27; 28; 29; 30; 31; 32; 33; 34; 35; 36; 37; 38; 39; 40; 41; 42; 43; 44; 45; 46; 47; 49; 50; 51; 52; 53; 54; 55; 56; 57; 58; 59; 60; 61; 62; 63; 64; 65; 66; 67; 68; 69; 70; 71; 72; 73; 74; 75; 76; 77; 78; 79; 80; 81; 82; 83; 84; 85; 86; 87; 88; 89; 91; 92; 93; 94; 95; 96; 97; 98; 99; 100; 101; 102; 103; 104; 105; 109; 110; 111; 112; 113; 114; 115; 116; 119; 120; 122; 123; 125; 126; 128; 129; 130; 132; 133; 135; 136; 137; 140; 141; 142; 143; 144; 145; 146; 147; 148; 149; 151; 152; 153; 154; 155; 156; 157; 158; 159; 161; 164; 167; 169; 170; 171; 172; 178; 182; 183; 183; 184; 185; 187; 189; 194; 195; 196; 199; 203; 206; 208; 214; 215; 217; 220; 225; 226; 229; 230; 231; 232; 234; 243; 247; 249; 253; 255; 258.	183

	Quality	1; 3; 4; 9; 10; 11; 12; 13; 14; 15; 16; 17; 18; 19; 20; 21; 24; 26; 28; 29; 31; 33; 34; 35; 36; 37; 38; 39; 40; 43; 44; 45; 46; 47; 50; 51; 52; 53; 54; 56; 57; 60; 61; 62; 63; 64; 65; 66; 72; 74; 75; 76; 77; 78; 79; 81; 82; 83; 85; 86; 90; 91; 93; 95; 98; 99; 100; 105; 109; 111; 125; 129; 131; 132; 133; 134; 136; 138; 143; 144; 146; 148; 151; 152; 154; 155; 156; 158; 159; 161; 163; 166; 167; 169; 170; 171; 171; 172; 173; 174; 175; 176; 177; 178; 180; 181; 182; 186; 187; 188; 189; 190; 191; 192; 194; 195; 196; 197; 198; 200; 201; 202; 203; 204; 205; 207; 208; 210; 211; 212; 213; 214; 215; 216; 217; 218; 219; 220; 223; 225; 226; 227; 228; 230; 231; 232; 234; 235; 236; 237; 238; 239; 240; 241; 243; 244; 246; 247; 249; 250; 251; 252; 253; 254; 255; 258; 259; 260.	171
	Delivery	4; 5; 8; 11; 12; 14; 15; 16; 17; 18; 20; 24; 26; 27; 30; 31; 33; 34; 36; 38; 46; 51; 52; 62; 64; 65; 72; 74; 77; 78; 79; 81; 82; 83; 84; 85; 86; 89; 90; 92; 93; 94; 96; 99; 100; 102; 108; 109; 111; 133; 138; 140; 142; 143; 144; 146; 147; 148; 149; 155; 156; 161; 163; 166; 167; 169; 172; 181; 182; 183; 184; 185; 186; 188; 189; 194; 196; 197; 206; 208; 214; 215; 217; 219; 225; 226; 231; 232; 235; 241; 247; 249; 253; 255; 258.	94
	Social	3; 10; 11; 14; 15; 20; 23; 24; 25; 28; 29; 31; 36; 40; 42; 64; 76; 99; 101; 104; 111; 122; 128; 140; 151; 156; 158; 159; 167; 173; 175; 178; 182; 223; 232; 250; 254; 232; 250; 254.	36
	Flexibility	3; 10; 15; 17; 26; 31; 44; 52; 72; 74; 77; 109; 133; 136; 143; 146; 161; 166; 167; 171; 173; 199; 213; 214; 225; 231; 255.	26
	Innovation	10; 20; 34; 47; 63; 72; 75; 79; 88; 94; 104; 129; 133; 142; 144; 148; 218; 223; 246; 251; 255.	20
	Service	17; 18; 19; 36; 38; 51; 54; 66; 72; 74; 81; 93; 97; 133; 148; 151; 161; 206; 236.	18

2. Decision Areas

Operations Strategy		**Studies**	**Total of Studies**
Decision Areas	**Performance measurement system**	2; 3; 4; 7; 9; 11; 14; 17; 19; 20; 22; 23; 24; 25; 26; 27; 28; 30; 32; 33; 34; 36; 37; 38; 39; 40; 42; 43; 44; 45; 49; 51; 53; 54; 60; 61; 62; 64; 65; 68; 69; 70; 71; 72; 74; 76; 77; 78; 79; 80; 81; 82; 83; 85; 86; 88; 89; 90; 91; 95; 98; 99; 101; 103; 104; 105; 109; 110; 111; 113; 114; 116; 121; 122; 123; 128; 131; 132; 134; 135; 136; 137; 138; 139; 142; 146; 147; 148; 149; 150; 151; 152; 154; 154; 155; 156; 157; 158; 174; 175; 178; 181; 183; 184; 186; 187; 190; 192; 195; 196; 197; 200; 202; 204; 205; 207; 209; 213; 224; 227; 230; 232; 233; 238; 241; 243; 247; 249; 252; 254; 256; 258.	131

	Supply Chain	1; 3; 5; 6; 7; 9; 11; 15; 17; 19; 20; 21; 22; 23; 24; 25; 28; 33; 35; 37; 44; 45; 46; 49; 50; 51; 52; 53; 54; 55; 56; 57; 59; 62; 63; 64; 66; 67; 68; 72; 74; 75; 76; 77; 78; 80; 81; 82; 83; 85; 86; 87; 88; 90; 92; 93; 94; 97; 98; 102; 108; 115; 116; 118; 131; 132; 133; 134; 136; 140; 143; 144; 145; 147; 148; 149; 150; 151; 152; 155; 159; 163; 167; 170; 173; 176; 177; 183; 184; 194; 198; 199; 201; 203; 205; 206; 208; 211; 212; 216; 217; 218; 223; 227; 228; 235; 237; 239; 243; 245; 246; 247; 250; 251; 254; 255.	115
	Human Resources	3; 4; 5; 7; 9; 10; 12; 14; 16; 19; 20; 21; 24; 25; 26; 31; 33; 35; 39; 40; 42; 43; 46; 47; 48; 49; 50; 56; 60; 61; 63; 71; 73; 75; 79; 79; 80; 83; 84; 88; 92; 95; 98; 99; 101; 111; 112; 128; 129; 131; 132; 134; 137; 138; 139; 146; 147; 148; 151; 153; 155; 156; 167; 171; 175; 181; 184; 187; 189; 192; 197; 203; 204; 207; 208; 217; 224; 227; 232; 256.	79
	Quality Management	3; 4; 9; 10; 11; 12; 14; 17; 18; 19; 20; 21; 22; 26; 28; 29; 33; 34; 38; 39; 43; 47; 50; 53; 55; 57; 59; 61; 63; 64; 67; 67; 69; 70; 71; 75; 76; 78; 79; 83; 95; 98; 99; 132; 140; 143; 146; 151; 152; 156; 158; 162; 163; 164; 171; 183; 194; 195; 206; 216; 220; 221; 228; 230; 239; 243; 244; 254.	67
	Technology	3; 4; 5; 9; 10; 11; 14; 16; 18; 19; 22; 27; 28; 32; 33; 34; 35; 37; 43; 44; 45; 50; 53; 54; 60; 63; 63; 72; 74; 75; 78; 83; 88; 92; 98; 100; 104; 112; 115; 118; 125; 140; 141; 142; 146; 148; 154; 155; 157; 161; 163; 167; 170; 173; 176; 178; 199; 200; 202; 205; 222; 243; 246; 249.	63
	Organization	3; 10; 11; 14; 16; 17; 19; 22; 26; 31; 34; 39; 40; 49; 50; 57; 59; 63; 71; 72; 73; 78; 79; 80; 98; 99; 105; 111; 112; 118; 128; 129; 132; 134; 142; 145; 148; 153; 155; 157; 163; 167; 171; 175; 184; 189; 203; 208; 209; 217; 218; 222; 223; 224; 233; 240; 246; 256.	57
	Product Development	2; 5; 9; 11; 13; 14; 17; 19; 21; 22; 24; 28; 32; 33; 35; 43; 44; 45; 46; 47; 47; 49; 51; 53; 54; 57; 60; 61; 62; 63; 75; 83; 89; 93; 108; 132; 140; 142; 144; 147; 150; 159; 166; 187; 200; 217; 246.	47
	PCP	1; 5; 9; 14; 18; 20; 33; 35; 36; 37; 45; 49; 50; 52; 57; 63; 64; 72; 74; 84; 90; 92; 105; 108; 117; 135; 141; 149; 155; 161; 163; 173; 174; 180; 183; 201; 202; 203; 206; 213; 217; 219; 227; 230; 235; 241.	45
	Installation	1; 2; 3; 8; 9; 12; 14; 20; 31; 32; 33; 36; 41; 42; 46; 49; 50; 56; 58; 61; 63; 86; 90; 104; 109; 136; 156; 161; 200; 227; 233; 237.	31
	Capacity	3; 6; 37; 42; 50; 64; 163,	6

3. Lean Practices

Lean Practices	**Paper**	**Number of papers**
Just in Time (JIT)	2; 3; 9; 10; 11; 16; 17; 20; 21; 22; 25; 31; 33; 34; 44; 45; 46; 48; 49; 50; 51; 52; 53; 54; 56; 57; 59; 60; 62; 63; 64; 72; 74; 75; 76; 77; 78; 79; 83; 85; 86; 92; 93; 94; 95; 96; 98; 99; 100; 102; 108; 114; 116; 117; 120; 123; 126; 127; 136; 137; 141; 143; 146; 149; 152; 155; 156; 161; 162; 166; 169; 173; 177; 179; 180; 181; 188; 189; 194; 203; 204; 205; 206; 211; 216; 217; 218; 219; 220; 221; 222; 224; 227; 235; 241; 245; 246; 251; 252; 253; 260.	102

Value Stream Mapping – VSM	1; 2; 3; 4; 5; 6; 7; 8; 9; 11; 12; 17; 20; 23; 24; 35; 36; 37; 49; 50; 61; 62; 65; 68; 69; 70; 91; 96; 97; 99; 100; 101; 102; 105; 111; 113; 114; 120; 121; 123; 125; 126; 128; 129; 131; 136; 150; 152; 156; 157; 162; 184; 185; 188; 189; 194; 200; 204; 208; 209; 214; 224; 229; 231; 241; 252; 253; 259.	69
Total Productive Maintenance TPM	3; 4; 9; 10; 11; 12; 14; 17; 18; 20; 22; 25; 31; 33; 42; 46; 49; 50; 56; 57; 61; 62; 63; 67; 70; 76; 77; 78; 80; 83; 98; 99; 105; 111; 112; 114; 120; 123; 126; 127; 132; 146; 152; 156; 162; 169; 175; 181; 184; 185; 186; 194; 203; 204; 205; 209; 218; 219; 224; 227; 232; 244; 245; 250; 252; 259.	67
Kaizen	1; 2; 3; 4; 8; 11; 12; 19; 20; 25; 28; 29; 40; 43; 46; 49; 50; 53; 56; 61; 62; 65; 65; 68; 76; 79; 83; 96; 99; 102; 105; 111; 113; 114; 123; 126; 132; 143; 144; 146; 151; 161; 169; 175; 185; 187; 190; 203; 204; 205; 207; 209; 212; 218; 220; 229; 231; 244; 246; 252; 253; 259.	65
5s	1; 3; 4; 9; 11; 12; 16; 20; 22; 25; 46; 48; 49; 50; 61; 62; 63; 65; 65; 70; 76; 80; 83; 86; 97; 98; 105; 111; 114; 120; 125; 126; 129; 131; 132; 144; 146; 151; 152; 156; 162; 169; 185; 186; 189; 190; 194; 200; 203; 204; 205; 208; 209; 212; 220; 224; 225; 226; 227; 229; 232; 246; 253; 259.	65
Continuous Improvement	1; 2; 3; 4; 7; 9; 10; 16; 19; 20; 21; 25; 26; 28; 29; 34; 39; 46; 47; 48; 50; 57; 60; 62; 78; 79; 83; 97; 102; 103; 105; 123; 126; 140; 144; 146; 147; 150; 151; 154; 155; 158; 162; 168; 171; 178; 179; 189; 203; 204; 205; 207; 208; 222; 227; 231; 240; 254; 259.	60
Total Quality Management - TQM	4; 9; 10; 12; 17; 20; 25; 26; 28; 31; 33; 43; 47; 48; 48; 49; 50; 52; 56; 57; 63; 71; 72; 76; 77; 78; 83; 95; 99; 120; 127; 143; 146; 156; 162; 189; 195; 204; 206; 216; 218; 219; 220; 221; 224; 239; 250; 252; 260.	48
SMED	1; 2; 9; 11; 16; 18; 20; 30; 31; 42; 46; 51; 61; 62; 63; 65; 70; 83; 94; 100; 105; 111; 114; 120; 125; 146; 161; 166; 169; 175; 181; 184; 185; 186; 194; 203; 205; 212; 219; 222; 224; 227; 245; 251; 259.	46
Root cause diagram	3; 9; 14; 16; 20; 21; 28; 38; 39; 39; 40; 46; 49; 55; 61; 65; 78; 83; 96; 105; 123; 134; 136; 150; 151; 152; 154; 154; 156; 175; 178; 196; 205; 207; 212; 224; 227; 259.	39
Supply chain management	9; 11; 37; 42; 44; 46; 49; 50; 51; 54; 64; 70; 74; 75; 76; 81; 83; 85; 92; 98; 133; 143; 144; 146; 203; 208; 211; 218; 222; 224; 227; 231; 235; 239; 245; 250; 251; 252.	37
Standardization	1; 3; 11; 14; 20; 22; 34; 36; 40; 50; 61; 70; 80; 96; 102; 105; 112; 123; 136; 150; 152; 172; 184; 194; 200; 208; 224; 225; 227; 229; 240; 246; 253.	34
Kanban	1; 2; 4; 11; 18; 20; 33; 46; 50; 57; 60; 62; 63; 65; 70; 83; 111; 114; 117; 143; 146; 150; 184; 204; 205; 206; 213; 219; 228; 231; 241; 259.	33
Visual Management	1; 3; 4; 11; 14; 19; 20; 32; 33; 40; 46; 61; 70; 80; 98; 99; 123; 129; 131; 132; 146; 150; 184; 185; 188; 204; 224; 225; 227; 228; 229; 252; 259.	32
Cellular Manufacturing	; 3; 9; 11; 20; 30; 42; 49; 50; 58; 62; 63; 76; 94; 99; 105; 120; 123; 126; 143; 146; 156; 166; 174; 179; 184; 203; 204; 219; 224; 227; 228.	30
Pulled production	9; 19; 26; 42; 44; 46; 49; 51; 83; 99; 104; 111; 132; 143; 174; 179; 188; 203; 210; 217; 219; 222; 224; 227; 245; 251; 253.	26
Poka yoke	2; 4; 11; 24; 40; 42; 46; 61; 65; 70; 99; 105; 111; 123; 129; 132; 162; 175; 184; 187; 196; 205; 226; 228; 259.	24
Multifunctional team	2; 11; 18; 19; 20; 21; 25; 31; 38; 50; 112; 143; 146; 175; 187; 204; 227; 231; 246.	18
Statistical process control -SPC	2; 3; 9; 18; 19; 20; 40; 55; 98; 134; 156; 162; 184; 222; 227; 245; 250.	18
Heijunka	13; 34; 42; 54; 62; 65; 79; 105; 111; 150; 169; 204; 253; 259.	13

Continuous Flow	11; 19; 20; 42; 49; 56; 166; 184; 222; 227; 259.	11
Jidoka	2; 11; 34; 46; 79; 136; 155; 166; 184; 222; 227; 259.	11
A3 report	2; 9; 20; 50; 113; 150; 169; 227; 253; 259.	9
Quality Circles	8; 21; 49; 203; 219; 226; 234; 244; 246.	8
Gemba Walk	7; 43; 99; 175; 181; 196; 207; 259.	7
Value Engineering	2; 4; 9; 33; 150.	4
Hoshin Kanri	4; 43; 99; 204; 259.	4
Daily management	2; 4; 16.	2
Spaguetti Diagram	2; 40; 204.	2

4. Green Practices

Green Practice	Papers	Total of studies
Environment Management System - ISO14000	1; 3; 4; 9; 10; 11; 12; 14; 16; 17; 21; 22; 26; 28; 35; 39; 41; 45; 46; 48; 49; 50; 51; 52; 54; 58; 59; 61; 64; 65; 67; 69; 70; 72; 73; 74; 75; 76; 79; 83; 85; 88; 97; 99; 100; 101; 108; 111; 114; 115; 120; 123; 134; 136; 138; 143; 144; 147; 148; 158; 159; 162; 164; 186; 194; 207; 224; 228; 244; 248; 250; 260.	74
Life Cycle Assessment – LCA	2; 3; 4; 7; 11; 17; 19; 21; 22; 23; 24; 30; 32; 33; 35; 38; 45; 49; 50; 51; 52; 54; 58; 61; 62; 63; 68; 79; 82; 83; 85; 88; 89; 90; 93; 94; 101; 104; 108; 114; 116; 120; 122; 128; 134; 136; 138; 144; 147; 148; 150; 152; 155; 159; 163; 166; 187; 194; 195; 209; 219; 224; 243; 248.	66
Green Supply Chain	9; 11; 15; 17; 20; 44; 49; 50; 51; 53; 54; 55; 57; 59; 64; 68; 74; 77; 81; 83; 85; 92; 94; 101; 117; 118; 133; 140; 144; 145; 147; 148; 149; 159; 176; 177; 185; 205; 206; 208; 211; 212; 216; 218; 221; 237; 239; 245; 248; 250.	50
3R (Reduce, Reuse, Recycle)	1; 9; 11; 12; 13; 14; 17; 22; 25; 32; 40; 45; 46; 50; 51; 63; 64; 68; 74; 76; 83; 97; 106; 108; 122; 132; 134; 140; 143; 144; 147; 156; 159; 166; 181; 187; 194; 205; 208; 215; 224; 225; 244; 248; 250.	47
Cleaner Production (Pollution Prevention)	4; 14; 16; 20; 22; 23; 25; 28; 30; 40; 45; 63; 66; 72; 75; 78; 83; 89; 96; 97; 98; 105; 115; 119; 129; 136; 138; 140; 143; 144; 164; 194; 231; 248; 249; 260.	38
Design for Environment (Ecodesign)	11; 14; 19; 27; 35; 45; 50; 51; 52; 53; 57; 58; 59; 61; 62; 77; 83; 89; 94; 108; 140; 144; 147; 148; 150; 152; 159; 166; 167; 187; 194; 224; 246; 248; 250.	37
Reverse Logistics	50; 74; 83; 85; 94; 106; 136; 159; 224; 239.	10
Industrial Ecology	63; 82; 93.	3
Circular Economy	11; 32; 248	3
Eco-Label	9; 11.	2
Material Flow Cost Accounting (MFCA)	135.	1

5. Lean-Green Practices

Lean-Green Practices	Papers	Total of Papers
Environmental Value Stream Mapping - E-VSM	3; 4; 5; 6; 7; 8; 16; 20; 23; 31; 36; 37; 40; 49; 50; 51; 53; 61; 62; 65; 68; 69; 70; 79; 80; 82; 83; 91; 99; 100; 101; 103; 104; 105; 113; 120; 121; 122; 132; 134; 136; 140; 151; 152; 155; 157; 169; 174; 175; 181; 183; 186; 190; 196; 197; 203; 209; 210; 213; 224; 232; 243; 253; 258.	65
7s	3; 4; 12; 48; 49; 50; 61; 99; 123; 132; 134; 137; 152; 159; 169; 231.	16
Green Lean Six sigma	3; 19; 38; 40; 50; 53; 61; 71; 91; 140; 152; 171; 209; 210; 240.	15
Overall Environmental Equipment Effectiveness – OEEE	11; 32; 65; 68; 70; 79; 109; 152; 162; 253.	10
Total Quality Environmental Management – TQEM	9; 17; 47; 57; 72; 75; 83; 159.	8
SBSC - Sustainable Balanced Score Card	139; 162.	2
Root cause analysis for environmental problems	2; 3; 105.	2
Lean 3R	13; 97.	2
Green MRP	52.	1
Lean and Green Supply Chain	59.	1
Kaizen with green goals	49.	1

APÊNDICE B – TERMO DE CONSENTIMENTO (UFSCAR E UNIVERSITÉ DE SHERBROOKE)

UNIVERSIDADE FEDERAL DE SÃO CARLOS
DEPARTAMENTO DE ENGEHARIA DE PRODUÇÃO/ PROGRAMA DE PÓS GRADUAÇÃO EM ENGENHARIA DE PRODUÇÃO

TERMO DE CONSENTIMENTO LIVRE E ESCLARECIDO

(Resolução 466/2012 do CNS)

ESTRATÉGIAS DE OPERAÇÕES E PRÁTICAS LEAN-GREEN: UM ESTUDO MULTI-CASOS

Prezado (a) entrevistado (a),

Eu, Geandra Alves Queiroz, estudante do Programa de Pós-Graduação em Engenharia de Produção da Universidade Federal de São Carlos – UFSCar o (a) convido a participar da pesquisa "Estratégias de operações e práticas Lean-Green: Um estudo multi-casos" orientada pela Profa. Dra. Ana Lúcia Vitale Torkomian.

O objetivo deste estudo é identificar e analisar mudanças nos conteúdos de estratégias de operações de empresas do setor automotivo que estejam implantando práticas Green e que tenham antes implantado práticas Lean. Para alcançar o objetivo geral desta pesquisa, faz-se necessário atingir os seguintes objetivos específicos:

- Investigar como a literatura até o momento explica as contribuições e alterações das abordagens Lean e Green nas prioridades competitivas e areas de decisão.
- Verificar, por meio de estudos de caso quais e como são ordenadas as prioridades competitivas de produção e que mudanças foram implementadas nas áreas de decisão de empresas que adotam práticas Lean-Green.
- Identificar quais práticas foram implementadas e em que estágios de implementação se encontram em função das estratégias de operações adotadas.
- Explicar como as práticas Lean-Green se integram, apoiam, reforçam ou apresentam eventuais trade offs ou incompatibilidades (conflitos) sob a perspectiva estratégica (alterações e contribuições às prioridades competitivas e áreas de decisão),.

• Investigar se e como o Lean facilita a implantação de práticas Green na Estratégia de Operações.

Por meio deste estudo, espera-se chegar à contribuições tanto no âmbito teórico quanto prático. Os resultados poderão preencher uma lacuna identificada com a elaboração de uma revisão sistemática da literatura e fornecer uma explicação e uma discussão dos conteúdos de estratégias de operações adotadas com a implementação de práticas Lean e Green, gerando uma contribuição teórica neste campo. Isto envolve apresentar as prioridades competitivas escolhidas e priorizadas, as práticas adotadas, as mudanças promovidas nas áreas de decisão, além explicar relações entre tais constructos. Trata-se do emprego de uma abordagem holística e da consideração das práticas Lean-Green por uma perspectiva estratégica – explicitando algumas das principais relações entre tais práticas, prioridades competitivas das operações e áreas de decisão.

Você foi selecionado (a) por ser um profissional envolvido em atividades de gerenciamento de fabricação na indústria automotiva e suas respostas serão muito valiosas para esta pesquisa. Sua participação neste projeto de pesquisa consiste em uma entrevista com o pesquisador utilizando uma ferramenta de videoconferência "Google Meet", mediante agendamento prévio e disponibilidade do senhor (a). Solicito sua autorização para gravação em áudio da entrevista. As gravações realizadas durante a entrevista semiestruturada serão transcritas pela pesquisadora e por mais um profissional experiente nessa ação, garantindo que se mantenha o mais fidedigna possível. Depois de transcrita será apresentada aos participantes para validação das informações. O tempo da entrevista será entre 1 hora e 1 hora e 30 minutos e será (de preferência) gravado.

A entrevista e os arquivos de transcrição da entrevista serão armazenados no computador do pesquisador protegidos por nome de usuário e senha e senhor não será identificado pelo nome, buscando preservar seu anonimato. Esta transcrição estará disponível somente para o pesquisador responsável, que poderá acessá-la usando um nome de usuário e senha previamente criados. Nenhum respondente poderá ver a resposta um do outro e nenhum, exceto o pesquisador, terá acesso ao banco de dados. Ressalto também que as perguntas não serão invasivas à intimidade dos participantes, dirá respeito somente aos processos e práticas organizacionais relativas a empresa no qual o (a) senhor (a) trabalha.

Sua participação é voluntaria e não haverá compensação em dinheiro pela sua participação. A qualquer momento o (a) senhor (a) pode desistir de participar e retirar seu consentimento. Sua recusa ou desistência não lhe trará nenhum prejuízo profissional, seja em sua relação ao pesquisador, à Instituição em que trabalha ou à Universidade Federal de São Carlos. Todas as informações obtidas por meio da pesquisa serão confidenciais, sendo assegurado o sigilo sobre sua participação em todas as etapas do estudo. Caso haja menção a nomes, a eles serão atribuídas letras, com garantia de anonimato nos resultados e publicações, impossibilitando sua identificação.
A participação nesta entrevista para o estudo de caso não oferece um risco imediato ao senhor (a). Entretanto, o senhor (a) poderá sentir-se cansado mentalmente em consequência da duração da entrevista. Portanto, caso isso aconteça, o senhor terá total assistência dos pesquisadores e poderá desistir da pesquisa a qualquer momento. Novamente salienta-se que a sua desistência não tratá nenhum prejuíxo na sua relação com o pesquisador ou com a instiuição que forneceu os dados. Além disso, o senhor(a) não terá nenhum custo ou compensasção financeceira ao participar do estudo.

Desta forma, caso ocorra algum problema decorrente de sua partipação na pesquisa, você terá acompanhamento e assitência de forma gratuita, por meio de contato via e-mail após a realização da entrevista para verificar se houve algum incoveninente ou alguma dúvida. Em caso de custos para deslocamento, alimentação e outros gastos, ou necessidade de indenização por dano resultante da sua participação durante a aplicação da pesquisa, estes serão garantidos pelo pesquisador responsável por meio de ressarcimento e indenização. Fica, também, garantido o seu direito de requerer indenização em caso de danos comprovadamente decorrentes da participação na pesquisa.

Os benefícios ao participar deste projeto estão relacionados à contribuição para o avanço do conhecimento no campo da gestão e sustentabilidade das operações. Este estudo apresentará resultados que podem trazer uma contribuição gerencial para a organização em estudo, uma vez que o entendimento destas questões pode fornecer subsídios (diretrizes) para que as organizações adotem e implementem estratégias de operações, abrangendo práticas de Produção Enxuta (Lean) e práticas Green (preservação ambiental), de forma eficaz, eficiente e para atender às novas demandas de preservação ambiental.

Caso seja de interesse, o (a) senhor (a) receberá uma via deste termo, rubricada em todas as páginas por você e pelo pesquisador, onde consta o telefone e o endereço do pesquisador principal. Você receberá poderá tirar suas dúvidas sobre o projeto e sua participação, agora ou a qualquer momento.

Declaro que entendi os objetivos, riscos e benefícios de minha participação na pesquisa e concordo em participar. O pesquisador me informou que o projeto foi aprovado pelo Comitê de Ética em Pesquisa em Seres Humanos da UFSCar que funciona na Pró-Reitoria de Pesquisa da Universidade Federal de São Carlos, localizada na Rodovia Washington Luiz, Km. 235 - Caixa Postal 676 - CEP 13.565-905 - São Carlos - SP – Brasil. Fone (16) 3351-9685. Endereço eletrônico: cephumanos@ufscar.br.

Endereço para contato (24 horas por dia e sete dias por semana):

Pesquisador Responsável: Geandra Alves Queiroz

Endereço: Grupo de Gestão de Tecnologia - Departamento de Engenharia de Produção Universidade Federal de São Carlos – UFSCar, Rod. Washington Luís - Km 235, C.P. 676 São Carlos, São Paulo – Brasil,CEP: 13565-905

Contato telefônico: +55 16 98153 2963E-mail: geandraqueiroz@gmail.com

Local e data: São Carlos, ____

____

Geandra Alves Queiroz

____

Nome do Participante

INFORMATION AND CONSENT FORM

You are invited to participate in a research study "Lean and green: synergies and trade-offs from the perspective of operations strategy". This document describes the study procedures. Feel free to ask questions about any words or paragraphs you do not understand. To take part in the study, you must sign the consent section at the end of this document; a signed and dated copy will be returned to you. Please take all the time you need to make your decision.

Researcher Responsible for the Research Study

This project is being carried out as part of the doctoral studies of Geandra Alves Queiroz, a visiting researcher enrolled in the doctoral program in business administration at the Université de Sherbrooke and recipient of an scholarship from the Coordination for the Improvement of Higher Education Personnel (CAPES) – Brazil. The research is supervised by professors Luis Antonio De Santa-Eulalia. professor at the School of Management of the Université de Sherbrooke.

Contact information for those responsible for the research project

Geandra Alves Queiroz : PhD Candidate in Production Engineering

Adresse : geandraqueiroz@gmail.com , Téléphone +55 16 98153 2963

Pr Luis Antonio De Santa-Eulalia : codirecteur de recherche

Adresse : l.santa-eulalia@usherbrooke.ca, Téléphone 819-821-8000 poste 65042.

Purpose of the Research Study

The objective of this research is understand how the content of the operations strategy is defined when Lean Manufacturing and Green Manufacturing are combined. In particular, the study aims to help understand possible synergies and trade-offs from the operations strategy perspective.

Description of the Research Procedures

You are being invited to take part in this research study because
you are identified as a professional involved in manufacturing management activities in such industries and your answers will be very valuable for this research. Your participation in this research project consists of an interview with the researcher using a videoconference tool. The interview time will be between 1 hour and 1 hour and 30 minutes and will be (preferably) recorded.

Potential Benefits

By participating in this project, you will contribute to the advancement of knowledge in the field of operations management and sustainability. This study will present results that can bring (also) a managerial contribution, since the understanding of these issues can provide subsidies (guidelines) for organizations to adopt and implement strategies of operations, covering lean practices and green practices, in an effective, efficient and to meet new demands for environmental preservation.

Potential Risks

There are no risks involved in your participation and it will not involve any significant inconveniences. The research will be conducted by video conference through the skype software. They will only be recorded with the interviewee's authorization. The interview and interview transcript files will be stored on the researcher's computer protected by username and password. Interviewees will not be identified by name.

It will be available only for the researcher who may access it using a previously created username and password. No respondent can see each other answer and none except the researcher have access to the database.

Your participation does not pose any psychological risk because there will be no vulnerable situation and total secrecy is guaranteed so that superiors or any other person in a position of authority over you will not have access to any information that could be harmful to them. Furthermore, the subject is strictly related to the management practices of the organizations studied. In short, your participation should not involve any significant inconveniences, other than taking up some of your time. You may ask to take a break or to continue the interview at a more convenient time.

Voluntary Participation and the Right to Withdraw

Your participation in this research project is voluntary. Therefore, you may refuse to participate. You may also withdraw from the project at any time, without giving any reason, by informing a member of the research team.

Confidentiality

During your participation in this study, the researcher responsible and the research team will collect and record information about you in a study file. They will only collect information required to meet the scientific goals of the study. No other personal information will be asked or collected. No IP address, e-mail address will be attached to the collected data and no cookies will be added to your computer.
All the information collected during the research project will remain confidential to the extent provided by law. The study data will be stored for 5 years by the researcher responsible for this study for research purposes as described in this information and consent form and then they will be destroyed.

The data may be published or shared during scientific meetings; however, it will not be possible to identify you.

Study Results

If you wish to receive a summary of the study results when they are completed, please provide an address. Email or Mailing address:
____

<u>Contact Information</u>

If you have questions or if you have a problem you think may be related to your participation in this research study, + or with someone on the research team at the following number: +55 16 981532963.

<u>Approval of the Research Ethics Board</u>

The Research Ethics Board – Letters and Human Sciences of the Université de Sherbrooke (approved this research and is responsible for the monitoring of the study.

For any question concerning your rights as a research participant taking part in this study, or if you have comments, or wish to file a complaint, you may communicate with the Research Ethics Board at the following phone number 819-821-8000 (or toll free at 1-800-267-8337) extension 62644, or by email at cer_lsh@USherbrooke.ca.

<u>Signature of the Participant</u>

I have reviewed the information and consent form. Both the research study and the information and consent form were explained to me. My questions were answered, and I was given sufficient time to make a decision. After reflection, I consent to participate in this research study in accordance with the conditions stated above.

AND Communication with the participant about future research (where applicable)

I authorize the researcher responsible of this research study to communicate with me directly to ask if I am interested in participating in other research.

Yes ☐ No ☐

AND Specific authorization [Include all other authorization clauses relevant to the research study.]
ex.:

- Use of video or audio recording for scientific presentations;
- Secondary uses of the research data;
- If the potential participant is unable to read the consent form.

Name of participantSignatureDate

Signature of the Person Obtaining Consent

I have explained the research study and the terms of this information and consent form to the research participant, and I answered all his/her questions.

Name of the person obtaining consentSignatureDate

Commitment of the Researcher Responsible of the Research Study

I certify that this information and consent form were explained to the research participant, and that the questions the participant had were answered.

I undertake, together with the research team, to respect what was agreed upon in the information and consent form, and to give a signed and dated copy of this form to the research participant.

Name of the Researcher Responsible

SignatureDate

APÊNDICE C – PROTOCOLO DE PESQUISA

Título da pesquisa: Estratégia de operações e práticas Lean-Greeen

Questão de Pesquisa: Como as práticas Lean-Green influenciam as estratégias de operações?

Objetivos da pesquisa:

1. **Verificar, por meio de estudos de caso quais e como são ordenadas as prioridades competitivas de produção e que mudanças foram implementadas nas áreas de decisão de empresas que adotam práticas Lean-Green.**
2. **Identificar quais práticas foram implementadas e em que estágios de implementação se encontram em função das estratégias de operações adotadas.**
3. **Explicar como as práticas Lean-Green se integram, apoiam, reforçam ou apresentam eventuais trade offs ou incompatibilidades (conflitos) sob a perspectiva estratégica (alterações e contribuições às prioridades competitivas e áreas de decisão).**
4. **Investigar se e como o Lean facilita a implantação de práticas Green na Estratégia de Operações.**

Informações gerais e consentimento de participação:

Prezado (a); Senhor (a);

O Senhor (a) está convidado (a) a participar da pesquisa que explora a relação entre as práticas Lean e Green de sua organização sob a perspectiva da estratégia de operações.

Este estudo faz parte de um projeto de pesquisa de doutodorado de Geandra Alves Queiroz, candidata ao título de doutora, na Universidade Federal de São Carlos (Brasil) em colaboração com a Université de Sherbrooke (Canadá).

O(a) Senhor (a) foi seleccionado (a) como participante porque é uma pessoa chave no que diz respeito às práticas Lean e/ou Green. As suas respostas e opiniões irão lançar luz sobre as sinergias e os trade-offs da implementação das práticas Lean e Green.

A sua participação é totalmente gratuita e pode retirar-se do estudo em qualquer altura. O documento anexo "Termo de Consentimento Livre e esclarecido" explica em pormenor os objetivos do projeto, as pessoas responsáveis, as suas diretrizes, os potenciais benefícios e riscos da sua participação, a natureza voluntária da sua participação, bem como as medidas tomadas para preservar a confidencialidade das suas informações.

O processo de coleta de dados está estruturado em duas partes. A primeira parte é este questionário em linha sobre (nome da plataforma), cuja duração estimada é de 30 minutos.

A segunda parte é uma entrevista semi-estruturada que será realizadapor meio da plataforma on-line de sua escolha (Equipas, Zoom, Google Meet, outros). A entrevista tem perguntas abertas e estima-se que tenha duração máxima de 60 minutos.

Atenciosamente,

Geandra Queiroz (doutoranda em Engenharia de Produção- Universidade Federal de São Carlos)

Prof. Alceu Gomes Alves Filho (Universidade Federal de São Carlos)

Prof. Luis Antonio Santa Eulália (Université de Sherbrooke)

Anexo: Termo de consentimento e cartas de aprovação do comitê de ética

Parte 1 – Questionário estruturado

Link: https://forms.gle/akjz29J9M9XPVMZi7

ESTRATÉGIAS DE OPERAÇÕES E PRÁTICAS LEAN-GREEN: UM ESTUDO MULTI-CASOS

Prezado (a); Senhor (a);

O Senhor (a) está convidado (a) a participar da pesquisa que explora a relação entre as práticas Lean e Green de sua organização sob a perspectiva da estratégia de operações.

Este estudo faz parte de um projeto de pesquisa de doutorado de Geandra Alves Queiroz, candidata ao título de doutora, na Universidade Federal de São Carlos (Brasil) em colaboração com a Université de Sherbrooke (Canadá).

O(a) Senhor (a) foi seleccionado (a) como participante porque é uma pessoa chave no que diz respeito às práticas Lean e/ou Green. As suas respostas e opiniões irão lançar luz sobre as sinergias e os trade-offs da implementação das práticas Lean e Green.

A sua participação é totalmente gratuita e pode retirar-se do estudo em qualquer altura. O documento anexo "Termo de Consentimento Livre e esclarecido" explica em pormenor os objetivos do projeto, as pessoas responsáveis, as suas diretrizes, os potenciais benefícios e riscos da sua participação, a natureza voluntária da sua participação, bem como as medidas tomadas para preservar a confidencialidade das suas informações.

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A segunda parte é uma entrevista semi-estruturada que será realizadapor meio da plataforma on-line de sua escolha (Equipas, Zoom, Google Meet, outros). A entrevista tem perguntas abertas e estima-se que tenha duração máxima de 60 minutos.

Atenciosamente,

Geandra Queiroz (doutoranda em Engenharia de Produção- Universidade Federal de São Carlos)
Prof. Alceu Gomes Alves Filho (Universidade Federal de São Carlos)
Prof. Luis Antonio Santa Eulália (Université de Sherbrooke)

---

*Obrigatório

1. Declaro voluntária minha participação nesta pesquisa.

Marcar apenas uma oval.

- Sim
- Não

Pular para a pergunta 2

A. Caracterização do respondente

2. A1. Posição na organização *

Marcar apenas uma oval.

- Diretor de operações/manufatura
- Gestor de Operações/Fabricação
- Coordenador de Operações/Fabricação
- Engenharia Industrial
- Gestor Ambiental
- Outro

3. A2. Experiência em gestão de operações ou gestão ambiental *

Marcar apenas uma oval.

- Menos de 2 anos
- 2 a 5 anos
- 5 a 10 anos
- Mais de 10 anos

4. A3. Experiência na organização atual *

Marcar apenas uma oval.

- Menos de 2 anos
- 2 a 5 anos
- 5 a 10 anos
- Mais de 10 anos

5. A4. Formação acadêmica *

Marcar apenas uma oval.

- Formação técnica
- Curso superior
- Especialização/Mestrado
- Doutorado

B. Visão Geral da Empresa

6. B1. Número de funcionários *

Marcar apenas uma oval.

- Menos de 50
- 50 a 100 empregados
- 100 a 500 empregados
- 500 a 1000 empregados
- Mais de 1000 empregados

7. B2. Principais produtos fabricados *

8. B3.Posição na cadeia de suprimentos (Nível relativo ao Fabricante do Equipamento Original ao fornecedor n-camada) *

Marcar apenas uma oval.

- Empresa Focal
- Primeira camada
- Segunda camada
- Terceira camada
- Quarta camada
- Quinta camada ou mais

Estrutura de uma cadeia de suprimentos

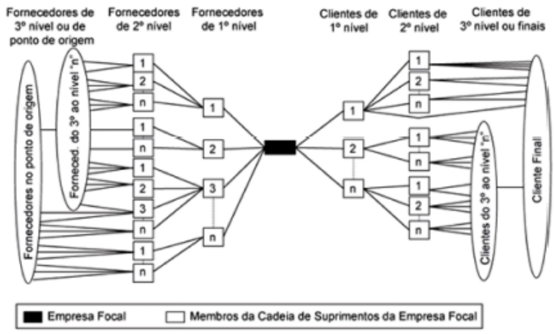

Figura 2. Estrutura da rede de uma cadeia de suprimentos. Fonte: Lambert et al., 1998.

9. B4. Cobertura geográfica (mercados de destino dos seus produtos) *

Marque todas que se aplicam.

- [ ] Estadual
- [ ] Nacional
- [ ] América do Sul
- [ ] América do Norte
- [ ] América Central
- [ ] Europa
- [ ] África
- [ ] Ásia
- [ ] Global

C. Estratégia de Operações

10. C1. Qual é o seu principal cliente? *

Marcar apenas uma oval.

- ◯ Consumidor final
- ◯ Fabricante do equipamento original (OEM)
- ◯ Mercado de reposição (aftermarket)
- ◯ Outro: ____________________

11. C2. Qual das opções abaixo é a principal vantagem competitiva da sua organização? *

Marcar apenas uma oval.

- ◯ Entrega
- ◯ Menor Impacto Ambiental
- ◯ Nível de Serviço
- ◯ Personalização
- ◯ Preço
- ◯ Qualidade
- ◯ Outro: ____________________

12. C3.No que diz respeito à estratégia competitiva, classifique por ordem de importância os 5 factores principais para a competitividade da sua empresa (sendo 1 o menos importante e 5 o mais importante).

Marcar apenas uma oval por linha.

	1	2	3	4	5
Capacidade de inovação	◯	◯	◯	◯	◯
Confiabilidade da entrega	◯	◯	◯	◯	◯
Design (características do produto, tecnologia)	◯	◯	◯	◯	◯
Flexibilidade do mix de produção (variedade de produtos)	◯	◯	◯	◯	◯
Flexibilidade de volume	◯	◯	◯	◯	◯
Preço	◯	◯	◯	◯	◯
Qualidade	◯	◯	◯	◯	◯
Velocidade de entrega	◯	◯	◯	◯	◯
Sustentabilidade ambiental	◯	◯	◯	◯	◯

13. Outro (Exemplo: Localização, serviços agregados, etc.)

____

14. C4.No que diz respeito ao objetivo global da sua estratégia de operações, classifique os seguintes objetivos por ordem de importância (1 sendo o menos importante e o 5 o menos importante).

Marcar apenas uma oval por linha.

	1	2	3	4	5
Aumentar a produtividade	◯	◯	◯	◯	◯
Reduzir o custo	◯	◯	◯	◯	◯
Reduzir os defeitos	◯	◯	◯	◯	◯
Reduzir o tempo de espera (lead time)	◯	◯	◯	◯	◯

15. Outros ou alguma observação? *

16. C5. Prioridades Competitivas (Por favor utilize esta escala para assinalar o grau de importância para cada prioridade competitiva das suas operações). *

Marcar apenas uma oval por linha.

	Não é nada importante	Ligeiramente Importante	Importante	Significativamente Importante	Muito importante
Ações para reduzir o desperdício de materiais, o consumo de energia, o consumo de água e as emissões.	◯	◯	◯	◯	◯
Apoio ao fornecedor (no desenvolvimento de produtos, planeamento de processos e produção de componentes)	◯	◯	◯	◯	◯
Confiabilidade (probabilidade de o produto não falhar)	◯	◯	◯	◯	◯
Conformidade com as especificações (produto fabricado de acordo com as especificações de concepção)	◯	◯	◯	◯	◯
Custo de produção (custo total dos produtos vendidos)	◯	◯	◯	◯	◯
Custos gerais (administração, manutenção)	◯	◯	◯	◯	◯

Custos diretos (mão-de-obra e material)	⬭	⬭	⬭	⬭	⬭
Flexibilidade de Processo (inclui flexibilidade de mistura de produção, flexibilidade de sequenciamento e flexibilidade de encaminhamento	⬭	⬭	⬭	⬭	⬭
Flexibilidade do produto (capacidade de adaptar os produtos às necessidades do cliente)	⬭	⬭	⬭	⬭	⬭
Flexibilidade de volume (capacidade de responder a variações nas quantidades requeridas)	⬭	⬭	⬭	⬭	⬭
Qualidade do design (desempenho projectado das principais características do produto)	⬭	⬭	⬭	⬭	⬭
Rapidez do serviço (tempo decorrido entre a encomenda e a entrega do produto ao cliente)	⬭	⬭	⬭	⬭	⬭
Responsividade (probabilidade de entregar o produto certo na quantidade certa e a tempo)	⬭	⬭	⬭	⬭	⬭
Resolução de problemas do cliente	⬭	⬭	⬭	⬭	⬭
3R - Remanufatura, reutilização e reciclagem	⬭	⬭	⬭	⬭	⬭

17. C6. Com relação à competitividade das suas operações, quais são as áreas de decisão da sua organização que apoiam a sua posição competitiva?Escolha cinco áreas e classifique-as (sendo 5 a mais importante para 1 a menos importante).

Marcar apenas uma oval por linha.

	1	2	3	4	5
Cadeia de abastecimento: Integração vertical (fases do processo externalizado ou integrado, a empresa trabalha com desenvolvimento de projetos em parceria com os seus clientes);	◯	◯	◯	◯	◯
Capacidade (capacidade de produção instalada);	◯	◯	◯	◯	◯
Desenvolvimento de novos produtos/materiais (trabalha com parcerias - fornecedores, clientes, universidades, centros de investigação; departamento específico);	◯	◯	◯	◯	◯
Gestão da Qualidade (certificação, ferramentas de melhoria	◯	◯	◯	◯	◯
Instalações (localização das instalações; layout, projetos de modernização);	◯	◯	◯	◯	◯
Organização (estilo de gestão, estrutura de organização).	◯	◯	◯	◯	◯
Recursos Humanos (educação, competências, sexo, faixa etária, métodos de recrutamento, níveis hierárquicos, formação, rotatividade, avaliações periódicas);	◯	◯	◯	◯	◯
Sistemas de medição do desempenho (indicadores utilizados);	◯	◯	◯	◯	◯
Sistemas de planeamento e controlo (software utilizado, método de planeamento).	◯	◯	◯	◯	◯
Tecnologia (novas tecnologias, equipamento, máquinas)	◯	◯	◯	◯	◯

D. Lean Manufacturing (Produção Enxuta)

18. D1. Indique o período em que as práticas de Lean Manufacturing foram implementadas na sua organização. *

Marcar apenas uma oval.

- Antes de 1990
- Entre 1990 e 2000
- Entre 2001 e 2005
- Entre 2006 e 2010
- Entre 2011 e 2015
- A partir de 2016

19. D2. Na sua opinião, qual dos seguintes fatores motivou a implementação das práticas de Lean Manufacturing na sua organização? (Pode escolher mais de uma opção, se necessário). *

Marque todas que se aplicam.

- [ ] Concorrência de mercado
- [ ] Exigência do cliente
- [ ] Estratégia empresarial
- [ ] Melhoria da qualidade
- [ ] Redução de custos

Outro: [ ] ______________________

20. D3. Práticas Lean. Por favor, use essa escola para sinalizar o nível de implementação das práticas Lean nas operações de sua organização. *

Marcar apenas uma oval por linha.

	1. Nada foi feito	2. Atualmente ao nível do "projeto" mas ainda não implementado	3. Implementação incipiente	4. Parcialmente implantado	5. Totalmente implantado e rastreado
Gestão Visual	◯	◯	◯	◯	◯
Just-in-Time (JIT)	◯	◯	◯	◯	◯
Kaizen	◯	◯	◯	◯	◯
Kanban (produção pull)	◯	◯	◯	◯	◯
Manufatura Celular	◯	◯	◯	◯	◯
Manutenção Produtiva Total (TPM)	◯	◯	◯	◯	◯
Mapeamento do fluxo de valores (VSM)	◯	◯	◯	◯	◯
Poka-Yoke (sistema à prova de erros)	◯	◯	◯	◯	◯
Trabalho padronizado	◯	◯	◯	◯	◯
5 porquês/ diagrama Ishikawa (espinha de peixe)	◯	◯	◯	◯	◯
5s (cinco S)	◯	◯	◯	◯	◯

21. Outras práticas Lean (por favor, especificar)

22. D4. Quem é o responsável pelas iniciativas pelo Lean Manufacturing na sua organização? *

Marcar apenas uma oval.

- Gerente de produção/operações
- Coordenador de operações
- Analista de processos
- Coordenador Lean
- Diretor da fábrica/operações/manufatura

23. Other (please, specify) *

24. D5. Existe na sua organização uma equipe ou um comitê que gerencia as iniciativas de Lean Manufacturing? *

Marcar apenas uma oval.

- Sim
- Não

25. D6. Da lista abaixo de indicadores possivelmente utilizandos em ambientes Lean, escolha aqueles que são atualmente observados nas suas atividades de Lean Manufacturing. *

Marque todas que se aplicam.

- [ ] Lead Time médio (dias/horas)
- [ ] % do Tempo de agregação de valor (%TAV)
- [ ] Tempo de ciclo médio (dias/horas/minutos/segundos)
- [ ] Produtividade
- [ ] Takt Time (Capacidade média de produção/ Demanda)
- [ ] OTIF - On-Time In-Full (No prazo e completo)
- [ ] % de defeitos ou peças não conformes
- [ ] First Time Through FTT = (Unidades processadas - Unidades rejeitadas)/(Unidades processadas)
- [ ] Outro:

Outro: [ ] ______________________

E. Green Manufacturing (Manufatura Verde)

Práticas para redução dos impactos ambientais

26. E1. Indicar o período em que as práticas Green foram implementadas na sua organização. *

Marcar apenas uma oval.

- ( ) Antes de 1990
- ( ) Entre 1990 e 2000
- ( ) Entre 2001 e 2005
- ( ) Entre 2006 e 2010
- ( ) Entre 2011 e 2015
- ( ) A partir de 2016

27. E2. Com base no seu conhecimento, qual dos seguintes fatores motivou a implementação de práticas de Green Manufacturing na sua organização? Pode escolher várias opções, se necessário. *

Marque todas que se aplicam.

- [ ] Concorrência de mercado
- [ ] Estratégia empresarial
- [ ] Exigência do cliente
- [ ] Legislação
- [ ] Melhoria da qualidade
- [ ] Redução de custos

Outro: [ ] ______________________

28. E3. Com relação às práticas Green listadas a baixa. Por favor, utilize esta escala para assinalar o nível de implementação destas práticas nas suas operações atuais. *

Marcar apenas uma oval por linha.

	1. Nada foi feito	2. Atualmente ao nível do "projeto" mas ainda não implementado	3. Implementação incipiente	4. Parcialmente implantado	5. Totalmente implantado e controlado
Acreditação ambiental de fornecedores	◯	◯	◯	◯	◯
Análise do ciclo de vida do produto	◯	◯	◯	◯	◯
Logística inversa	◯	◯	◯	◯	◯
Plano/ Sistema de Gestão Ambiental	◯	◯	◯	◯	◯
Política de gestão de resíduos	◯	◯	◯	◯	◯
Programa de redução do consumo de água	◯	◯	◯	◯	◯
Programa de conservação de energia	◯	◯	◯	◯	◯
Programa de Reciclagem	◯	◯	◯	◯	◯
Programas de educação ambiental para a comunidade	◯	◯	◯	◯	◯
Programa para reduzir o consumo de material	◯	◯	◯	◯	◯

Programas de partilha de recursos entre processos	⬭	⬭	⬭	⬭	⬭
Programa de produção mais limpa	⬭	⬭	⬭	⬭	⬭
Publicação de relatórios com informação ambiental	⬭	⬭	⬭	⬭	⬭
Tratamento de Efluentes	⬭	⬭	⬭	⬭	⬭

29. Outros (por favor, especificar)

____

30. E4. Quem é o responsável pelas iniciativas de Green Manufacturing na sua organização. *

Marcar apenas uma oval.

- ⬭ Gerente de produção/operações/manufatura
- ⬭ Gerente de Meio Ambiente
- ⬭ Coordenador de produção/operações/manufatura
- ⬭ Coordenador de meio ambiente
- ⬭ Analista de meio ambiente
- ⬭ Consultor de sustentabilidade da sua empresa
- ⬭ Consultor de sustentabilidade externo a sua empresa
- ⬭ Outro: ____________________

31. Outro (por favor, especificar)

____

32. E5. Da lista abaixo de indicadores ambientais, escolha os que são atualmente observados nas suas atividades de redução dos impactos ambientais. *

Marque todas que se aplicam.

- [ ] Utilização de materiais (peso e volume)
- [ ] Consumo de energia
- [ ] Consumo de água
- [ ] Biodiversidade
- [ ] Emissões (gases com efeito de estufa, NOx, SOx)
- [ ] Utilização (consumo) de substâncias tóxicas (materiais)
- [ ] Quantidade de resíduos gerados
- Outro: [ ] ________________________

33. E6. Algum dos indicadores mencionados na pergunta anterior são utilizados no sistema Lean da empresa? Qual deles? *

Marque todas que se aplicam.

- [ ] Utilização de materiais (peso e volume)
- [ ] Consumo de energia
- [ ] Consumo de água
- [ ] Biodiversidade
- [ ] Emissões (gases com efeito de estufa, NOx, SOx)
- [ ] Utilização (consumo) de substâncias tóxicas (materiais)
- [ ] Quantidade de resíduos gerados
- Outro: [ ] ________________________

Parte 2. Entrevista semi-estruturada (será realizada por meio de uma entrevista on-line)

1.Como o sistema de produção da empresa consolida as práticas Lean e Green?

Categoria: Sistema de Produção da Empresa

Concept: Estratégia de Operações

2.De que maneira as práticas Lean e Green estão alinhadas à estratégia de operações da empresa?

Categoria: Práticas Implementadas

Concept: Estratégia de Operações

3.Como é conduzida a capacitação dos funcionários em práticas Lean e Green na sua organização?

Categoria: Práticas Lean e Green

Code: Áreas de decisão – Recursos Humanos

4.De acordo com sua opinião como foi a implementação das Práticas Lean e Green nas operações?

Categoria: Integração Lean-Green

Code: Mudanças na estratégia de operações (áreas de decisão e prioridades competitivas)

5.Na sua opinião, qual a contribuição do Lean para as práticas Green?

Categoria: Integração Lean-Green

Code: Lean facilitador do Green

6.Como a sua organização consegue integrar as práticas Lean e Green nas operações

Categoria: Integração Lean-Green

Code: Integração Lean-Green

7.Você considera que as práticas Lean melhoram o desempenham ambiental das operações? Se sim, de que maneira?

Categoria: Práticas Lean

Code: melhora da prioridade ambiente

8.Quais os principais fatores que facilitaram a integração das práticas Lean e Green

Categoria: Integração Lean-Green

Code: facilitador da integração

9.É possível identificar os fatores que dificultam a complete integração entre Lean e Green nas operações?

Categoria: Integração Lean-Green

Code: barrreira para integração

10.Como a integração das práticas Lean e Green contribuem para alcançar os objetivos da produção?

Categoria: Integração Lean-Green

Code: impactos nas prioridades competitivas

11.De que forma a implantação de práticas Lean e Green contribuem para as prioridades competitivas da sua organização?

Categoria: Práticas Lean e Green

Code: impactos nas prioridades competitivas

12.Você pode explicar quais e como são as compatibilidades entre as práticas Lean e Green na sua organização?

Categoria: Integração Lean e Green

Code: compatibilidades entre Lean e Green

13.Você pode explicar quais são as principais diferenças e conflitos entre as práticas Lean e Gren?

Categoria: Práticas Lean e Green

Code: diferenças

14.**Você poderia explicar quais são os trade-offs entre as práticas Lean e Green**
Categoria: Práticas Lean e Green

Code: trade-offs

15. **Como os conflitos entre as práticas Lean e Green são solucionados?**:
Categoria:Integração Lean e GreenLean and Green Integration
Code: trade-offs.

16.Existe algo que você gostaria de acrescentar relacionado à integração entre as práticas Lean e Green e a sua relação à sua estratégia de operações?

Part 3. Verificação de documentos (quanto autorizado)

O pesquisador deve verificar o discurso corporativo de cada organização e comparar com os dados recolhidos (verificar o alinhamento).

Rever a missão, visão e valores de cada organização entrevistada. Se não estiverem disponíveis no seu website, pedir aos entrevistados uma cópia impressa.

Além disso, rever os websites para acessar os relatórios de responsabilidade social corporativa. Se não estiver disponível, pedir aos entrevistados um breve relatório interno sobre as suas iniciativas ambientais.

ANEXO A – COMPROVANTE DO COMITÊ DE ÉTICA DA UNIVERSITÉ DE SHERBROOKE

UNIVERSITÉ DE SHERBROOKE

Sherbrooke, le 11 janvier 2021

Mme Geandra Alves Queiroz
ÉCOLE DE GESTION (études)
Université de Sherbrooke

Directrice ou directeur de recherche :
M. Luis Antonio De Santa-Eulalia

N/Réf. 2020-2730/Alves Queiroz

Objet : Approbation finale de votre projet de recherche

Madame,

Le Comité d'éthique de la recherche – Lettres et sciences humaines a reçu les clarifications ou les modifications demandées concernant votre projet de recherche intitulé **« Lean and Green: synergies and trade-offs from the perspective of operations strategy »**(projet financé par Coordination for the Improvement of Higher Education Personnel (CAPES) - Brésil).

Les documents suivants ont été analysés :

- Formulaire de réponse aux conditions (F20-7930)
- Projet de recherche (Research Summary - reviewed.docx) [date : 04 janvier 2021, version : 2]
- Recrutement (APPENDIX B_E-mail for respondents VF_reviwed.docx) [date : 04 janvier 2021, version : 2]
- Formulaire d'information et de consentement (Information and Consent Form - reviewed_v2.docx) [date : 05 janvier 2021, version : 3]
- Recrutement (APPENDIX C_E-mail for companies_reviwed_v2.docx) [date : 05 janvier 2021, version : 2]

Le comité a le plaisir de vous informer que votre projet de recherche a été **approuvé**.

Cette approbation étant **valide jusqu'au 11 janvier 2022**, il est de votre responsabilité de remplir le formulaire de suivi (formulaire F5-LSH) que nous vous ferons parvenir annuellement. Il est également de votre responsabilité d'aviser le comité de toute modification au projet de recherche (formulaire F4-LSH) ou de la fin de votre projet (formulaire F6-LSH). Ces deux derniers formulaires sont disponibles dans Nagano.

Le comité vous remercie d'avoir soumis votre demande d'approbation à son attention et vous souhaite, Madame, le plus grand succès dans la réalisation de cette recherche.

Mme Carole Coulombe
Coordonnatrice à l'éthique de la recherche

pour P[re] Aurélie Desfleurs, Présidente
Comité d'éthique de la recherche – Lettres et sciences humaines
Université de Sherbrooke